Net-Zero GHG Analysis for the State of Washington

from

Greenhouse Gas Emissions from the Solid Waste Industry

January 2021

Prepared for:

WRRA
WASHINGTON REFUSE & RECYCLING ASSOCIATION

Prepared by:

Edgar & Associates

ACKNOWLEDGEMENTS

This report would not have been possible without the support and oversight of the Washington Refuse & Recycling Association (WRRA). WRRA represents Washington's diverse and multifaceted solid waste handling industry, providing its members with general legal support, educational seminars, workshops, and representation before regulatory agencies and the Legislature. WRRA is an association of solid waste companies and professionals who have gathered to promote the private solid waste and recycling industry and their member companies.

WRRA's Mission Statement is to: promote environmentally sound and efficient solid waste and recycling services within the Washington State regulatory system. WRRA supports the working definition of sustainability and goals adopted by the Department of Ecology, and the provisions of Executive Order 02-03, where sustainability is "Meeting the needs of the present without compromising the ability of future generations to meet their own needs." With that in mind, WRRA had this report prepared to determine the greenhouse gas (GHG) impacts of the solid waste industry, both private and public sector, in terms of a Net-Zero GHG analysis. To meet the definition of Net-Zero GHG, one's avoided GHG emissions must be greater than, or equal to, one's operational GHG emissions. By analyzing the operational versus avoided emissions, it will be possible to demonstrate that the solid waste industry within Washington State has achieved this Net-Zero GHG goal for the year 2017 and provides a strong sustainability platform to achieve the Washington states' carbon neutrality goals.

This report would not have been possible without the quality data provided by the Department of Ecology for their GHG emissions inventory for landfills and their recycling and composting tonnage data for 2017.

Edgar & Associates, Inc. was retained by WRRA to prepare this report. Edgar & Associates, Inc. is an environmental management consulting and regulatory compliance firm based in Sacramento, California, and is comprised of qualified professionals experienced in all aspects of solid waste management collection, processing, recycling, composting, and disposal and have participated in most greenhouse gas reduction programs and diversion strategies. Edgar & Associates, Inc. has successfully completed the third-party verified greenhouse gas inventories for ten private independent solid waste and recycling companies in California, spanning 86 calendar years of data. Edgar & Associates has also been intimately involved in the preparation of the California AB 32 Scoping Plan and each update defining strategies for Net-Zero GHG programs and carbon neutrality policies.

EXECUTIVE SUMMARY

The World Resources Institute, among many other studies, shows that global greenhouse gas (GHG) emissions will need to drop in half by 2030, and then reach Net-Zero around the mid-century to avoid the worst projected climate impacts. Recognizing this urgency an unprecedented number of business and local government leaders are supporting strong national climate ambitions through the United Nations High Level Climate Champions Race to Zero campaign.

In pursuit of reducing GHG Emission, businesses and local government leaders must measure their impact on climate change. The GHG footprint refers to the amount of GHG that is emitted during the creation of products or services. Measuring the GHG impacts of a company, or even a state has become increasingly important as states pave the way to battle climate change through a range of regulatory and policy measures. Specifically, the solid waste industry can use the GHG impacts to determine their progress toward Net Zero GHG emissions. Net-Zero GHG. for the solid waste industry has been defined by the California Air Resource Board in their 2014 Scoping Plan and will be utilized herein. To meet Net-Zero GHG, one's avoided GHG emissions must be greater than, or equal to, one's operational GHG emissions. By analyzing the operational versus avoided emissions, it will be possible to demonstrate that the solid waste industry within Washington State has achieved this Net-Zero GHG goal for the year 2017. Based upon available Washington State data coupled with best practices in GHG modeling, it is estimated the solid wase industry has avoided 2.8 times more GHGs than have been emitted.

Net-Zero GHG Analysis 2017

• Scope 1	Landfill Activity – DOE Data	2,363,000	$MTCO_2e$
• Scope 1	Fleet – DOT data	117,887	$MTCO_2e$
• Scope 2	Energy Use – Industry averages	17,683	$MTCO_2e$
• Scope 3	Recycling (Composting, AD, Combustion) DOE Data with Federal WARM Model	<7,064,545>	$MTCO_2e$

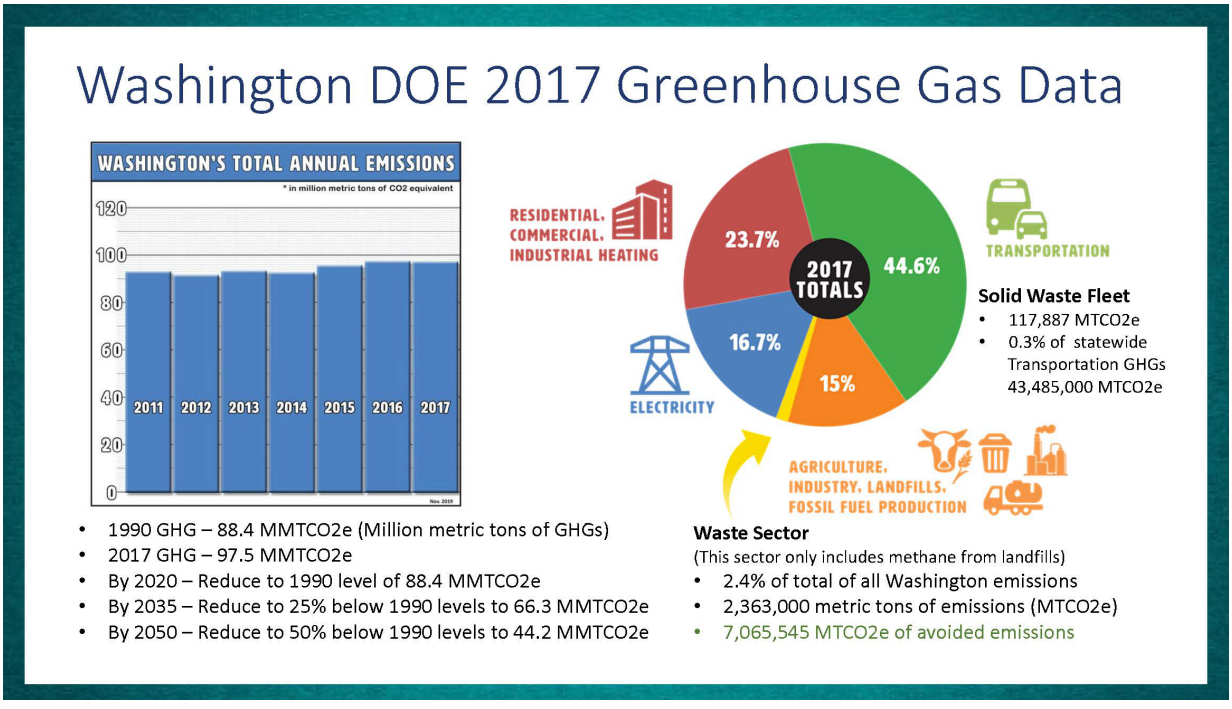
$$\frac{\text{Avoided GHG Emissions – Scope 3}}{\text{GHG Emissions – Scope 1 and 2}} = \frac{7{,}064{,}545}{2{,}498{,}570} = \textbf{2.8 Times}$$

GREENHOUSE GAS EMMSSIONS

This Net-Zero GHG Analysis used 2017 as the reporting year, which was the last calendar year with a complete and reliable data set of GHG emissions from landfills, fleet inventory, and the amount of material that was recycled, composted, and combusted in Washington State.

The Washington Department of Ecology (DOE) compiled an annual GHG emissions inventory which estimates the combined emissions from all sources in Washington State. This estimate is based on data from the Washington Department of Commerce, EPA, and the U.S. Energy Information Administration. The 2017 Washington DOE GHG Data is presented below, where GHG emissions have increased to 97.5 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) in 2017 with a state goal to reduce that amount to the 1990 GHG level of 88.4 $MMTCO_2e$ by 2020.

The solid waste industry is ubiquitous in all sectors. Solid waste fleet emissions are part of the transportation sector and represent less than 0.3% of the 43.5 $MMTCO_2e$ for that sector. The electricity used to process waste and materials is in the electricity sector and is about 0.1% of the 16.3 $MMTCO_2e$ for that sector. Methane from landfills totals 2.36 $MMTCO_2e$ and is 2.4% of all of Washington's GHG emissions. The avoided GHG emissions due to recycling, composting, and combustion is estimated to be 7.06 $MMTCO_2e$ and is not part of the GHG inventory since these emissions are avoided based upon a lifecycle analysis[1].



[1] See definitions of Scope 1, Scope 2 and Scope 3 emissions in Section GHG Emissions and Identification and Data Sources.

GHG EMISSIONS IDENTIFICATION AND DATA SOURCES

Industry standards and best practice were followed in the preparation of this greenhouse gas emissions inventory. Emissions in the following categories were analyzed:

Scope 1 – Direct GHG Emissions

Direct Emissions from Landfill Methane
Fugitive methane emissions from all landfills in Washington State as reported by the Washington DOE was used in this report.

Direct Emissions from Mobile Combustion – Transportation Sector
Direct emissions burning transportation fuels from the refuse fleets. The major solid waste companies that have registered with The Climate Registry used their General Reporting Protocol to determine their fleet emissions. Industry standards and extrapolation were used to determine this Scope 1 GHG for the fleet emissions.

Scope 2 – in-Direct GHG Emissions

Indirect Emissions from Imported Electricity – Electricity Sector
Indirect emissions are from using electricity for processing, maintenance, and office operations, purchased from utility companies. The major solid waste companies that have registered with The Climate Registry used their General Reporting Protocol to determine their material processing emissions. Industry standards and extrapolation were used to determine this Scope 2 emissions.

Scope 3 – Avoided GHG Emissions

Recycling, Composting and Combustion
Recycling, composting, and combustion avoid indirect emissions from compost production and from recycling other components of the waste stream from the material recovery facility operations. Recovering organic materials reduces methane emissions from landfills. Recycling reduces the demand for raw or virgin materials while remanufacturing recycled materials generally reduces overall energy use. Recycling also results in increased carbon sequestration by forests, since fewer trees need to be harvested for wood and paper products. The best practice estimation method for greenhouse gas impacts from recycling and composting is the Environmental Protection Agency's (EPA) Waste Reduction Model (WARM), which provides emission factors for a broad spectrum of recycled and composted commodities that are derived from comprehensive life-cycle assessment methodologies. The WARM model estimates overall avoided emissions due to recycling, composting and combustion and is considered the best practices.

DATA EFFICACY

"Data Efficacy" is, in essence, the ability for organizations to manage data in such a way to drive informed decisions. This Net-Zero GHG Analysis will use state data and the best practices in modeling data for the major categories – Scope 1 (Direct Emissions for Landfill Methane Emissions) and Scope 3 (Avoided GHG Emissions from Recycling, Composting and Combustion) – which accounts for 98.6% of the data set used in the analysis. These data sources are highly reliable, effectively provide information in a cost-effective manner, and can produce results on the status of the solid waste industry in Washington State.

The methodology used to determine the minor categories - Scope 1 (Direct Emissions from Mobile Combustion – Transportation Sector) and Scope 2 (Indirect Emissions from Imported Electricity – Electricity Sector) will use a top-down industry standard approach with conservative assumptions. These emissions account for just 1.4% of the data set in the analysis and will not impact the Net-Zero GHG Analysis but are important to recognize that those GHG impacts that can further be reduced with less carbon intense electricity.

The data utilized for this Net-Zero GHG Analysis will not be verified by a third party or be used to submit to The Climate Registry. If it were submitted, a typical mid-size private solid waste company could spend $15,000 to $20,000 per year, where major companies spend millions per year on nationwide data collection and third-party verification for The Climate Registry, and to produce their Sustainability Reports.

Scope 1 – Landfill Methane and **Scope 3 – Avoided GHG Emissions**

- Landfill Methane Emissions Data by Washington State DOE updated every year, but lags by 3 years (2017 is the most recent year)
- Recycling, Composting, and Combustion data by Washington State DOE updated every year, but lags by 3 years (2017 is the most recent year)
- High Quality tonnage data provided by State agencies and the best practices of Federal GHG modeling
- Accounts for 9,427,545 metric tons of GHG data, or 98.6% of the data set.

Scope 1- Fleets and **Scope 2 – Electricity**

- Utilizes industry averages from The Climate Registry and Sustainability Reports
- Accounts for only 135,572 metric tons of CO_2e data (Less than 0.14% of State total)
- With respect to Net-Zero GHG Analysis, precision and verification of this data is not as important since it has negligible effects on the Net-Zero analysis
- This data is "good enough" for the Net-Zero GHG Analysis, but more precision and verification would be needed to set individual company future climate goals just on fleet emissions reduction.

NET-ZERO GHG ANALYSIS

Net-Zero GHG for the solid waste industry has been defined by the California Air Resource Board (CARB) in their 2014 Scoping Plan. To meet Net-Zero GHG, one's avoided GHG emissions must be greater than or equal to one's operational GHG emissions. By analyzing the operational versus avoided emissions, it will be possible to demonstrate that the solid waste industry can be Net-Zero GHG.

Net-Zero GHG Equation

$$\text{Operational GHG Emissions} - \text{Avoided GHG Emissions} \leq 0$$

Achieving Net-Zero GHG Emissions from the Waste Sector

Beyond 2020, additional reductions in GHG emissions from the Waste Sector will be needed to achieve a Net-Zero GHG emissions goal. To achieve these reductions, even greater diversion of organics and other recyclable commodities from landfills must be realized and further expansion and enhancement of the alternative non-disposal pathways must be developed. In addition, greater emphasis will need to be placed on reducing the volume of waste generated, recycling/reusing products at the end-of-life and remanufacturing these materials into beneficial products. To achieve Net-Zero, the direct GHG emissions from the Waste Sector would have to be fully offset by avoided GHG emissions. Avoided GHG emissions are reductions in life cycle GHG emissions that would occur because waste is shifted from landfilling to alternative non-disposal pathways.

Waste Management Inc. determined they are 3 times Net-Zero GHG now with a moonshot goal to be 4 times Net-Zero within 20 years, with a cleaner fleet and more recycling referenced in their 2018 Sustainability Report, linked here: http://sustainability.wm.com/downloads/report.php.

In 2017, our GHG-reducing services saved over

3X

The total GHG emissions Waste Management's operations generated all year.

Waste Management Inc. - Aiming Higher with New Goals

As Waste Management have publicly advocated in recent years, it's time for the recycling industry to focus on GHG emissions reduction as the life cycle goal of waste and materials management programs. In 2017, that ratio was three times (3X). WM's journey to four times (4X) will be supported by two additional goals: reducing fleet emissions by 40 percent through renewable fuel use in our growing fleet of natural gas vehicles; and collecting two million more tons of recycled materials to offset emissions associated with raw material used by 20 percent.

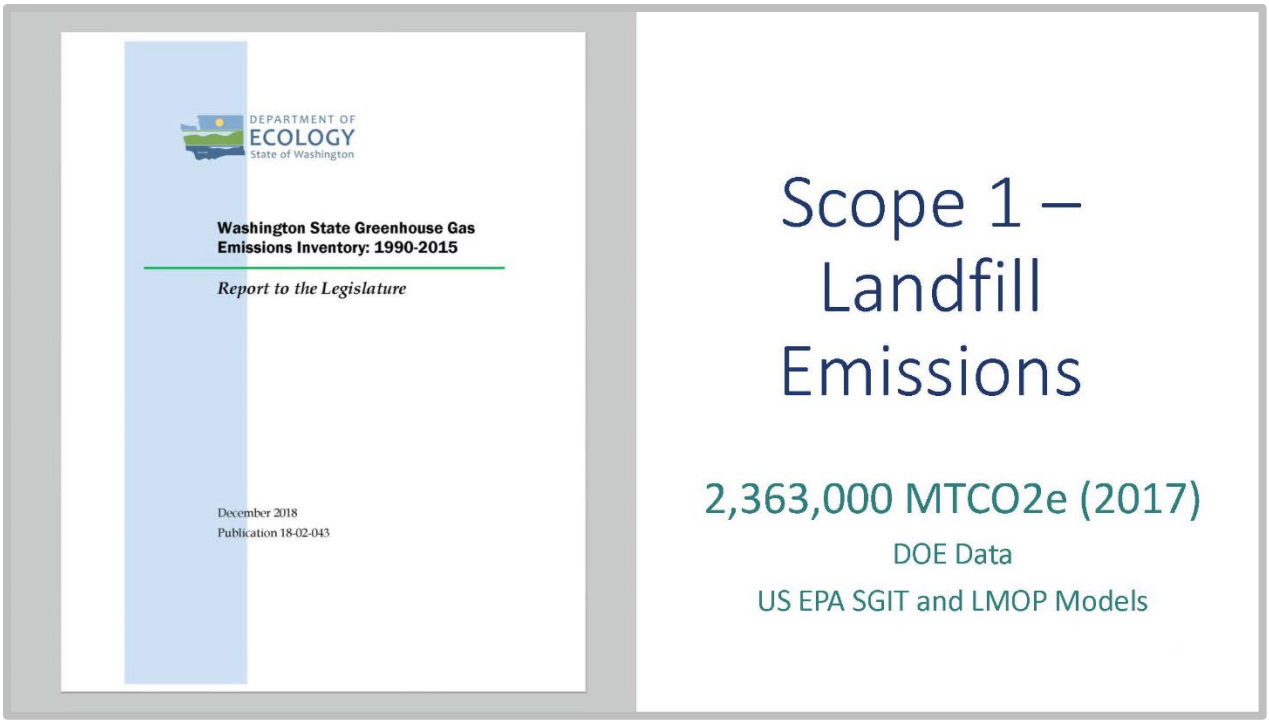
SCOPE 1 - DIRECT EMISSIONS FROM LANDFILL METHANE

Washington DOE publishes an inventory of Washington's greenhouse gases every two years, measuring the state's progress in reducing greenhouse gases compared to a 1990 baseline. This inventory helps DOE design policies to reduce greenhouse gas emissions and track progress toward meeting the state's reduction limits. In the last published report, greenhouse gas emissions in Washington State show that greenhouse gas emissions rose by 1.9 percent in 2016. The overall state emissions were 97.8 million metric tons of carbon dioxide in 2016. From 2016 to 2017, equivalent to 97.5 million metric tons.

The waste management sector of this report includes greenhouse gas emissions from landfills and wastewater treatment facilities. This inventory does not include waste exported from Washington to other states for disposal. The 1990 baseline emissions from this sector was updated due to: 1) improved methodology in the U.S. EPA State Inventory Tool module, and 2) the use of Fourth Assessment Report global warming potentials. Calendar year 2016 data was not readily available.

The following data just for landfills are provided by the DOE in these reports:

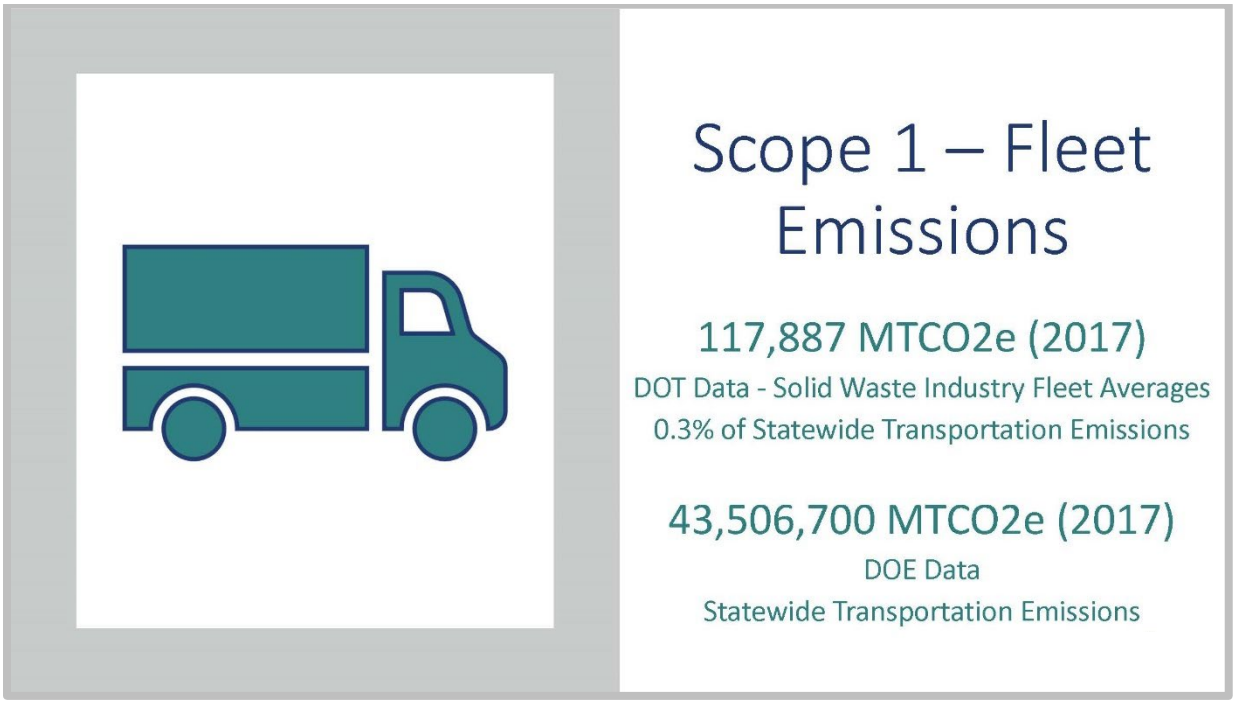
- 2012: 2,360,000 Metric Tons CO_2e
- 2013: 2,540,000 Metric Tons CO_2e
- 2014: 2,610,000 Metric Tons CO_2e
- 2015: 2,680,000 Metric Tons CO_2e
- 2017: 2,363,000 Metric Tons CO_2e



SCOPE 1 - DIRECT EMISSIONS FROM MOBILE COMBUSTION – TRANSPORTATION SECTOR

Direct emissions burning transportation fuels from the refuse fleet will be determined using industry standards and extrapolation. The major solid waste companies in Washington State (Waste Connections and Recology) that have registered with The Climate Registry used their General Reporting Protocol to determine their fleet emissions. Waste Management, Inc. and Republic Services publish annual Sustainability Reports that provide information on their fleet emissions and size. The fleet emissions from the public sector is fragmented in local and regional GHG emissions reports and was not aggregated. A fleet survey on fuel amount and types was considered to collect data but was not pursued due to the limited cost-benefit and perceived limited participation in that request by the public sector and some private independent companies. The methodology will use a top-down industry standard approach with conservative assumptions. These emissions account for just 1.4% of the data set in the analysis and will not impact the Net-Zero GHG Analysis but are an important GHG source to recognize as they can be readily reduced by using less carbon intensive fuel types.

Washington State operates 1,282 Refuse Vehicles in 2017 as reported by the Department of Transportation (DOT). From the U.S. Department of Energy, on average, CNG refuse trucks and the comparable diesel trucks both traveled about 14,500 miles per year, consuming 6,800 diesel gallons each year. Each gallon of diesel produces 0.0135 $MTCO_2e$ per CARB emissions factors. With those conservative assumptions, the average vehicles generate 92 metric tons of CO_2e, or 117,887 metric tons of CO_2e per year, assuming a diesel fleet. Upon further review, with an assumed industry average for alternative fuel blends, the Washington State refuse fleet generating just 55 metric tons of CO_2e per truck, would emit about 70,000 metric tons of CO_2e per year.



Solid Waste Industry average ranges from 49 to 58 metric tons (MT) of CO_2e for a refuse fleet with diesel as well as alternative fuels use such as renewable diesel, biodiesel, CNG, RNG, LNG, and electrification. Obtaining actual fuel usage and fuel type that would significantly lower total amount but would not affect Net-Zero GHG determination, individual companies could then track fuel usage and carbon intensity to lower GHG emissions and set future goals.

The Climate Registry's (TCR) Voluntary Greenhouse Gas (GHG) Reporting Program is now called the Carbon Footprint Registry. The Registry includes the same training and resources, proprietary software(CRIS), and help desk it always has. TCR is a non-profit organization governed by U.S. states and Canadian provinces and territories. TCR empowers North American organizations to reduce GHGs by helping them measure, report, and verify their carbon footprints. TCR also drives climate ambition by developing innovative programs and services that reduce carbon, recognizing and showcasing sub-national leadership, and building strategic partnerships with and between national and international entities, and is considered the gold standard.

Both Waste Connections and Recology were TCR members in 2017 and had their fleet emissions verified. Coupled with Waste Connections Sustainability Report, 58 $MTCO_2e$ of GHG were emitted per truck. Recology emitted 49 $MTCO_2e$ of GHG per truck, as Recology uses up to 8 fuel types to drive down their carbon footprint. Each fuel type has a specific carbon intensity that is significantly less than diesel.

Waste Management, Inc. and Republic Services publish annual Sustainability Reports that provide information on their fleet emissions and relative size where their fleet emit approximately 50 $MTCO_2e$ of GHG were emitted per truck, and 59 $MTCO_2e$ of GHG were emitted per truck, respectively.

	Waste Connections, Inc.	Waste Management	Republic Services	Recology	Washington State
Scope 1 Emissions (Source)	749,964 MTCO2 The Climate Registry 2017 – Third Party verified	1,597,000 MTCO2 Sustainability Report 2017	1,467,576 MTCO2 Sustainability Report 2017	63,390 MTCO2 The Climate Registry 2107 - Third Party verified	117,887 MTCO2 Conservative Calculation
Fleet Total (Source)	12,756 Sustainability Report 2017	32,000 Sustainability Report 2017	25,000 Sustainability Report 2017	1,300 Google Search	1,282 Washington DOT
Fleet Alternative Fuel (Source)	1,400 CNG truck Sustainability Report 2017	6,536 CNG Sustainability Report 2017	3,200 CNG Sustainability Report 2017	Varies by 8 Fuel types	Unknown Possible Survey Questions Assumes all Diesel for this Draft Report
GHG Emissions per Truck	58 MTCO2/truck/yr	50 MTCO2/truck/yr	59 MTCO2/truck/yr	49 MTCO2/truck/yr	92 MTCO2/truck/yr

LOW CARBON FUEL STANDARD

The Low Carbon Fuel Standard (LCFS) is designed to decrease the carbon intensity of transportation fuel pool and provide an increasing range of low-carbon and renewable alternatives, which reduce petroleum dependency and achieve air quality benefits. The California Air Resources Board (CARB) identified the LCFS as one of the nine discrete early action measures to reduce California's GHG emissions that cause climate change. The LCFS is a key part of a comprehensive set of programs in California to cut GHG emissions and other smog-forming and toxic air pollutants by improving vehicle technology, reducing fuel consumption, and increasing transportation mobility options.

CARB approved the LCFS regulation in 2009 and began implementation on January 1, 2011. In 2018, the Board approved amendments to the regulation, which included strengthening and smoothing the carbon intensity benchmarks through 2030 in-line with California's 2030 GHG emission reduction target, adding new crediting opportunities to promote zero emission vehicle adoption, alternative jet fuel, carbon capture and sequestration, and advanced technologies to achieve deep decarbonization in the transportation sector.

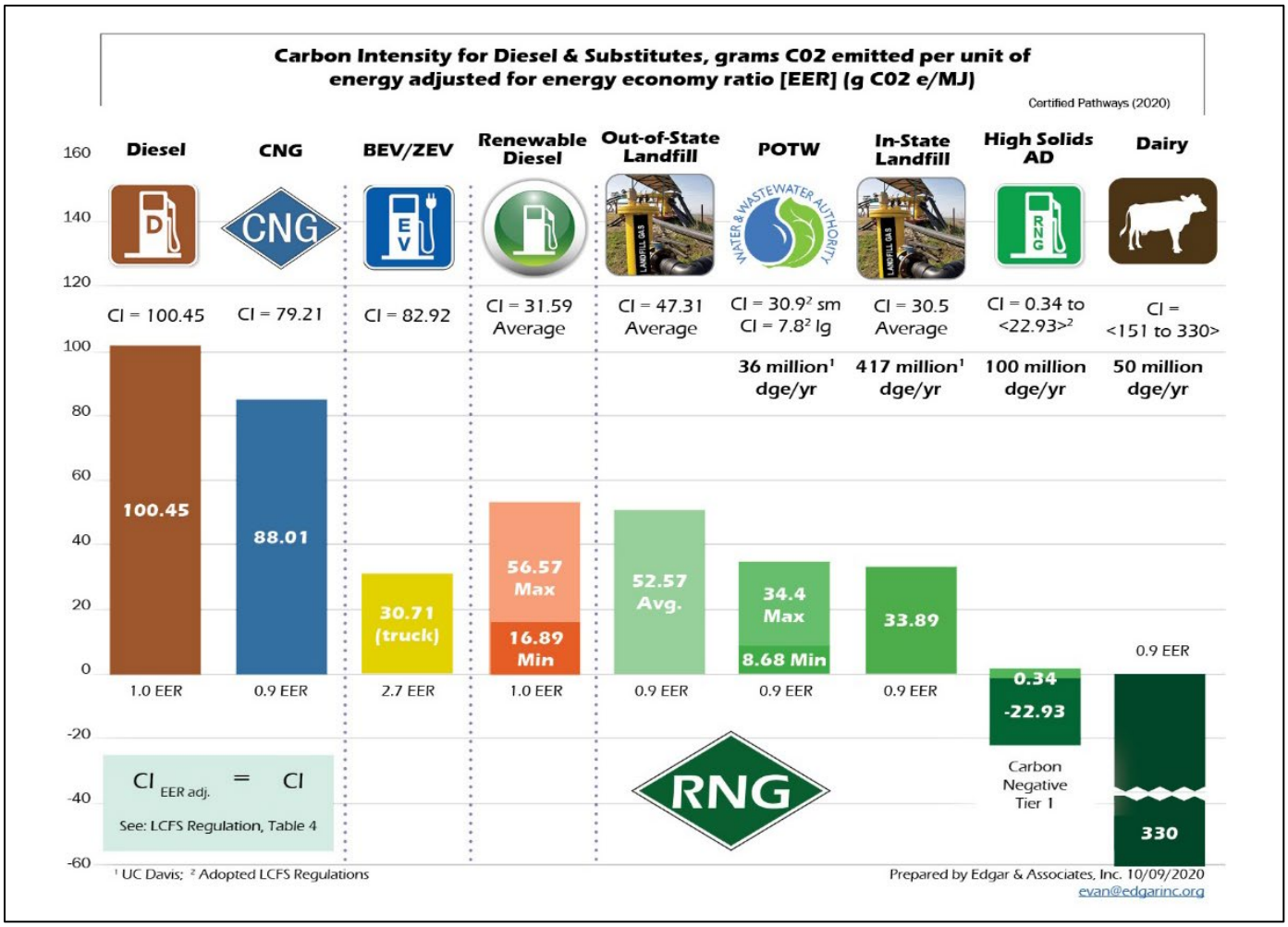
The LCFS is designed to encourage the use of cleaner low-carbon transportation fuels in California, encourage the production of those fuels, and therefore, reduce GHG emissions and decrease petroleum dependence in the transportation sector. The LCFS standards are expressed in terms of the "carbon intensity" (CI) of gasoline and diesel fuel and their respective substitutes. The program is based on the principle that each fuel has "life cycle" greenhouse gas emissions that include CO_2, CH_4, N_2O, and other GHG contributors. This life cycle assessment examines the GHG emissions associated with the production, transportation, and use of a given fuel. The life cycle assessment includes direct emissions associated with producing, transporting, and using the fuels, as well as significant indirect effects on GHG emissions, such as changes in land use for some biofuels.

California adopted the LCFS where the Carbon Intensity of Transportations Fuels is required to be 20% less than 2010 levels by 2030, with a 2019 benchmark of 6.5% reduction. This has resulted in over $2 billion per year of carbon incentives to develop low carbon fuel projects. The responsibility of meeting the reduction of carbon intensity of the fuel for the LCFS falls on the fuel producers and not on fleet owners. A fleet owner can reduce their carbon footprint by choosing alternative fuels over diesel and can set individual company goals, where some refuse fleets can be carbon negative using renewable natural gas (RNG) in their CNG collection vehicles.

Washington State had a proposed HB 1110 for their LCFS to be 10% below 2017 levels by 2028, and 25% by 2035 with a 2017 baseline. The bill was championed by a coalition of Governor Inslee allies that includes many statehouse Democrats, environmental groups, healthcare workers, the Port of Seattle, and some local governments. They argue that the legislation can pay dividends to rural Washington by encouraging the development of new biofuel plants that will increase competition in state fuel markets where the oil industry now enjoys high retail margins. These fuels, as well as electric vehicles, would combine to bring down state greenhouse gas emissions to meet the legislative targets.

British Columbia, California, and Oregon have LCFS programs in place that are stimulating market demand for low carbon-intensity fuels, helping to meet the region's goal of 80% greenhouse gas reduction by 2050. Together, these jurisdictions are collaborating on best practices for program design and implementation, and policy alignment to create an integrated West Coast market for cleaner, lower carbon fuels.

Recent 2018 data from the California Air Resources Board (CARB) indicates that the LCFS continues to drive production of a growing volume of cleaner transportation fuels for California consumers; to date, almost 3.3 billion gallons of petroleum diesel have been displaced by clean, low-carbon alternatives. The 2018 data also shows fuel producers are in 100% compliance with the LCFS. The alternative fuel's carbon intensity (CI) value is divided by its Energy Economy Ratio (EER) to obtain the EER-adjusted CI value, representing the emissions that occur from the use of alternative fuel per mega-Joule of diesel fuel displaced. The graph below shows the ranges of CI for each type of fuel compared to diesel. The graph represents an individual certified fuel pathway CI, adjusted by the EER.



SCOPE 2 - INDIRECT EMISSIONS FROM IMPORTED ELECTRICITY – ELECTRICITY SECTOR

Indirect emissions are from using electricity for processing, maintenance, and office operations, purchased from utility companies, and will be determined using industry standards and extrapolation. The major solid waste companies in Washington State (Waste Connections and Recology), which have registered with The Climate Registry, used their General Reporting Protocol to determine their Scope 2 emissions. Waste Management, Inc. and Republic Services published an annual Sustainability Reports that provide information on their Scope 2 emissions.

Industry standards and extrapolation were used to determine these Scope 2 emissions for the Net-Zero Analysis. The Climate Registry used their General Reporting Protocol to determine their material processing emissions. The use of the default industry average would have no effect on Net-Zero GHG Analysis. These emissions account for less than 0.1% of the data set in the analysis but are important to recognize because those GHG impacts can further be reduced where companies decide to generate their own power on-site or purchase renewable energy credits. Individual companies have reduced their GHG emissions with on-site solar, combined heat and power from renewable natural gas, or bioenergy from biomass power plants.

The data utilized will not be verified by a third party or be used to submit to The Climate Registry. If it were, a typical mid-size private solid waste company could spend $15,000 to $20,000 per year, where major companies spend millions per year on nationwide data collection and third-party verification for The Climate Registry, and to produce their Sustainability Reports.

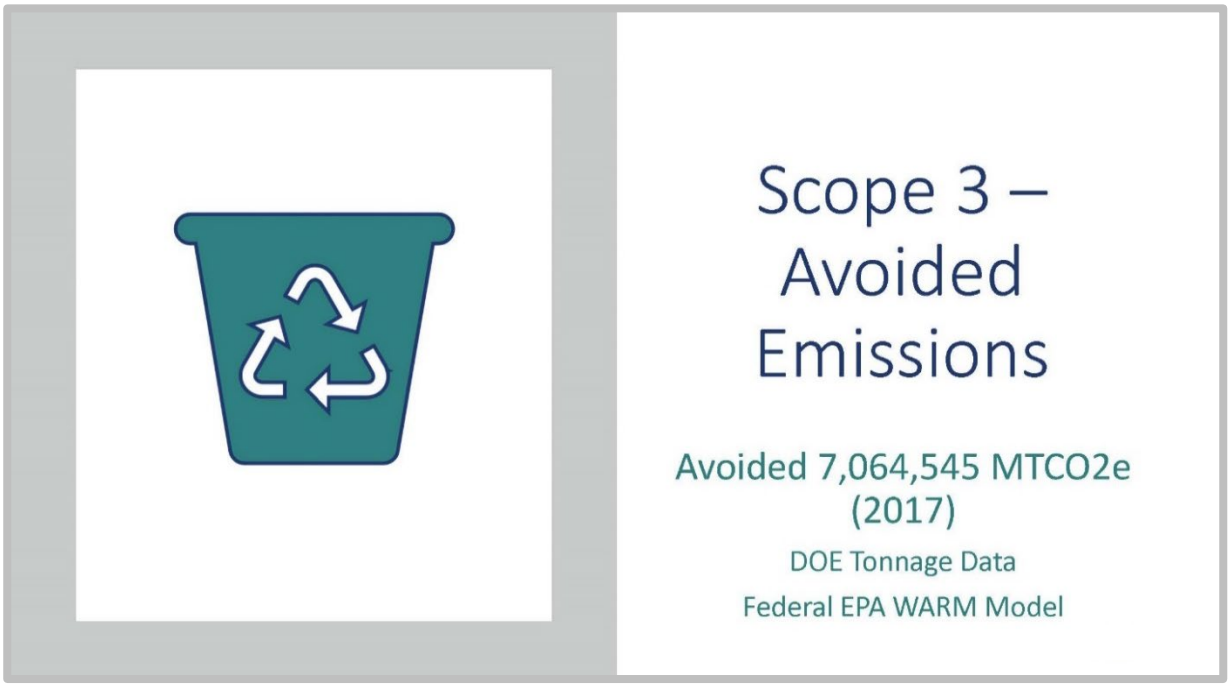
The Scope 2 Emissions for major companies who report to The Climate Registry, range from 6.5% to 7.4% of their Scope 1 fleet emissions, as shown in the table below. For California independent hauling companies that are registered with The Climate Registry, Scope 2 emissions average 10% of their Scope 1 fleet emissions. The Sustainability Reports shows that Scope 2 emissions are 13% to 15% of the Scope 1 fleet emissions. To be conservative, for this Net-Zero GHG Analysis, an amount of 15% of the Scope 1 fleet emissions will be used to estimate Scope 2 electricity emissions.

	Waste Connections	Waste Management	Republic Services	Recology	Washington State
Scope 2 Emissions (Source)	55,396 MTCO2 The Climate Registry 2017 - Third Party verified	232,709 MTCO2 Sustainability Report 2017	262,872 MTCO2 Sustainability Report 2017	4,385 MTCO2 The Climate Registry 2017 - Third Party verified	17,683 MTCO2 Conservative Calculation
Industry Averages	7.4% of Scope 1 is Scope 2 amount	13% of Scope 1 is Scope 2 amount	15% of Scope 1 is Scope 2 amount	6.5% of Scope 1 is Scope 2 amount	Use conservative amount of 15% of Scope 1 is Scope 2 amount

SCOPE 3 – AVOIDED GHG EMISSIONS - RECYCLING, COMPOSTING AND COMBUSTION

Recycling, composting, and combustion avoid indirect emissions from compost production and from recycling other components of the waste stream from the material recovery facility operations. Recovering organic materials reduces methane emissions from landfills. Recycling reduces the demand for raw or virgin materials, while remanufacturing recycled materials generally reduces overall energy use. Recycling also results in increased carbon sequestration by forests, since fewer trees need to be harvested for wood and paper products. The best practice estimation method for greenhouse gas impacts from recycling and composting is the Environmental Protection Agency's (EPA) Waste Reduction Model (WARM) Version 15, which provides emission factors for a broad spectrum of recycled and composted commodities that are derived from comprehensive life-cycle assessment methodologies. The WARM model estimates overall avoided emissions due to recycling and composting. The Net-Zero GHG Analysis depends upon the diversion of materials using the WARM model to off-set the landfill methane emissions.

Washington DOE provided tonnage data from 2017 by commodity type, which were then matched to the material type in the WARM model. Each commodity type has a 'Material Profile' in detail that provides specific information on the recycling rate, the GHG avoided per ton, and the total amount of GHG avoided, along with the recyclability and compostability of that material.



MATERIAL MANAGEMENT IN WASHINGTON STATE

The most recent available data shows that Washington State generated 18,633,069 tons of waste in 2017[2]. This data, which is provided by the Washington DOE, classifies 8,326,844 tons of this waste as diverted, and 10,306,226 tons disposed of, resulting in a 44.7% statewide recycling rate. This information is further detailed by how the material was recovered, what materials were recovered, and what materials were landfilled. The detailed categorizations of the disposed materials are provided by the Washington State Waste Characterization[3].

Based on these sources, the following tables detail what became of Washington State's discarded waste:

Table 1 – Recovered Materials

Tons Recovered	
Recovery Type	**Tons**
Recycled Paper	948,524
Recycled Metal	1,543,249
Recycled Glass	146,065
Recycled Plastic	67,235
Reclaimed HHW	84,787
Recycled Electronics	19,965
Recovered C&D	3,259,950
Reclaimed Wood	210,732
Other Recycled	53,362
Green Composted/Mulch	1,166,111
Food Composted	268,327
Combusted for Energy	517,120
Land Application	10,907
Anaerobic Digestion	30,510
TOTAL:	**8,326,844**

Table 2 – Disposed Materials

Tons Disposed	
Recovery Type	**Tons**
Paper	1,607,268
Metal	599,020
Glass	232,155
Plastic	959,211
HHW	23,002
Electronics	76,851
C&D	787,936
Wood	1,356,698
Other Disposal	1,731,016
Green	1,136,784
Food	1,796,285
TOTAL:	**10,306,226**

A flow chart of the Washington State's waste tonnage is provided on the following page.

[2] Source: State of Washington, Department of Ecology. https://ecology.wa.gov/Research-Data/Data-resources/Solid-waste-recycling-data

[3]. Source: State of Washington, Department of Ecology, 2015-2016 Washington State Waste Characterization https://fortress.wa.gov/ecy/publications/documents/1607032.pdf

Washington State Waste Flow Diagram 2017

18,633,069
Total Tons Generated

8,326,844
Tons Recovered

7,768,307
Tons Diverted

2,705,073
Tons of Other Recycling

19,965
Tons of Electronics

3,259,950
Tons of Construction & Demolition

53,362
Tons of Other Materials

210,732
Tons of Wood

84,787
Tons of Household Hazardous Waste

118,540
Tons of Landclearing

3,747,335
Tons Recycled

948,524
Tons of Paper

1,543,249
Tons of Metal

146,065
Tons of Glass

67,235
Tons of Plastic

1,315,898
Tons Composted

268,327
Tons of Food

1,047,571
Tons of Yard Waste

558,537
Other Recovery

517,120
Tons Combusted

10,907
Tons Land Applied

30,510
Tons AD

10,306,226
Tons Disposed

1,607,268
Tons of Paper

76,851
Tons of Electronics

787,936
Tons of Construction & Demolition

599,020
Tons of Metal

1,356,698
Tons of Wood

1,731,016
Tons of Other Materials Disposed

23,002
Tons of Household Hazardous Waste

1,136,784
Tons of Yard Waste

959,211
Tons of Plastic

232,155
Tons of Glass

1,796,285
Tons of Food Waste

Source: State of Washington, Department of Ecology. https://ecology.wa.gov/Research-Data/Data-resources/Solid-waste-recycling-data

GREENHOUSE GAS IMPLICATIONS OF MATERIAL MANAGEMENT

Greenhouse gases (GHG) are air emissions that contribute to the increasing average temperatures of Earth. The waste sector contributes to anthropogenic climate change in several ways, and as such provides several opportunities to reduce and avoid GHG emissions. The waste sector, though reuse, waste prevention, and recycling can reduce the emissions resulting from the manufacturing sector by provided alternatives to products made using virgin raw materials. The production of metal, for instance, produces substantial emissions during the processing of raw inputs. However, the process of recycling metals produces fewer GHG emissions on average. Recovering otherwise discarded materials, and remanufacturing goods with these materials instead of virgin inputs, results in quantifiable avoided GHG emissions.

The United States Environmental Protection Agency has released guidelines and tools for quantifying these avoided emissions, known as the Waste Reduction Model or the WARM model[4]. This model covers 60 different material types and five different management technologies to compare the GHG emissions of different material management strategies against a baseline scenario of disposal. Using the WARM model, with tonnage information gained from the Washington State DOE, produces an estimation of GHG reductions that have resulted from the diversion of these materials from landfills.

For this analysis, the following assumptions were input into the WARM model:

WARM Version:	**15**
Geographic Location:	**Washington State**
Recyclable vs Virgin Content:	**Default (current mix)**
Landfill Gas Control:	**National Average**
Landfill Gas Recovery for Energy:	**Yes**
Landfill Gas Recovery Efficiency:	**National Average**
Moisture Conditions:	**Wet**
Digestion Tech:	**Dry**
Digestate Curing:	**Yes**
Transportation Distances:	**Default**

During initial analysis, carbon storage credits for landfilling of solid wastes were included by default in the WARM model and is recognized as a best practice by many organizations. More conservative analysis by other organizations, such as the California Air Resource Board, lowers the risk of overstating the benefits of current practices that can be achieved by not including carbon sequestration in a landfill as a greenhouse gas strategy.

[4]United States Environmental Protection Agency, WARM Model Version 15. https://www.epa.gov/warm/versions-waste-reduction-model-warm#15.

The WARM model results show that in 2017, Washington State's diversion of 8,326,844 tons of waste resulted in GHGs avoided. This is calculated by modelling the disposal baseline scenario in Table 3, under which **653,269 $MTCO_2e$** is avoided and comparing it to Washington State's existing practices under which **7,717,814.79 $MTCO_2e$** is avoided as shown on Table 4 and taking the difference between the disposal baseline and the current practice, which is **7,064,545 $MTCO_2e$**.

There are some restrictions to the WARM categories, for which not all diverted material fit well into the categories presented. LDPE, HHW, and land-clearing debris are the three material categories that were modified to fit the model. LDPE and HHW do not have emission factors, so to remain conservative these materials were modelled as landfilled in the alternative scenario. For land clearing debris, the tonnages that were listed as 'recovered' under the Department of Ecology are assumed to be 'Yard Waste' that is composted.

NET-ZERO GHG ANALYSIS

Net-Zero GHG for the solid waste industry has been defined by the California Air Resource Board in their 2014 Scoping Plan. To meet Net-Zero GHG, one's avoided GHG emissions must be greater than or equal to one's operational GHG emissions. By analyzing the operational versus avoided emissions, it will be possible to demonstrate that the solid waste industry can be Net-Zero GHG. By analyzing the operational versus avoided emissions, it will be possible to demonstrate that the solid waste industry within Washington State has achieved this Net-Zero GHG goal for the year 2017. Based upon available Washington State data coupled with best practices in GHG modeling, the solid wase industry has avoided 2.8 times more GHGs than have been emitted.

Net-Zero GHG Analysis 2017

• Scope 1	Landfill Activity – DOE Data	2,363,000	$MTCO_2e$
• Scope 1	Fleet – DOT data	117,887	$MTCO_2e$
• Scope 2	Energy Use – Industry averages	17,683	$MTCO_2e$
• Scope 3	Recycling (Composting, AD, Combustion) DOE Data with Federal WARM Model	<7,064,545>	$MTCO_2e$

$$\frac{\text{Avoided GHG Emissions – Scope 3}}{\text{GHG Emissions – Scope 1 and 2}} = \frac{7{,}064{,}545}{2{,}498{,}570} = \textbf{2.8 Times}$$

Table 3 – Baseline Scenario

GHG Emissions from Baseline Waste Management (MTCO2E):	(653,269.63)

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$
Corrugated Containers	-	834,227.31	-	NA	NA	231,800.76
Magazines/third-class mail	-	23,714.63	-	NA	NA	(8,924.08)
Newspaper	-	304,931.24	-	NA	NA	(248,077.84)
Office Paper	-	130,368.98	-	NA	NA	164,114.58
Mixed Paper (general)	-	1,262,549.69	-	NA	NA	199,307.45
Food Waste	NA	1,537,668.01	-	-	-	875,926.55
Food Waste (meat only)	NA	535,326.42	-	-	-	304,946.60
Yard Trimmings	NA	2,418,559.11	-	-	-	(392,631.36)
Branches	NA	119,755.23	-	-	-	(57,173.04)
HDPE	-	188,193.36	-	NA	NA	3,811.77
LDPE	NA	507,256.16	-	NA	NA	10,274.23
PET	-	131,293.19	-	NA	NA	2,659.28
PP	NA	40,103.44	-	NA	NA	812.28
Mixed Plastics	-	159,599.20	-	NA	NA	3,232.61
Mixed Electronics	-	96,816.33	-	NA	NA	1,960.97
Aluminum Cans	-	60,857.15	-	NA	NA	1,232.63
Steel Cans	-	1,880,196.64	-	NA	NA	38,082.48
Mixed Metals	-	201,215.44	-	NA	NA	4,075.52
Glass	-	378,220.20	-	NA	NA	7,660.67
Asphalt Concrete	-	2,812,071.06	NA	NA	NA	56,957.15
Asphalt Shingles	-	342,977.54	-	NA	NA	6,946.85
Carpet	-	247,584.27	-	NA	NA	5,014.70
Concrete	-	434,196.65	NA	NA	NA	8,794.44
Dimensional Lumber	-	1,878,726.97	-	NA	NA	(1,899,586.21)
Drywall	-	211,056.36	NA	NA	NA	(12,883.16)
Fly Ash	-	1,789,641.96	NA	NA	NA	36,248.34
Tires	-	105,962.83	-	NA	NA	2,146.23

Table 4 – Alternative Scenario

GHG Emissions from Alternative Waste Management Scenario ($MTCO_2E$): (7,717,814.79)

Material	Tons Recycled	Tons Landfilled	Tons Combusted	Tons Composted	Tons Anaerobically Digested	Total $MTCO_2E$	Change (Alt – Base) $MTCO_2E$
Corrugated Containers	504,179.40	330,047.91	-	NA	NA	(1,489,064.23)	(1,720,864.99)
Magazines/third-class mail	19.00	23,695.63	-	NA	NA	(8,975.26)	(51.17)
Newspaper	207,276.58	97,654.66	-	NA	NA	(640,808.55)	(392,730.71)
Office Paper	58,895.84	71,473.14	-	NA	NA	(78,688.99)	(242,803.57)
Mixed Paper (general)	178,153.39	1,084,396.30	-	NA	NA	(460,463.10)	(659,770.54)
Food Waste	NA	1,350,621.42	-	181,282.01	5,764.58	737,493.02	(138,433.52)
Food Waste (meat only)	NA	448,281.30	-	87,045.12	-	240,040.70	(64,905.90)
Yard Trimmings	NA	1,145,073.04	82,630.08	1,166,110.75	24,745.24	(366,440.66)	26,190.70
Branches	NA	-	119,755.23	-	-	(11,665.12)	45,507.92
HDPE	12,216.46	175,976.90	-	NA	NA	(6,856.85)	(10,668.61)
LDPE	NA	507,256.16	-	NA	NA	10,274.23	0.00
PET	18,525.60	112,767.59	-	NA	NA	(18,988.24)	(21,647.52)
PP	NA	40,103.44	-	NA	NA	812.28	(0.00)
Mixed Plastics	4,048.33	155,550.87	-	NA	NA	(1,022.95)	(4,255.55)
Mixed Electronics	19,964.96	76,851.37	-	NA	NA	(14,197.76)	(16,158.73)
Aluminum Cans	11,069.83	49,787.33	-	NA	NA	(100,030.08)	(101,262.71)
Steel Cans	1,350,851.22	529,345.43	-	NA	NA	(2,464,139.67)	(2,502,222.15)
Mixed Metals	181,328.36	19,887.08	-	NA	NA	(795,839.15)	(799,914.67)
Glass	146,064.98	232,155.22	-	NA	NA	(35,624.91)	(43,285.58)
Asphalt Concrete	2,736,135.90	75,935.16	NA	NA	NA	(219,896.99)	(276,854.13)
Asphalt Shingles	29,807.60	313,169.94	-	NA	NA	3,664.14	(3,282.71)
Carpet	3,141.10	244,443.17	-	NA	NA	(2,529.86)	(7,544.56)
Concrete	434,196.65	-	NA	NA	NA	(3,469.91)	(12,264.35)
Dimensional Lumber	210,731.90	1,356,698.46	311,296.62	NA	NA	(2,009,650.89)	(110,064.68)
Drywall	56,668.72	154,387.64	NA	NA	NA	(7,945.73)	4,937.43
Fly Ash	-	1,789,641.96	NA	NA	NA	36,248.34	0.00
Tires	34,899.64	67,633.16	3,430.03	NA	NA	(10,048.62)	(12,194.84)

Material Profile

Cardboard

Mixed Paper is an aggregate category and assumes the following composition of mixed paper: 48% cardboard (corrugated containers), 8% cartons (including magazines, third class mail), 24% newspaper, and 20% office paper. While this category is currently largely landfilled, several of the constituent paper categories (cardboard, office paper, and newspaper) are recycled effectively in Washington. Additional greenhouse gas reductions in this category could be achieved with more effective sorting into high grade papers to capture some of the remaining 86% that is currently being landfilled.

Tons Recovered	504,179
Estimated Tons Disposed	330,048
Recycling Rate	60%
GHG Avoided per Ton Recycled	3.41 $MTCO_2e$
GHG Avoided Achieved	1,720,865 $MTCO_2e$
Recyclability	Good
Compostability	Marginal

Material Profile

Magazines

The magazines/third-class mail category represents coated paper produced from mechanical pulp. This category includes cartons and other glossy paper products. Although these products decompose in landfills, they do not make suitable compost feedstock. Furthermore, this material type is difficult to recycle, even before the National Sword policy and COVID 19. The most effective improvements in this category could be achieved through source reduction programs, such as junk mail opt-out programs, promoting reusable or recyclable substitutes, and opting into environmentally preferable purchasing programs (such as recycled office paper). Source reduction of this material has the highest GHG reduction factor of any paper product at 8.18 $MTCO_2e$ avoided for each ton of material prevented from manufacture.

Tons Recovered	19
Estimated Tons Disposed	23,715
Recycling Rate	0.0008%
GHG Avoided per Ton Recycled	2.69 $MTCO_2e$
GHG Avoided Achieved	51 $MTCO_2e$
Recyclability	Poor
Compostability	Contaminant

Material Profile

Newspaper

Newspaper still represents a significant, but declining waste stream. This material is recoverable in traditional recycling streams, however it is not recovered as a compost feedstock. Newspaper decomposes in a landfill, but the WARM model has determined that only 0.82 $MTCO_2e$ is stored in the landfill compared to the 2.71 $MTCO_2e$ that is spared through the recycling of newspaper. Further, landfilling of newspaper is much less preferable to the 4.68 $MTCO_2e$/ton that would be avoided via source reduction of the newspaper. Newspaper is both more recyclable and requires less emissions to produce than cartons, magazines, and other glossy paper. Substitution from these categories of paper to newspaper, coupled with robust recycling of newspaper yields the greatest GHG gains.

Tons Recovered	207,277
Estimated Tons Disposed	97,656
Recycling Rate	68%
GHG Avoided per Ton Recycled	1.89 $MTCO_2e$
GHG Avoided Achieved	392,731 $MTCO_2e$
Recyclability	Good
Compostability	Marginal

Material Profile

Office Paper

Office paper is greenhouse gas intensive to produce, and is second only to cartons and magazines of the paper categories. Further, office paper produces the most greenhouse gas emissions per ton of any paper when landfilled. Successful recycling of office paper mitigates these emissions substantially, and at 45% recovered in 2017 there is still a lot of opportunity to improve the State's waste greenhouse gas impacts through recycling. Given the high level of emissions associated with both the production (7.95 $MTCO_2e$/ton) and landfilling (1.25 $MTCO_2e$/ton) of office paper, source reduction practices such as double-sided printing, digitization, and print-when-necessary policies are very effective at reducing emissions from this category.

Tons Recovered	58,896
Estimated Tons Disposed	71,473
Recycling Rate	45%
GHG Avoided per Ton Recycled	4.12 $MTCO_2e$
GHG Avoided Achieved	242,804 $MTCO_2e$
Recyclability	Good
Compostability	Marginal

Material Profile

Mixed Paper

Mixed Paper is an aggregate category and assumes the following composition of mixed paper: 48% cardboard (corrugated containers), 8% cartons (including magazines, third class mail), 24% newspaper, and 20% office paper. While this category is currently largely landfilled, several of the constituent paper categories (cardboard, office paper, and newspaper) are recycled effectively in Washington. Additional greenhouse gas reductions in this category could be achieved with more effective sorting into high grade papers to capture some of the remaining 86% that is currently being landfilled.

Tons Recovered	178,153
Estimated Tons Disposed	1,084,396
Recycling Rate	14%
GHG Avoided per Ton Recycled	4.12 $MTCO_2e$
GHG Avoided Achieved	659,771 $MTCO_2e$
Recyclability	Marginal
Compostability	Poor

Material Profile

Food Waste

Food waste is the largest waste category by weight in the State of Washington. This trend is consistent with the rest of the United States. Notably, much of this food waste is edible food. In California, a 2018 Waste Characterization reveals that 19% of this food waste is edible and could have been donated. In 2016, Washington State rescued 5,804 tons of food. In 2017, this figure dropped to 23 tons. Although food rescue in the state has fluctuated throughout the years, if the State were to regularly rescue food as it had in 2016, substantial GHG reductions will be achieved. Preventing food waste and source reducing some food wastes, such as beef, can result in greenhouse gas reductions up to 33 times the weight of the food itself.

Currently, 5,764 of the tons diverted are through anaerobic digestion with the remaining 268,327 tons of diverted food being diverted through conventional composting. Most food waste goes into landfills, where it decomposes anaerobically producing methane gas.

Tons Recovered	274,092
Estimated Tons Disposed	1,798,903
Recycling Rate	13%
GHG Avoided per Ton Recycled	0.75 $MTCO_2e$
GHG Avoided Achieved	203,339 $MTCO_2e$
Recyclability	Contaminant
Compostability	Compostable and Anaerobically Digestible

Given the volume of food waste disposed, the food waste category is one of the largest potential sources of greenhouse gas reduction for the Washington.

Material Profile

Yard Trimmings

Yard trimmings are grass clippings, leaves, small branches, and other plant wastes. This waste category is currently managed in four different ways: anaerobic digestion, composting, combustion, and landfilling. For yard trimmings, source reduction is largely outside of the control of anyone other than nature itself. Additionally, much of this material exists outside of the disposal system, as trees and other plants naturally discard and recycle organic matter. However, over one million tons of this material has left this cycle and entered into the landfill system.

The US EPA Waste Reduction Model (WARM) credits composting as a materials management for yard trimmings at -0.15 $MTCO_2e$/ ton and credits landfill carbon storage and landfill electricity generation at -0.18 $MTCO_2e$/ ton (0.02 difference after rounding).

Tons Recovered	1,276,486
Estimated Tons Disposed	1,145,073
Recycling Rate	53%
GHG Avoided per Ton Recycled	-0.02 $MTCO_2e$
GHG Avoided Achieved	-26,191 $MTCO_2e$
Recyclability	Contaminant
Compostability	Compostable and Anaerobically Digestible

Material Profile

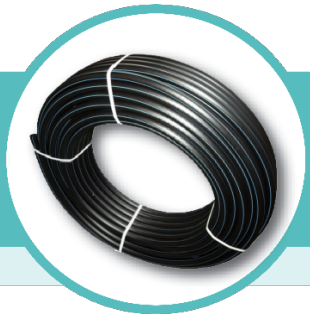
Branches

Branches are part of the yard trimmings category, and specifically refer to those branches that are larger. These branches are managed through combustion. Due to the WARM model's credit for biogenic carbon storage, the WARM model has landfilling of branches as 0.38 $MTCO_2e$ fewer emissions per ton than combusting branches.

Tons Recovered	119,755
Estimated Tons Disposed	N/A

Recycling Rate	N/A
GHG Avoided per Ton Recycled	-0.38 $MTCO_2e$ /ton
GHG Avoided Achieved	-45,508 $MTCO_2e$
Recyclability	Contaminant
Compostability	Marginal - Compostable with size reduction

Material Profile HDPE



HDPE is High-Density Polyethylene which is a plastic material used for containers such as laundry detergent and other durable packaging. Like all plastics, HDPE recycling markets have diminished greatly with the Chinese National Sword policy. HDPE has the lowest emissions per ton during production of the plastics at 1.42 $MTCO_2e$/ton, although it is also one of the heaviest plastics. Recycling the plastic, when such options are available, has a WARM avoided emissions of 0.85 $MTCO_2e$/ton recycled.

Tons Recovered	12,216
Estimated Tons Disposed	175,977
Recycling Rate	6%
GHG Avoided per Ton Recycled	0.87 $MTCO_2e$
GHG Avoided Achieved	10,669 $MTCO_2e$
Recyclability	Poor
Compost Ability	Contaminant

Material Profile PET

PET is Polyethylene terephthalate, a common plastic used for the production of items such food containers and beverage bottles. PET typically has higher value than HDPE and other plastics, especially in states that have price supports via a bottle bill. Without such a bill, PET has a much lower recovery rate. National Sword has reduced markets for this material, which remains consistently below a 20% recovery rate. PET and HDPE are the only two plastics under WARM that have a measurable GHG benefit for recycling. Further, due to the physical properties of plastic, recycling downgrades the material thus limiting the offset GHG impact of the recycled material. As such, increasing recycling avoided GHG for PET will be difficult with constricted markets and low recoverability. Source reduction for PET is 2.17 $MTCO_2e$ per ton, which presents the largest potential for GHG reduction.

Tons Recovered	18,526
Estimated Tons Disposed	112,768
Recycling Rate	14%
GHG Avoided per Ton Recycled	1.17 $MTCO_2e$
GHG Avoided Achieved	21,648 $MTCO_2e$
Recyclability	Marginal
Compostability	Contaminant

Material Profile

LDPE, PP, and Other Plastics

Low-Density Polyethylene, Polypropylene, polystyrene, and other plastics are sometimes recovered in Washington, however the WARM model calculates no recycling benefit for these plastics.

Expanded Polystyrene, also known as Styrofoam, is typically made into to-go containers and packing material. It presents a unique problem within the waste stream because it is so light-weight. The product is approximately 95% air. It also easily breaks up into little bits. These two characteristics makes it very difficult to capture and recycle.

Tons Recovered	31,897
Estimated Tons Disposed	514,915
Recycling Rate	6%
GHG Avoided per Ton Recycled	None
GHG Avoided Achieved	None
Recyclability	Poor
Compostability	Contaminant

Material Profile

Mixed Plastics

Mixed Plastics are a category of material recovered in Washington with no particular designation as to type. WARM guidance documents use a default of 40% HDPE and 60% PET. This convention is used in this context. Mixed plastics, like segregated plastics, continue to suffer from reduced markets resulting from the Chinese National Sword policy.

Tons Recovered	4,048
Estimated Tons Disposed	155,551
Recycling Rate	3%
GHG Avoided per Ton Recycled	1.05 $MTCO_2e$
GHG Avoided Achieved	4,256 $MTCO_2e$
Recyclability	Poor
Compostability	Contaminant

Material Profile

Mixed Electronics

When electronics are “Recycled” it is important to note that there are a variety of components that are recovered as well as components that are disposed. The avoided emissions from recycling electronics are attributed to the reduction of virgin material inputs that result from introducing recovered materials from these electronics. These recovered components include steel, copper, aluminum, lead, nickel, precious metals, and lithium.

Improving the recycling rate of electronics can be achieved through the introduction of special collection days, improvements in sorting at material recovery facilities, right to repair programs and legislation, as well as improving and expanding in-store take back programs.

Improving the recovery and reducing the production of electronic devices is effective by weight compared to other materials. Recycling results in 12 $MTCO_2e$ avoided per ton, and source reduction efforts result in 19 $MTCO_2e$ avoided.

As with mixed plastics, mixed electronics consists of multiple material types as a proxy. The US EPA WARM model assumptions as to the composition of electronic waste are weighted as follows: Desktop CPUs at 11%, Portable Electronic Devices at 5%, Flat-Panel Displays at 23%, CRT Displays at 44%, Electronic Peripherals at 2%, and Hard-Copy Devices at 15%.

Tons Recovered	19,965
Estimated Tons Disposed	76,851
Recycling Rate	20%
GHG Avoided per Ton Recycled	12.15 $MTCO_2e$
GHG Avoided Achieved	16,159 $MTCO_2e$
Recyclability	Variable
Compostability	Contaminant