Rayonier
More than trees

2023 CARBON REPORT METHODOLOGY

Overview

This document is a companion to the Carbon Report published on Rayonier's website that outlines the methods, data sources, and provides examples of the calculations that result in the metrics shared in the Report, including an estimate of standing carbon across the estate, carbon stored in harvested wood products, and carbon emissions associated with forest management and supply chain operations. Under the Equity Share approach, all calculations for Rayonier Matariki Forests are prorated 77% to Rayonier.

Note: The examples outlined below are examples only to help the reader understand the calculations, and do not reflect real world data as it relates to Rayonier primary data. Additionally, certain emissions factors and input data have been truncated to a few decimal places to save space, so results from calculations may be slightly different due to rounding.

United States Calculations

Methodology

Rayonier's 2023 carbon footprint is based on data from January 1, 2023 to December 31, 2023. Carbon in harvested timber and Scope 1, 2, and 3 carbon emissions are based on audited accounting data for 2023, where possible. The data on total ecosystem carbon storage and removals is extracted from Rayonier's Land Management System (LMS) database as of January 1, 2024. Any acres sold during 2023 are excluded from the calculations regardless of the date of sale since they are not included in the LMS data on January 1. Likewise, any acres acquired during 2023 are included in the calculations regardless of the date of acquisition since the acres are included in the LMS data on January 1. Ecosystem carbon storage and removals in stands where timber was harvested during the year is calculated for a stand with an age of 0, regardless of when the stand was harvested. Stands replanted during the year are assigned a stand age of 1 for carbon calculations.

Note: Carbon in harvested timber IS NOT INCLUDED IN total ecosystem carbon storage or removals presented in the Carbon Report since this carbon has already been accounted for by setting the stand age to 0. Thus, carbon in harvested timber SHOULD NOT BE SUBTRACTED from total ecosystem carbon storage or removals.

Carbon storage

Carbon content in forest ecosystems in the United States is summarized by the U.S. Forest Service in "Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types in the United States. General Technical Report NE-343."[4] Carbon stocks and stock changes at 5-year intervals are presented as dry carbon densities (metric tonnes of carbon/hectare) for a specific region, forest type, management intensity, and age class for six different ecosystem pools: live trees, standing dead trees, understory vegetation, down dead wood, forest floor, and soil organic carbon (Table 1).

Table 1: Excerpt from GTR-343 Appendix A showing the carbon yield table for Douglas-fir intensively managed forests.4 Carbon densities are reported in dry metric tonnes per hectare.

A23.— Regional estimates of timber volume and carbon stocks for Douglas-fir stands on forest land after clearcut harvest in the Pacific Northwest, West; volumes are for high-productivity sites (growth rate greater than 165 cubic feet wood per acre per year) with high-intensity management (replanting with genetically improved stock, fertilization, and precommercial thinning)

Age	Mean volume	Mean carbon density						
		Live tree	Standing dead tree	Under-story	Down dead wood	Forest floor	Soil organic	Total nonsoil
years	*m³/hectare*	*tonnes carbon/hectare*						
0	0.0	0.0	0.0	4.6	49.3	27.5	94.8	81.4
5	0.0	9.5	0.9	4.4	43.1	23.7	94.8	81.7
15	19.8	23.4	2.3	4.0	33.3	20.7	94.8	83.8
25	169.7	84.6	8.5	3.5	31.2	21.2	94.8	148.9
35	445.7	187.4	10.0	3.2	35.4	23.3	94.8	259.3
45	718.8	286.2	10.6	3.0	40.8	26.0	94.8	366.7

Stand data is extracted from Rayonier's Land Management System (LMS) database for all fee and lease land. Rayonier stand types are reclassified into the closest USFS forest type reported in GTR-343 based on the region of the U.S., species group, management intensity, and age class (Table 2). Stand acres represent net acres, with forest roads within stands removed and classified separately as non-forested (NonFor) in their respective regions.

Table 2: Breakdown of Rayonier's U.S. landholdings into USFS Forest Type categories as described in GTR-343.4 The Species Group Table reflects the Carbon Density Yield Tables referenced for either reforestation (Appendix A) or afforestation (Appendix B). The RYN Gulf Region includes Alabama, Louisiana, and Texas and the RYN Atlantic Region includes Florida, Georgia, and South Carolina.

USFS Forest Type	Species Group Table	Region
Alder-Maple (RYN Northern Region)	A21	PWW
Douglas-fir with intensive management (RYN Northern Region)	A23	PWW
Hemlock - Sitka Spruce with intensive management (RYN northern Region)	A26	PWW
Loblolly - Shortleaf with intensive management (RYN Atlantic Region)	A40	SE
Loblolly - Shortleaf with intensive management (RYN Gulf Region)	A48	SC
Longleaf - Slash with intensive management (RYN Atlantic Region)	A42	SE
NonFor-Atlantic	B39	SE
NonFor-Gulf States	B47	SC
NonFor-Northern	B25	PWW
NonStock-Atlantic	B39	SE
NonStock-Gulf States	B47	SC
NonStock-Northern	B25	PWW
Oak - Gum - Cypress (RYN Atlantic Region)	A43	SE
Oak - Gum - Cypress (RYN Gulf Region)	A49	SC
Oak - Pine (RYN Atlantic Region)	A45	SE
Oak - Pine (RYN Gulf Region)	A51	SC
Oak -Hickory (RYN Gulf Region)	A47	SC
Oak-Hickory (RYN Atlantic Region)	A44	SE

Once stands are appropriately classified, the acres for each region, forest type, and age class are summarized across stands in LMS. The acres (ac) of forest types are then converted to hectares (ha) by dividing the total number of acres in each category by 2.47 ha/ac (Equation 1). Carbon content for each of the different ecosystem components is calculated by multiplying the total hectares by the carbon density (metric tonnes/hectare) for each ecosystem component (Table 1).

Carbon content is converted into CO_2 equivalents (CO_2-e) according to methods described in the U.S. EPA Greenhouse Gases Equivalencies Calculator, where the CO_2 equivalent is equal to the carbon content multiplied by the ratio of the atomic weight of CO_2 to the atomic weight of carbon, or 44/12 (Equation 3).

Total ecosystem carbon for all the carbon pools in all combinations of region, forest type, management intensity, and age class are summed to produce the final total ecosystem carbon presented in the Carbon Report. The summaries are broken down between managed and natural stands to reflect the relative importance of each type of management.

Equation 1: *Convert acres to hectares*

h = a ÷ 2.47

Where h = hectares, a = acres

Example 1: *Douglas-fir with Intensive Management, age 15*

24,700 ac ÷ 2.47 ac/ha= 10,000 ha

Equation 2: *Ecosystem carbon content*

Ci = h x Di

Where Ci = carbon content of ith ecosystem component, h = hectares, Di = mean carbon density of ith ecosystem component

Example 2: *Carbon content of various ecosystem pools for Douglas-fir, age 15 (Table A23 in GTR-343)*

Trees (live + standing dead): 10,000 ha x (23.4 tonnes C/ha +2.3 tonnes C/ha) = 257,000 tonnes C

Understory: 10,000 ha x 4 tonnes C/ha = 40,000 tonnes C

Forest floor and down dead wood: 10,000 ha x (20.7 tonnes C/ha + 33.3 tonnes C/ha) = 540,000 tonnes C

Soil: 10,000 ha x 94.8 tonnes C/ha = 948,000 tonnes C

Total Ecosystem (∑ ecosystem pools): 257,000 + 40,000 + 540,000 + 948,000 = 1,785,000 tonnes C

Equation 3: *Carbon storage CO_2 equivalents*

Ei = Ci x (44 ÷ 12)

Where Ei = CO_2 equivalents of the ith ecosystem component, Ci = carbon content of ith ecosystem component

Example 3: *CO_2 equivalents of various ecosystem pools for Douglas-fir, age 15*

Trees: 257,000 tonnes C x (44 ÷ 12) = 942,333 tonnes CO_2

Understory: 40,000 tonnes C x (44 ÷ 12) = 146,667 tonnes CO_2

Forest floor: 540,000 tonnes C x (44 ÷ 12) = 1,980,000 tonnes CO_2

Soil: 948,000 tonnes C x (44 ÷ 12) = 3,476,000 tonnes CO_2

Total Ecosystem (∑ ecosystem pools): 942,333 + 146,667 + 1,980,000 + 3,476,000 = 6,545,000 tonnes CO_2

Carbon removals

The carbon removal (sequestration) metrics are determined using the carbon yield tables presented in GTR 343.[4] The stand data is extracted from LMS and categorized using the same approach used for total ecosystem carbon, except stands are grouped into 1 year age classes.

The annual carbon sequestration (metric tonnes/ha/yr) is calculated for each ecosystem component by region, forest type, management intensity, and age using data from GTR 343 Appendix A and B.[4] Stand ages in the publication are reported in 5- or 10-year increments, so linear interpolation is used to calculate the sequestration rates between age classes as described in GTR-343. This is accomplished by taking the difference in carbon densities between one age class and the next older age class and dividing it by the number of years between the age classes (Equation 4). Using this approach produces sequestration rates that are the same for all ages in a specific age class.

The total hectares by region, forest type, management intensity, and one-year age class are multiplied by the different sequestration rates for each of the ecosystem components to obtain the annual carbon sequestration in each carbon pool (Equations 5). The carbon is then converted to CO_2 equivalents by multiplying by 44/12, or 3.67 (Equation 6). The individual CO_2-e pools are then summed to produce the total annual CO_2-e sequestration in each combination of region, forest type, management intensity, and age category. All the categories are then summed to produce the total CO_2-e sequestered, which is the metric presented on page 6 of the Carbon Report. Like carbon storage, the final summary breaks down stands into managed and natural classifications to highlight the importance of working forests on removing carbon from the atmosphere.

Equation 4: *Annual sequestration linear interpolation*

$S_{ij} = ((D_{ij+1}) - (D_{ij})) \div A$

Where S_{ij} *= annual carbon sequestration of* i^{th} *carbon pool and* j^{th} *age class,* D_{ij} *= carbon density of* i^{th} *carbon pool and* j^{th} *age class, A = years in age class*

Example 4: *Annual sequestration rate of Douglas-fir with Intensive Management, age increment 6 to 15*

Live tree: (23.4 tonnes/ha – 9.5 tonnes/ha) ÷ 10 years = 1.39 tonnes/ha/yr

Standing dead tree: (2.3 tonnes/ha – 0.9 tonnes/ha) ÷ 10 years = 0.14 tonnes/ha/yr

Understory: (4 tonnes/ha – 4.4 tonnes/ha) ÷ 10 years = -0.04

Down Dead Wood: (33.3 tonnes/ha – 43.1 tonnes/ha) ÷ 10 years = -0.98 tonnes/ha/yr

Forest floor: (20.7 tonnes/ha – 23.7 tonnes/ha) ÷ 10 years = -0.3 tonnes/ha/yr

Soil: (94.8 tonnes/ha – 94.8 tonnes/ha) ÷ 10 years = 0 tonnes/ha/yr

Equation 5: *Ecosystem carbon sequestration*

$C_{ij} = h \times S_{ij}$

Where C_{ij} *= carbon sequestration of* i^{th} *ecosystem component at* j^{th} *age class, h = hectares,* S_{ij} *= annual carbon sequestration of* i^{th} *ecosystem component and* j^{th} *age class*

Example 5: *Total sequestration of different carbon pools of Douglas-fir, age 15*

Trees (live and standing dead): 10,000 ha x (1.39 tonnes/ha/yr + 0.14 tonnes/ha/yr) = 15,300 tonnes C/yr

Understory: 10,000 ha x -0.04 tonnes/ha/yr = -400 tonnes C/yr

DWD and Forest floor: 10,000 ha x (-0.98 tonnes/ha/yr + -0.3 tonnes/ha/yr) = -12,800 tonnes C/yr

Soil: 10,000 ha x 0 tonnes/ha/yr = 0 tonnes C/yr

Equation 6: *Carbon sequestration* CO_2 *equivalents*

$E_i = C_i \times (44 \div 12)$

Where E_i *=* CO_2 *equivalents of the* i^{th} *ecosystem component,* C_i *= carbon sequestration of* i^{th} *ecosystem component*

Example 6: CO_2 *equivalents of various ecosystem pool sequestration for Douglas-fir, age 15*

Trees: 15,300 tonnes C/yr x (44/12) = 56,100 tonnes CO_2*/yr*

Understory: -400 tonnes C/yr x (44/12) = -1,467 tonnes CO_2*/yr*

DWD and floor: -12,800 tonnes C/yr x (44/12) = -46,933 tonnes CO_2*/yr*

Soil: 0 tonnes C/yr x (44/12) = 0 tonnes CO_2*/yr*

Ecosystem total (∑ ecosystem pools): 56,100 + -1,467 + -46,933 + 0 = 7,700 tonnes CO_2*/yr*

Scope 1, 2, and 3 carbon emissions

Greenhouse gas emissions (emissions) in the Carbon Report are calculated using the methods specified by the Greenhouse Gas (GHG) Protocol Corporate Standard developed by the World Resource Institute and the World Business Council for Sustainable Development.[5] Emissions are based on the CO_2-e released as the result of combustion of fossil fuels from an activity. We calculate CO_2, CH_4, and N_2O emissions separately but combine them in our reporting since CH_4 and N_2O comprise less than 0.1% of our total emissions. Global Warming Potentials (GWPs) from the IPCC's Fifth Assessment Report are applied to convert methane and nitrous oxide to carbon dioxide equivalents. We use a materiality threshold of 25,000 tCO2-e.

Rayonier defines our operational boundary as cradle-to-gate but includes upstream and downstream emissions outside our operational boundary in our report for transparency and completeness. Rayonier has selected the equity share approach to report our consolidated GHG emissions with no exclusions. We have selected 2020 as our base year for GHG inventory.

The following sections outline carbon emissions across three scopes, as outlined by the GHG Protocol Corporate Value Chain (Scope 3) Standard.

- Scope 1 emissions pertain to emissions that originate directly from assets owned or controlled by Rayonier.
- Scope 2 emissions pertain to indirect emissions resulting from the production of purchased energy in the form of electricity, steam, heating, and cooling.
- Scope 3 emissions pertain to the timber value chain.

Scope 1: Direct emissions

Emissions from fuel use in company vehicles and equipment

Rayonier owns vehicles and equipment that burn fossil fuels, such as work trucks, dozers, and lawnmowers. The emissions factors for gasoline and diesel use are reported in kilograms of CO_2 per gallon of fuel consumed.[7] The primary data available for these assets are the gallons of fuel purchased from our expense reporting software (Table 3). This data is extracted and summarized by fuel type. The emissions factors for diesel and gasoline (Table 3) are then multiplied by the total gallons used to estimate the kilograms of CO_2 emitted (Equation 7).

Table 3: Data sources and emissions factors for Scope 1 emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Company equipment	Gallons of gasoline purchased	Expense reporting software	Not applicable	Not applicable	8.78 kg of CO2/gal	EPA GHG Emission Factor Hub7
Company equipment	Gallons of diesel purchased	Expense reporting software	Not applicable	Not applicable	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]
Company equipment	Gallons of diesel purchased	Purchase Order (PO) Invoices	Not applicable	Not applicable	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]
Methane from prescribed burning	SGTs biomass burned or acres of broadcast burning	Sr RLMs/LMS	MC of species mix and tons/ac burned	USFS Research Note NRS-38[19] and local knowledge	126 g of CH_4/dry short ton	EPA GHG Emission Factor Hub[7]
Nitrous oxide from prescribed burning	SGTs biomass burned or acres of broadcast burning	Sr RLMs/LMS	MC of species mix and tons/ac burned	USFS Research Note NRS-38[19] and local knowledge	63 g of N_2O/dry short ton	EPA GHG Emission Factor Hub[7]

Example 7: *Travel fuel calculation for company vehicles*

T = (g x e) ÷ 1,000

Where T = metric tonnes CO_2-e, g = gallons of fuel, e = emissions factor for gasoline (kg CO_2/gallon)

(1,000 gallons gas x 8.78 kg CO_2/gal) ÷ 1,000 kg/tonne = 8.78 tonnes CO_2

Emissions from prescribed burning

The CO_2 emissions from prescribed fires are considered biogenic emissions and are reported outside of Scope 1. Methane and nitrous oxide emissions from prescribed burning are non-biogenic emissions and are included in Scope 1 emissions in accordance with the GHG Protocol. The emissions factors for CH_4 and N_2O are reported in grams of GHG per dry short ton of material consumed, adjusted by the Global Warming Potential of CH_4 or N_2O. The primary data available for this calculation is SGTs of biomass in the Pacific Northwest region and acres of broadcast burns in the Southeast region. The secondary data needed for both regions is the average moisture content by species,[8] and for the Southeast, the estimated average tons of biomass consumed per acre burned. In the southeast, the SGTs are calculated by multiplying the acres by the tons per acre to get total SGTs. For both regions, the water weight is then removed by multiplying the moisture content by the total SGTs and then subtracting this value from the total SGTs. The emissions are then calculated by multiplying the oven-dry short tons by the emissions factor for each respective GHG, and then dividing by 1 million to get metric tonnes of GHG (Example 8).

Example 8: *Methane emissions from prescribed burning*

*T =(((SGT -(SGT * MC)) * e) ÷ 1,000,000) * GWP*

Where T = metric tonnes CO_2-e, SGT = short green tons biomass, MC = moisture content, e = emissions factor for biomass (g CO_2/dry short ton), and GWP = global warming potential for methane (28 MT CO_2/MT CH_4)

*T = (((10,000 SGTs – (10,000 SGTs * 0.371)) * 126 g CH_4/dry short ton) ÷ 1,000,000 g/MT * 28 MT CO_2/MT CH_4 = 22.2 MT CO_2-e*

Scope 2: Indirect emissions from purchased electricity and heating

Scope 2 emissions are those from purchased electricity and heating at company facilities. The emissions factors for electricity usage vary by Emissions & Generation Resource Integrated

Database (eGRID) subregion and are reported in pounds of CO_2 per kilowatt hour (kWh) of electricity used.[7] The primary data, kilowatt hours, is obtained from electricity bills at each facility and reported monthly (Table 4). These values are multiplied by the emissions factors from the respective subregions and summarized across the company (Example 9).

Example 9: *Scope 2 purchased electricity emissions at Wildlight*

T = (k x e) x 0.00045

Where T = metric tonnes CO_2-e, k = kWh of electricity used, e = emissions factor for electricity (lbs of CO_2 per kWh)

T = (100,000 kWh x 0.848 lbs CO_2/kWh) x .00045 tonnes/lb= 38.2 tonnes CO_2

The emissions factor for propane is reported in kilograms of CO_2 per gallon of fuel consumed.[7] The primary data available is gallons of propane use based on invoices for fuel purchases. The total gallons of propane are multiplied by the emissions factor to calculate the total emissions (Example 10).

Example 10: *Scope 2 heating propane emissions at Port Gamble*

P = (g x e) ÷ 1,000

Where P = emissions from propane (MT CO_2-e), g = gallons of propane, and e = emissions factor for propane (5.75 kg CO_2/gallon)

P = (10,000 gal x 5.72 kg CO_2/gallon) ÷ 1,000 kg/tonne

P = 57.2 tonnes CO_2

The emissions factor for natural gas is reported in kilograms of CO_2 per cubic feet of natural gas consumed.[7] The primary data available for this category is cubic feet (CF) of natural gas reported on utility bills from office administrators. The CF of natural gas is multiplied by the emissions factor to calculate kilograms of CO_2 (Example 11).

Example 11: Scope 2 natural gas emissions at the Poulsbo office in January

N = (cf x e) ÷ 1,000

Where N = emissions from natural gas (MT CO_2-e), cf = cubic feet (aka scf) of natural gas, and e = emissions factor for natural gas (0.0544 kg CO_2/cf)

N = (10,000 x 0.0544) ÷ 1,000

N = 0.544 tonnes CO_2

The emissions factor for diesel is reported in kilograms of CO_2 per gallon of diesel consumed.[7] The primary data for diesel consumption is the gallons of fuel purchased from our expense reporting software for the St. Paul Church in Port Gamble, WA. The gallons of diesel are multiplied by the emissions factor to calculate kilograms of CO_2.

Table 4: Data sources and emissions factors for Scope 2 emissions.

Type	Primary Data	Source	Emissions factor	Source
Electricity use at facilities	Kilowatt hours (kWh) of electricity	Facility energy bills	Range: 0.635-1.032 lbs CO_2/kWh	EPA GHG Emission Factor Hub[7]
Propane use at facilities	Gallons of propane	Propane invoices	5.72 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]
Natural gas use at facilities	Cubic feet (CF) of natural gas	Facility energy bills	0.0544 kg of CO_2/CF	EPA GHG Emission Factor Hub[7]
Heating fuel use at facilities	Gallons of diesel	Expense reporting software	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

Scope 3: Indirect emissions in the value chain

Most of Rayonier's operations are conducted as contracted services and are therefore included as Scope 3 emissions. Additionally, there are other activities upstream and downstream of Rayonier, such as the production of materials and disposal of products made from our logs, which are included as Scope 3 emissions. The GHG Protocol categorizes Scope 3 emissions into 15 categories, with categories 1-8 being upstream of the reporting company and categories 9-15 being downstream of the reporting company. The categories are outlined in order below.

Category 1: Purchased goods and services

This category includes the extraction, production, and transportation of goods and services procured by the reporting company that are not otherwise covered in categories 2-8. This largely relates to contracted activities that take place in Rayonier forests or in the real estate development areas owned by the company. These are grouped into seven categories:

community development, timber harvesting, road construction and maintenance, silviculture activities and support vehicles, LiDAR collection, lift rentals for our seed orchards, and fertilizer/herbicide production.

Community development activities contracted out largely deal with building roads and clearing land for building, which involves the use of heavy equipment such as excavators and off-road trucks that use diesel fuel. This category uses the supplier-specific calculation method and the emissions factor for diesel fuel is 10.21 kilograms of CO_2 per gallon of fuel.[7] The primary data for community development is the gallons of diesel fuel use reported on contractor invoices (Table 5). The total gallons of fuel use are multiplied by the emissions factor to calculate the kilograms of CO_2 emitted (Example 12).

Table 5: Data sources and emissions factors for Scope 3 Community Development emissions.

Type	Primary Data	Source	Emissions factor	Source
Community development	Gallons of diesel	Contractor invoices	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

Example 12: *Emissions from community development by Burnham Construction*

C = (g x e) ÷ 1,000

Where C = emissions from community development (MT CO_2-e), g = gallons of diesel, and e = emissions factor for diesel (10.18 kg CO_2/gallon)

C = (50,000 gal x 10.21kg CO_2/gal) ÷ 1,000

C = 510.5 tonnes CO_2

Equipment used to harvest timber uses diesel fuel. Harvesting contractors do not report the gallons of diesel fuel use in their activities, so the average data calculation method is applied. The primary data available is short green tons (SGTs) of timber harvested throughout the year (Table 6). To calculate the total gallons used, secondary data on the harvest fuel consumption (gallons/ton) per ton of timber harvested is used.[9-11] The SGTs are multiplied by the fuel consumption estimates from published literature to calculate the total gallons of diesel use. The gallons of diesel are then multiplied by the emissions factor to get kilograms of CO_2 emitted (Example 13).

Table 6: Data sources and emissions factors for Scope 3 Harvesting emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Harvesting emissions	Net harvest tons	Harvest production statistics	Harvest fuel consumption	FRA Technical Releases[9,10], internal NZ fuel consumption study, USFS estimates[11]	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

***Example 13:** Harvesting emissions in the southeast*

T = (h x c x e) ÷ 1,000

Where T = metric tonnes CO_2-e, h = harvest totals (SGTs), c = harvest fuel consumption (gal/ton), e = emissions factor for diesel (kg CO_2/gal)

T = (5,000,000 SGT x 0.445 gal/ton x 10.21 kg CO_2/gal) ÷ 1,000 = 22,717.3 tonnes CO_2

Emissions produced from road construction and maintenance are based on diesel fuel consumed. The emissions factor for diesel fuel is 10.21 kilograms of CO_2 per gallon of fuel.[7] Two different approaches to calculate emissions are used. For the Southeast, the calculation method is the average data method and the primary data used is equipment hours (Table 7). Data collected by several of the southern Resource Units (RUs) includes the number of hours spent on various road building and maintenance activities. The average cost per hour for each activity is calculated from this data. Total expenditures for road construction and maintenance are divided by the average cost per hour to determine the total hours required for road construction and maintenance activities. The secondary data needed is the diesel fuel use reported in gallons per hour for equipment, which is sourced from the Caterpillar User Handbook.[12] Total hours are multiplied by the gallons per hour to get total gallons, which are then multiplied by the emissions factor (Example 14).

***Example 14:** Road building and maintenance in the southeast*

T = (h x f x e) ÷ 1,000

Where T = metric tonnes CO_2-e, h = equipment hours, f = fuel consumption (gal/hr), e = emissions factor for diesel (kg CO_2/gal)

T = (30,000 hrs x 5 gal/hr x 10.21 kg CO_2/gal) ÷ 1,000 kg/tonne = 1,531.5 tonnes CO_2

For the Pacific Northwest, the calculation method is the spend based method and the primary data available is dollars spent and cost per hour for various activities. Total hours are calculated by dividing the total expenditures by the cost per hour. The result is then multiplied by the secondary data of diesel fuel use (gal/hr) to arrive at total gallons. These gallons are multiplied by the emissions factor for diesel fuel use to calculate emissions. Emissions are then summed across the various activity types (Example 15).

Table 7: Data sources and emissions factors for Scope 3 Road Construction and Maintenance emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Southeast road construction	Equipment hours	Contractor invoices	Diesel fuel use	Caterpillar User Handbook[12]	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]
Pacific Northwest road construction	Dollars spent on roading and average cost/hr	Contractor invoices and budget	Diesel fuel use	Caterpillar User Handbook[12]	10.21 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

Example 15: *Road brushing in the PRU*

$T = ((d \div c) \times f \times e) \div 1{,}000$

Where T = *metric tonnes* CO_2-*e*, d = *dollars*, c = *cost per hour*, f = *fuel consumption (gal/hr)*, e = *emissions factor for diesel (kg* CO_2*/gal)*

$T = ((\$200{,}000 \div \$90/hr) \times 5\ gal/hr \times 10.21\ kg\ CO_2/gal) \div 1{,}000\ kg/tonne = 113.4\ tonnes\ CO_2$

The process for calculating emissions from site preparation, planting, HWC, fertilization, and PCT is based on the gallons of fuel used, and the average data method is applied. The emissions factors for these activities are 9.75 kg of CO_2 per gallon for jet fuel, 10.21 kg of CO_2 per gallon for diesel fuel, and 8.78 kg of CO_2 per gallon for gasoline.[7] The primary data available is the acres for each treatment based on data from LMS (Table 8). The secondary data is the treatment rate (acres per hour) estimated by field foresters and fuel use (gallons per hour) reported by contractors or sourced from the CAT handbook.[12] The acres are divided by the treatment rate to estimate the hours spent on each activity, which is then multiplied by the fuel use to calculate the total gallons used. The gallons are then multiplied by the emissions factor for the different application methods (Example 16).

Table 8: Data sources and emissions factors for Scope 3 Site Prep, Planting, HWC, and PCT emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Silviculture activities	Acres of treatment type	Land Management System database	Treatment rate and fuel use	Rayonier foresters, self reported by contractors, Caterpillar handbook[12]	Jet fuel = 9.75 kg of CO_2/gal, Diesel = 10.21 kg of CO_2/gal, Gasoline = 8.78 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

Example 16: *Double bedding mechanical site prep emissions in the southeast*

$T = ((a \div r) * f * e) \div 1{,}000$

Where T *= metric tonnes* CO_2*,* a *= acres of treatment,* r *= rate (acres/hour),* f *= fuel use (gal/hour),* e *= emissions factor for diesel (kg* CO_2*/gal)*

$T = ((20{,}000 \text{ ac} \div 1 \text{ ac/hr}) * 5 \text{ gal/hr} * 10.21 \text{ kg } CO_2\text{/gal}) \div 1{,}000 \text{ kg/tonne} = 1{,}021 \text{ tonnes } CO_2$

Emissions from support vehicles are estimated for fertilization, site prep, planting, HWC, and PCT contractors. These emissions are based on fuel used to transport equipment and personnel to the treatment sites and apply the average data method. The emissions factors used for support vehicles are 10.21 kg of CO_2 per gallon for diesel fuel and 8.78 kg of CO_2 per gallon for gasoline.[7] The primary data used in this calculation is the number of support vehicles for a typical contractor based on input from the field foresters and the acres treated determined from LMS (Table 9). The secondary data is the treatment rate (acres per hour) and fuel use (gallons per day) based on miles traveled per day by contractors and MPG of the vehicles. The number of days of support vehicle use are calculated by multiplying the treatment rate by the number of people or machines on the crew to estimate the total acres treated per hour. This is then multiplied by the number of hours worked in a day to get the total acres treated per day. Finally, the total acres for a treatment are divided by the acres treated per day to estimate the total number of days worked on a treatment type. The days are multiplied by gallons per day to calculate the total gallons of fuel use by support vehicles. The gallons of fuel use are then multiplied by the emissions factor for the respective fuel type to estimate emissions from support vehicles (Example 17).

Table 9: Data sources and emissions factors for Scope 3 Support Vehicle emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Support vehicles	Acres of treatment type	Land Management System database	Treatment rate and fuel use	Rayonier foresters and self-reported by contractors	Diesel = 10.21 kg of CO_2/gal, Gasoline = 8.78 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

Example 17: *Support vehicle emissions for double bedding mechanical site prep in the southeast*

*D = (a ÷ (r * h) * c) ÷ m*

Where D = number of vehicle support days, a = total acres of treatment, r = application/production rate (acres/hour), h = hours per day, c = number of crew members, m = number of machines

*D = (20,000 ac ÷ (1 ac/hr * 6 hr/day))/ 3 machines = 1,111 days*

AND

*T = (D * g * e) ÷ 1,000*

Where T = metric tonnes CO_2, D = vehicle support days, g = gallons per day, e = emissions factor for diesel or gas (kg CO_2/gallon)

*T = (1,203 days * 65 gal/day * 10.21 kg CO_2/gal) ÷ 1,000 kg/tonne = 737 tonnes CO_2*

LiDAR acquisition uses the average data method. The emissions factor for LiDAR flights is 9.75 kilograms of CO_2 per gallon of jet fuel burned.[7] The primary data available for this category is flight hours reported by the contractors who collect the LiDAR data (Table 10). The secondary data needed is the fuel use (gallons per hour) for the aircraft used.[13] The total gallons of jet fuel are calculated by multiplying the flight hours by gallons per hour. Gallons are then multiplied by the emissions factor to estimate kilograms of CO_2 (Example 18).

Table 10: Data sources and emissions factors for Scope 3 LiDAR Acquisition emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
LiDAR acquisition	Flight hours	Self reported by contractor	Fuel use (gal/hr)	Guardian Jet[13]	9.75 kg of CO_2/gal	EPA GHG Emission Factor Hub[7]

Example 18: *Emissions from LiDAR acquisition*

$T = ((h \times g) \times e) \div 1{,}000$

Where T = metric tonnes CO_2, h = flight hours, g = fuel use (gal/hr), and e = emissions factor for jet fuel (kg CO_2/gallon)

$T = ((100 \text{ hrs} \times 60 \text{ gal/hr}) \times 9.75 \text{ kg } CO_2\text{/gal}) \div 1{,}000 \text{ kg/tonne} = 58.5 \text{ tonnes } CO_2$

Fertilizer and herbicide production are an important upstream emission to account for based on the amount of chemicals we apply to our ownership each year. The average data method is applied, and the primary data for these calculations are the kilograms of product applied (Table 11). The emissions factor for herbicide production is megajoules of energy per kilogram of active ingredient (MJ/kg ai)[14] and grams of CO_2 per kilogram (g CO_2/kg) for fertilizer (Table 11).[15]

The secondary data needed for herbicide production is the emissions factor to convert joules to metric tonnes of CO_2 (MT CO_2/terajoule).[16] The mass of each product is converted to kilograms (from ounces for herbicide and tons for fertilizer), and then the kilograms are multiplied by the emissions factor. For herbicide, the megajoules are converted to terajoules, which can then be multiplied by the emissions factor to get metric tonnes of CO_2-e (Examples 19 and 20).

Table 11: Data sources and emissions factors for Scope 3 fertilizer and herbicides emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Fertilizer production	Tons of fertilizer	Silviculture Operations Manager	Not applicable	Not applicable	Range: -270 to 420 g of CO_2/gal	Wood and Cowie 2004[15]
Herbicide production	Ounces of herbicide	Silviculture Operations Manager	MJ/kg of active ingredient	Audsley et al 2009[14]	20 MT CO_2/TJ	IPCC 1996[16]

Example 19: *Emissions from glyphosate production*

$T = (kg * E) \div 1{,}000{,}000 * e$

Where T = metric tonnes CO_2-e, kg = kilograms active ingredient (ai), E = emissions factor for megajoules, and e = emissions factor for MT CO_2-e/terajoule

$T = (10{,}000 \text{ kg} * 474 \text{ MJ/kg ai}) \div 1{,}000{,}000 * 20 \text{ MT } CO_2\text{/TJ} = 94.8 \text{ MT } CO_2\text{-e}$

Example 20: *Emissions from urea production*

$$T = (kg * e) \div 1{,}000{,}000$$

Where T = metric tonnes CO_2-e, kg = kilograms product, and e = emissions factor (g CO_2/kilogram)

$$T = (1{,}000{,}000 \text{ kg} * 420 \text{ g } CO_2/\text{kg}) \div 1{,}000{,}000 = 420 \text{ MT } CO_2\text{-e}$$

The final subcategory that we account for in purchased goods and services is the emissions associated with aerial lift operation in our seed orchards. The supplier-specific method is applied, and the emissions factor for this category is 10.21 kilograms of CO_2 per gallon of diesel fuel consumed.[7] The primary data available for this category is gallons of diesel fuel purchased via POs by our orchards. The gallons of diesel purchased are multiplied by the emissions factor for diesel fuel and then converted to metric tonnes of CO_2 by dividing the kilograms by 1,000.

Category 2: Capital goods

This category includes the production of capital goods that are purchased or acquired by the reporting company. Capital goods are considered fixed assets or plant, property, and equipment (PPE), and reporting companies should follow their own financial accounting procedures.

The company did not purchase any material capital goods in the reporting period. This category will be reviewed annually for purchases that may trigger a calculation.

Category 3: Fuel- and energy-related activities

This category includes well-to-tank emissions from the production of fuels and energy used for Scope 1 and 2 before combustion (tank-to-wheel). There are four subcategories: upstream emissions from purchased fuels, upstream emissions of purchased electricity, transmission and distribution (T&D) losses, and the generation of purchased electricity that is sold to end users. The generation of purchased electricity that is sold to end users relates to utility companies and, therefore, is not included.

The emissions factors for upstream emissions from fuel production are reported in kilograms of CO_2 per liter as reported by the U.K. Government's Department for Environment, Food, and Rural Affairs (DEFRA; Table 12).[17] The average data method is applied to use primary data available for this category, which is the gallons of various fuels used for Scope 1 and 2 emissions. The gallons are converted to liters by multiplying by 3.78 liters per gallon, which is then multiplied by the emissions factor. One difference to this category is natural gas, which is reported in centum cubic feet (CCF) and uses an emissions factor in kilograms of CO_2 per cubic meter. CCF is converted to cubic meters by multiplying 2.83 cubic meters per CCF and then multiplied by the emissions factor to get kilograms of CO_2 (Example 21).

Example 21: *Emissions from upstream diesel production*

$T = (L * e) \div 1,000$

Where T = metric tonnes of CO_2*-e, L = liters of fuel, and e = emissions factor (kg* CO_2*/liter)*

$T = (10,000 \text{ liters} * 0.617 \text{ kg } CO_2/L) \div 1,000 = 6.2 \text{ MT } CO_2\text{-e}$

The upstream emissions from electricity production uses an emissions factor reported in kilograms of CO_2 per kilowatt-hour[17] and the average data method is applied. The primary data used for this category is kilowatt-hours used in Scope 2 calculations. The kilowatt hours are multiplied by the emissions factor to get kilograms of CO_2 (Example 22).

Example 22: *Emissions from upstream electricity production*

$T = (kWh * e) \div 1,000$

Where T = metric tonnes of CO_2*-e, kWh = total kilowatt hours of electricity used, and e = emissions factor (kg* CO_2*/kWh)*

$T = (1,000,000 \text{ kWh} * 0.071\text{kg/kWh}) \div 1,000 = 71 \text{ MT } CO_2\text{-e}$

The emissions from transmission and distribution losses use emissions factors reported in both pounds per kilowatt hour[7] and kilograms per kilowatt hour (kWh).[17] The average data method is applied using primary data available for this category, which is kilowatt hours of electricity used in Scope 2 calculations. The secondary data needed for this category is grid gross loss (GGL), as reported by the EPA.[18] GGL, also known as line loss or T&D loss, is an estimate of the energy lost while supplying electricity to end consumers. The GGL is used to calculate the loss factor, calculated using GGL/(1-GGL). This loss factor is multiplied by the total kWh consumed to get the estimated line loss. This value is then multiplied by the emissions factor for upstream (well-to-tank) and downstream (tank-to-wheel) emissions and converted to metric tonnes of CO_2-e (Example 23).

Example 23: *Emissions from transmission and distribution losses*

$T = (GGL/(1-GGL) * kWh * e) \div 1,000$

Where T = metric tonnes of CO_2*-e, GGL = grid gross loss, kWh = total kilowatt hours, and e = emissions factor (kg* CO_2*/kWh)*

$T = (0.051/(1-0.051) * 1,000,000 \text{ kWh} * 0.071\text{kg } CO_2/\text{kWh}) \div 1,000 = 3.8 \text{ MT } CO_2\text{-e}$

Table 12: Data sources and emissions factors for Scope 3, Category 3.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Upstream fuel production	Gallons/CF of fuel used	Scope 1 and 2 fuel	Not applicable	Not applicable	Range 0.191-0.617 kg CO_2/liter	DEFRA[17]
Upstream electricity production	kWh of electricity used	Scope 2 electricity use	Grid Gross Loss	EPA eGRID	0.071 kg CO_2/kWh	DEFRA[17]

Category 4: Upstream transportation and distribution

This category accounts for the transportation and distribution of purchased goods between the reporting company's tier 1 suppliers and its own operations or sold goods where the transportation is paid for by the reporting company. This includes transportation of fertilizer, seedlings, ocean freight for export logs, and logs from delivered wood harvests.

The emissions factor for trucking of fertilizer is 10.21 kg of CO_2 per gallon of diesel fuel used, and the calculation method applied is the distance-based method. The primary data available is tons of product used based on data provided by the silviculture operations manager. The secondary data required is trucking miles, tons of product per truckload, and MPG for heavy-duty trucks (Table 13).[19] The tons of product applied is divided by the tons per truckload to get the number of loads. It is assumed that the trucking distance from fertilizer distribution locations is 200 miles round trip, so the number of loads is multiplied by 200 to estimate the number of miles traveled. The miles traveled are then divided by the miles per gallon for the trucks to calculate the total gallons of diesel used. The gallons are then multiplied by the emissions factor to determine CO_2 emissions (Example 24).

Table 13: Data sources and emissions factors for Scope 3 fertilizer transportation emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Fertilizer transportation	Tons of fertilizer	Rayonier application rates	MPG for heavy duty trucks	American Transport Research Institute[19]	10.21 kg CO_2/gallon	EPA GHG Emission Factors Hub[7]

Example 24: *Emissions from fertilizer transportation for establishment aerial fertilizer in Alabama*

*F = ((f ÷ 29.4) * 200) ÷ 6.5*

Where F = gallons of diesel fuel, f = tons of fertilizer, 29.4 = tons of fert per truck load, 200 = round trip miles per load, and 6.5 = MPG for heavy duty trucks

AND

*E = (F * e) ÷ 1,000*

Where E = emissions in metric tonnes CO_2-e, F = gallons of diesel fuel, e = emissions factor for diesel (kg of CO_2/gallon), and 1,000 = conversion from kilograms to metric tonnes

*F = ((500 tons ÷ 29.4 tons/load) * 200 miles) ÷ 6.5 MPG = 523.3 gallons*

*E = (523.3 gal * 10.21 kg CO_2/gal) ÷ 1,000 = 5.3 MT CO_2-e*

Emissions from trucking logs is based on diesel fuel, which is determined based on an emissions factor reported in kilograms of CO_2 per gallon used.[7] This category also uses the distance-based method, and the primary data for this calculation is the total miles driven from each harvest unit to the mill location (Table 14). The distance to each mill and the number of loads delivered to that mill are recorded for each timber sale, and this data is used to calculate the total trucking miles associated with harvest operations for the year. The secondary data needed is the average fuel efficiency for log trucks, reported as 5.1 miles per gallon.[20] The gallons of diesel are calculated by dividing the total miles by the miles per gallon, and the resulting gallons are multiplied by the emissions factor for diesel fuel to calculate emissions (Example 25).

Table 14: Data sources and emissions factors for Scope 3 log trucking emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Log trucking	Total miles driven	Harvest production statistics	Fuel efficiency for log trucks (MPG)	WA Log Trucking Industry[20]	10.21 kg CO_2/gallon	EPA GHG Emission Factors Hub[7]

Example 25*: Trucking emissions in the PRU*

T = ((m ÷ f) x e) ÷ 1,000

Where T = metric tonnes CO_2-e, m = total miles driven, f = fuel efficiency (MPG), e = emissions factor diesel (kg CO_2/gal)

T = ((5,000,000 miles ÷ 5.1 MPG) x 10.21 kg CO_2/gal) ÷ 1,000 = 10,010 tonnes CO_2

In addition to emissions from planting seedlings, the transportation of the seedlings must be accounted for as well, which includes trucking and cold storage, both of which rely on diesel fuel as an energy source. The emissions factor for diesel fuel is 10.21 kilograms of CO_2 per gallon of fuel consumed.[7] The distance-based method is applied, and the primary data available for seedling transportation is the number of miles traveled reported by the seedling nursery (Table 15). The secondary data needed to calculate gallons of diesel use is the average miles per gallon for heavy-duty trucks, reported as 6.5 MPG by the American Transport Research Institute.[21] The total gallons of diesel fuel used is calculated by dividing the total miles by the MPG. The gallons are then multiplied by the emissions factor to estimate kilograms of CO_2 (Example 26).

Example 26: *Emissions from seedling transportation*

$T = ((M \div m) \times e) \div 1{,}000$

Where T = metric tonnes CO_2, M = total miles driven, m = MPG of heavy duty trucks, and e = emissions factor for diesel fuel (kg CO_2/gallon)

$T = ((100{,}000 \text{ miles} \div 6.5) \times 10.21 \text{ kg } CO_2/\text{gal}) \div 1{,}000 = 157.1 \text{ tonnes } CO_2$

Refrigerated vans use diesel fuel to keep seedlings cool during transport and storage. The spend based method applies as the primary data for this emissions source, which is the total dollars spent on refrigeration fuel (Table 15). Secondary data on the average cost of diesel is used to calculate the total gallons of diesel fuel consumed. Total expenditures are divided by the average cost of diesel to get total gallons, which is then multiplied by the emissions factor to get the total kilograms of CO_2 emitted (Example 27).

Table 15: Data sources and emissions factors for Scope 3 reefer van and seedling transportation.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Reefer van	Dollars spent on diesel	Expense reporting software	Average cost of diesel	US Energy Information Administration[32]	10.21 kg CO_2/gallon	EPA GHG Emission Factors Hub[7]
Seedling transportation	Miles driven	Self-reported by contractor	Fuel efficiency for heavy duty trucks (MPG)	American Transport Research Institute[19]	10.21 kg CO_2/gallon	EPA GHG Emission Factors Hub[7]

***Example 27:** Emissions from refrigerated van use*

$T = ((D \div d) \times e) \div 1{,}000$

Where T = metric tonnes CO_2, D = total dollars spent, d = average cost of diesel, and e = emissions factor for diesel fuel (kg CO_2/gallon)

$T = ((\$5{,}000 \div \$4.99/gal) \times 10.21\ kg\ CO_2/gal) \div 1{,}000 = 10.2$ Metric tonnes CO_2

The emissions factor for ocean freight is 11.67 grams of CO_2 per ton per nautical mile (g/ton/nm).[22] The primary data available for this calculation is the number of tons (SGTs) shipped from an individual port to a destination port (Table 16), so the distance-based calculation method is applied. The distance (in nautical miles) to each destination is obtained from the online Port Distance Calculator.[23] SGTs are multiplied by the nautical miles and the emissions factor to calculate the grams of CO_2 emissions, which are converted into metric tonnes (Example 28).

Table 16: Data sources and emissions factors for Scope 3 ocean freight emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Ocean freight	Tons of logs shipped by destination	Harvest production statistics	Distance to destination port (nautical miles)	Port Distance Calculator[23]	11.67 g CO_2/ton/nautical mile	International Maritime Organization[22]

***Example 28:** Ocean freight emissions for exports from the PRU to China*

$T = (h \times d \times e) \div 1{,}000{,}000$

Where T = metric tonnes CO_2, h = export volume (SGT), d = distance between ports (nautical miles), e = emissions factor for ocean freight (grams CO_2/ton/nautical mile)

T = (100,000 SGT x 5,123 nautical miles x 11.67 g CO_2/ton/nm) ÷ 1,000,000 g/tonne = 5,979 tonnes CO_2

Category 5: Waste generated in operations

This category accounts for emissions associated with the disposal and treatment of waste. This equates to the disposal of municipal solid waste generated at Rayonier offices and facilities; all material is assumed to go to landfills.

The emissions factor for waste disposal and treatment is reported in metric tonnes of CO_2-e per short ton of material (in this case, municipal solid waste). The primary data available for this category is the volume of waste (in yards) produced throughout the year based on the size of the container and the number of pickups, so the average data calculation method is applied (Table 17). The secondary data needed to convert to weight (in tons) is the weight of commercial waste per cubic yard of garbage.[24] The volume of waste is converted to weight by multiplying by 138 pounds per cubic yard, then converted to tons by dividing by 2,000 pounds per ton, and then multiplied by the emissions factor to get metric tonnes of CO_2-e (Example 29).

Table 17: Data sources and emissions factors for Scope 3 waste generation emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Waste generation	Volume of trash bin	Facility managers	Volume to weight conversion	US EPA[24]	0.52 MT CO_2/short ton material	EPA GHG Emission Factors Hub[7]

***Example 29:** Emissions from waste disposal at Rayonier headquarters*

$T = ((v * p * 138) \div 2{,}000) * e$

Where T = metric tonnes CO_2-e, v = volume (in yards) of waste bin, p = number of annual pickups, and e = emissions factor (MT CO_2/ton of material)

$T = ((4 \text{ yds} * 104 \text{ pickups} * 138 \text{ lbs/yd}) \div 2{,}000 \text{lbs/ton}) * 0.52 \text{ MT } CO_2/\text{ton} = 14.9 \text{ tonnes } CO_2\text{-e}$

Category 6: Business travel

This category includes emissions associated with the transportation of employees for business purposes. This includes rental vehicles, domestic and international flights, personally owned vehicle (POV) program, and cab/rideshare services.

The emissions factor for medium-haul domestic air travel is 0.129 kilograms of CO_2 per mile and 0.163 kilograms of CO_2 per mile for long-haul and international flights (>2,300 miles).[7] The primary data available is the number of flights for domestic and international trips, which are extracted from our expense reporting software (Table 18), so the distance-based method is used. Secondary data on the distance of the most common flights is needed to calculate the total number of miles flown in the calendar year reported by the International Civil Air Organization GHG Emissions Calculator.[25] The number of flights is multiplied by the average distance per flight to calculate total miles, which is then multiplied by the emissions factor to estimate total emissions from air travel (Example 30).

Table 18: Data sources and emissions factors for Scope 3 airline emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Airline	Count of flights	Expense reporting software	Average flight distance of most common destinations	International Civil Air Organization[25]	Short haul 0.129 kg CO_2/mile Long haul 0.163 kg CO_2/mile	EPA GHG Emission Factors Hub[7]

Example 30: *Air travel emissions for domestic flights*

T = (d x n x e) ÷ 1,000

Where T = metric tonnes CO_2, d = average distance (in miles) per flight, n = number of flights, and e = emissions factor for medium haul air travel (0.129 kg CO_2/mile)

T = (3,000 miles x 523 flights x 0.129 kg CO_2/mile) ÷ 1,000 = 202.4 tonnes of CO_2

For vehicle travel, the emissions factor for gasoline combustion is 8.78 kilograms of CO_2 per gallon of fuel burned.[7] For POV emissions, the primary data is the amount reimbursed to individuals for business miles traveled that is extracted from our expense reporting software, so the spend based method is used. The rate per mile paid for personal vehicle use is used to convert the reimbursed amount to the total business miles traveled (Table 19). The secondary data used is vehicle miles per gallon (MPG) for employee vehicles. Vehicle make and model is self-reported by employees, and an average MPG for each vehicle is extracted from data on MPG from the Department of Energy database.[26] Total fuel use (gallons) is calculated by dividing the miles driven by the average MPG for vehicles, and total gallons of gasoline is multiplied by the emissions factor (Example 31).

Table 19: Data sources and emissions factors for the POV program.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
POV program	Dollars spent on POV program, rental cars, etc.	Expense reporting software	Vehicle make/model (for MPG), commute miles, average MPG	Self-reported by employees, Department of Energy[26]	8.78 kg CO_2/gallon	EPA GHG Emission Factors Hub[7]

Example 31: *POV emissions for PRU & Oklahoma*

M = d ÷ r

Where M = total miles, d = total dollars, and r = rate (dollars/mile)

$200,000 ÷ $0.41/mile = 487,805 miles

AND

T = ((M ÷ a) x e) ÷ 1,000

Where T =tonnes CO_2 emissions, M = total miles, a = average MPG POV, and e = emissions factor for gas (kg CO_2/gallon)

((487,805 miles ÷ 18.8 MPG) x 8.78 kg CO_2/gal) ÷ 1,000 kg/tonne = 227.8 tonnes CO_2

The emissions factors for ridesharing are reported in kilograms of CO_2 per vehicle or passenger mile (depending on the mode of transportation).[7] The primary data available is the number of miles traveled as reported by employees through our expense reporting software, thus the distance-based method is applied (Table 20). Emissions are calculated by multiplying the number of miles by the emissions factor for each respective mode of transportation (Example 32).

Table 20: Data sources and emissions factors for cab/ridesharing emissions.

Type	Primary Data	Source	Emissions factor	Source
Cab/ridesharing	Miles of transport	Expense reporting software	Range 0.055-0.313 kg CO_2/mile	EPA GHG Emission Factors Hub[7]

Example 32: *Emissions from cab/ridesharing*

*T = (m * e) ÷ 1,000*

Where T = metric tonnes CO_2, m = miles driven, and e = emissions factor for ground transportation (kg CO_2/mile)

*T = (7,000 miles * 0.313 kg CO_2/ mile) ÷ 1,000 = 2.2 tonnes CO_2*

Category 7: Employee commuting

This category includes emissions associated with the transportation of employees between their home and worksite, considered the employees office for Rayonier's purposes. We have also included emissions associated with employees working from home (WFH).

For emissions associated with commuting, the primary data is office entry card data and self-reported commuting distances, so the distance-based method is used (Table 21). Entry card data is used to determine the average number of days employees entered their respective offices, which is assumed to equal days commuting. This average is multiplied by the total commuting distance to estimate the total commuting miles throughout the year. Like POV emissions, the secondary data is MPG for employee vehicles. The total miles are divided by the average MPG to get the total gallons used. This is then multiplied by the emissions factor for gasoline to determine emissions.

Table 21: Data sources and emissions factors for commuting emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Commuting	Commuting distance	Self-reported by employees	Average MPG for employee vehicles	Department of Energy[26]	8.78 kg CO_2/gallon	EPA GHG Emission Factors Hub[7]

The emissions factor for work-from-home emissions is reported in kilograms of CO_2-e per working hour.[17] The primary data available for this category is the number of employees working for Rayonier in the U.S., so the average data method is applied (Table 22). The secondary data needed is the number of hours worked per employee per year, which is calculated based on the average number of work days in a year, subtracted by the amount of paid time off employees receive and the average number of days employees commuted to the office. The total number of employees is multiplied by the hours/employee/year to get total work-from-home hours in a year, which is then multiplied by the emissions factor to get tonnes of CO_2-e (Example 33).

Table 22: Data sources and emissions factors for working from home.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Working from home	Number of employees	Employee Data	Days worked per year	Estimate based on company policy	0.34075 kg CO_2/work hour	DEFRA[17]

Example 33: *Work from home emissions*

$T = ((E * h) * e) \div 1{,}000$

Where T *= metric tonnes* CO_2*,* E *= number of employees,* h *= hours/employee/yr, and* e *= emissions factor (kg* CO_2*/working hour)*

$T = ((326 \text{ employees} * 1500 \text{ hours/yr}) * 0.341 \text{ kg/hr}) \div 1{,}000 = 166.7 \text{ tonnes } CO_2$

Category 8: Upstream leased assets

This category includes emissions associated with the operation of assets that are leased by the reporting company. For Rayonier, the only leased assets in our financial accounting are printers used in our offices. Emissions associated with these assets are reported in our Scope 2 emissions. There are no additional sources of emissions as it relates to upstream leased assets.

Category 9: Downstream transportation and distribution

This category includes emissions associated with the transportation and distribution of sold products after the point of sale. This includes trucking of logs from stumpage sales and the transport of logs from the log yard to the port for export.

Emissions from trucking logs are based on diesel fuel, which is determined based on an emissions factor reported in kilograms of CO_2 per gallon used.[7] The primary data for this calculation is the total miles driven from each harvest unit to the mill location (Table 23), so the distance-based method is used. The distance to each mill and the number of loads delivered to that mill are recorded for each timber sale, and this data is used to calculate the total trucking miles associated with harvest operations for the year. The secondary data needed is the average fuel efficiency for log trucks, reported as 5.1 miles per gallon.[20] The gallons of diesel are calculated by dividing the total miles by the miles per gallon, and the resulting gallons are multiplied by the emissions factor for diesel fuel to calculate emissions.

Table 23: Data sources and emissions factors for Scope 3 log trucking emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Log trucking	Total miles driven	Harvest production statistics	Fuel efficiency for log trucks (MPG)	WA Log Trucking Industry[20]	10.21 kg CO_2/gal	EPA GHG Emission Factors Hub[7]

Category 10: Processing of sold products

This category includes emissions associated with the processing of intermediate products sold by the reporting company. This encompasses emissions from the mills that manufacture Rayonier logs into final products purchased by the end consumer. Since we do not have site specific data at this time, the average data method is used and applied across major product groups for the company.

The two raw materials for this category are sawlogs and pulpwood logs, each of which has different product pathways outlined in Appendix A for both domestic and export logs. Based on the different pathways, emissions are broken down into CO_2 processing emissions, biogenic emissions from the combustion of hog fuel and spent liquor, and methane and nitrous oxide emissions from combustion. Biogenic emissions are reported outside of the scope as described in the section below. The primary data available is the dry metric tonnes of volume harvested.

Except for sawlog conversion to lumber, the process to calculate emissions for sawlogs and pulp logs is the same with different emissions factors and secondary data. Thus, they are grouped together in the methods outlined below.

For sawlog conversion to lumber, the emissions factor is reported in kilograms of CO_2-e/cubic meter of lumber (Table 24).[28,29] The secondary data needed to apply this emissions factor to the primary data for this category is the specific gravity of a tree species for conversion of metric tonnes of roundwood to cubic meters[8] and the conversion efficiency of logs to lumber.[27] One is divided by the specific gravity (reported in metric tonnes/m3) to calculate the cubic meters of logs. This value is then multiplied by the conversion efficiency to get the cubic meters of lumber produced from one metric tonne of sawlogs. Finally, this value is then multiplied by the original emissions factor to calculate an emissions factor of metric tonnes of CO_2-e/metric tonne of dry sawlogs (Example 34).

Table 24: Data sources and emissions factors for processing sawlogs to lumber.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Processing sawlogs to lumber	Dry metric tonnes harvested	Production statistics warehouse	Specific gravity of timber; Conversion efficiency from sawlogs to lumber	Miles et al 2009[8], Bratkovich and Fernholz 2012[27]	Range 37.17-60.70 kg CO_2-e/m^3 lumber	Puetman 2020[28,29]

Example 34: *Sawlog to lumber emissions in the southeast*

$e = (E * (1 \div S) * C) \div 1{,}000$

Where e = calculated emissions factor (MT CO_2-e/dry tonne harvested), E = reported emissions factor (kg CO_2/m3), S = specific gravity of pine species, and C = conversion efficiency of mass of sawlogs to lumber.

$e = (60.7 \text{ kg } CO_2/m3 * (1 \div .505 \text{ mt}/m3) * .422) \div 1{,}000 = 0.051 \text{ MT } CO_2\text{-e/tonne}$

AND

$T = e * H$

Where T = total emissions (MT CO_2-e), e = calculated emissions factor (MT CO_2-e/dry tonne harvested), and H = sawlog harvest volume

$T = .051 \text{ MT } CO_2\text{-e/dry tonne harvest} * 100{,}000 \text{ dry tonnes}$

$T = 5{,}100 \text{ MT } CO_2\text{-e}$

For log conversion to chips to pulp used for paper products, the emissions factor is reported in metric tonnes of CO_2-e per metric ton of paper; this value is derived from the industry wide emissions from the pulp and paper sector[32] divided by the total output from the sector in 2022 (Table 25).[33] The secondary data needed to apply the primary data to the emissions factor is the conversion efficiency of logs to chips[27,30] and from chips to paper.[31] The proportion of logs converted to chips is multiplied by the proportion of chips converted to paper to get the proportion of logs to paper. This value is then multiplied by the emissions factor to get an emissions factor for the metric tonnes of CO_2 per metric ton of sawlogs used for paper (Example 35).

Table 25: Data sources and emissions factors for processing logs to chips which are converted into paper products.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Processing logs to chips to paper products	Dry metric tonnes harvested	Production statistics warehouse	Conversion efficiency from logs to chips; Conversion efficiency from chips to paper	Bratkovich and Fernholz 2012[27] and Quinde 2020[30]; Toberlin et al 2020[31]	0.384 MT CO_2-e/MT paper	EPA[32], AFPA[33]

Example 35: *Logs to chips to paper in the PRU*

$$e = (Ep \div Pp) * (Cc * Cp)$$

Where Ep = total emissions from pulp and paper sector (MT CO_2-e), Pp = total production from pulp and paper sector (metric tonnes), Cc = conversion efficiency from logs to chips (%), and Cp = conversion efficiency from chips to paper (%)

$$e = (31.1 \text{ mMT } CO_2\text{-e} \div 81 \text{ m tonnes}) * (.288 * .5) = 0.056 \text{ MT } CO_2\text{-e/tonne sawlogs}$$

AND

$$T = e * H$$

Where T = total emissions (MT CO_2-e), e = calculated emissions factor (MT CO_2-e/dry tonne harvested), and H = sawlog harvest volume

$$T = 0.056 \text{ MT } CO_2\text{-e/tonne sawlogs} * 50{,}000 \text{ dry tonnes}$$

$$T = 2{,}800 \text{ MT } CO_2\text{-e}$$

For log conversion to chips to spent liquor, the emissions factor is kilograms of CO_2-e per million British Thermal Units (BTUs; Table 26).[7] This represents the combined emissions factors for methane and nitrous oxide, as the carbon dioxide that results from the combustion of liquor is biogenic and thus carbon neutral. The secondary data needed to apply this emissions factor to the primary data is the BTUs/ton for spent liquor,[34] the conversion efficiency of logs to chips,[27] and the conversion efficiency of chips to spent liquor.[31] The kg CO_2-e/million BTU emissions factor is converted to tonnes of CO_2-e/metric tonne of dry product by multiplying the emissions factor by the energy output for burning spent liquor (BTU/lb) and converting pounds of spent liquor to metric tonnes by multiplying the pounds per ton and converting to metric tonnes. Next, the total conversion efficiency is calculated by multiplying the proportion of log mass converted to chips by the proportion of chips converted to spent liquor (i.e. not converted to paper). This final conversion efficiency is then multiplied by the emissions factor to get the kilograms of CO_2-e per dry metric tonne of sawlogs that are eventually emitted by burning spent liquor (Example 36).

Table 26: Data sources and emissions factors for burning spent liquor resulting from paper production.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Burning spent liquor resulting from paper production	Dry metric tonnes harvested	Production statistics warehouse	Spent liquor energy output; Conversion efficiency from logs to chips; Conversion efficiency from chips to spent liquor	Orr 2009[34], Bratkovich and Fernholz 2012[27]; Toberlin et al 2020[31]	0.1645 kg CO_2-e/million BTU	EPA GHG Emission Factors Hub[7]

Example 36: *Logs to chips to spent liquor in the southeast*

$e = (E * (B * 2,000 \div 1,000,000 * 0.907 \div 1,000) * (Cc * Cl)$

Where e = calculated emissions factor (MT CO_2-e/tonne sawlogs), E = reported emissions factor (kg CO_2-e/million BTU), B = energy output of spent liquor (BTU/lb), Cc = conversion efficiency of sawlogs to chips (%), and Cl = conversion efficiency of chips to spent liquor (%)

$e = (94.4 \text{ kg } CO_2\text{-e/million BTU} * ((6,000 \text{ BTU/lb} * 2,000 \text{ lb/ton}) \div 1,000,000) \div 0.907 \text{ tonnes/ton} \div 1,000 \text{ kg/tonne}) * (0.288 * 0.5)$

$e = 0.18 \text{ MT } CO_2\text{-e/tonne sawlogs}$

AND

$T = e * H$

Where T = total emissions (MT CO_2-3), e = calculated emissions factor (MT CO_2-e/dry tonne harvested), and H = sawlog harvest volume

$T = 0.18 \text{ MT } CO_2\text{-e/tonne sawlogs} * 100,000 \text{ dry tonnes}$

$T = 18,000 \text{ MT } CO_2\text{-e}$

For the portion of logs that are burned as hog fuel, the emissions factor is reported in kilograms of CO_2-e per green ton of material burned (Table 27).[7] Similar to spent liquor, this represents the combined emissions factors for methane and nitrous oxide, as the carbon dioxide that results from the combustion of liquor is biogenic and thus carbon neutral. The secondary data needed in this case is the log conversion rate to bark, chips, and sawdust burned as hog fuel.[27] The emissions factor is converted to metric tonnes (multiplied by 0.907) and then multiplied by the proportion of the mass of sawlogs that are burned as hog fuel, which can then be applied to the primary data of dry metric tonnes of harvest volume (Example 37).

Table 27: Data sources and emissions factors for burning hog fuel resulting from processing of logs.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Burning hog fuel resulting from processing of logs	Dry metric tonnes harvested	Production statistics warehouse	Conversion efficiency from logs to hogfuel	Bratkovich and Fernholz 2012[27]	20.22 kg CO_2-e/SGT material	EPA GHG Emission Factors Hub[7]

Example 37: *Logs to hog fuel in the PRU*

$e = ((E \div 1{,}000) * 0.907) * Ch$

Where e = calculated emissions factor (kg CO_2-e/tonne sawlogs), E = reported emissions factor (kg CO_2-e/SGT), and Ch = the conversion efficiency of sawlogs to hog fuel (%)

$e = ((1{,}640 \text{ kg } CO_2\text{-e}/ 1{,}000 \text{ kg/tonne}) * 0.907 \text{ tonnes/ton}) * 0.1125$

$e = 0.203$ MT CO_2-e/tonne harvested

AND

$T = e * H$

Where T = total emissions (MT CO_2-3), e = calculated emissions factor (MT CO_2-e/dry tonne harvested), and H = sawlog harvest volume

*T = 0.203 MT CO_2-e/tonne harvested * 50,000 dry tonnes harvested = 10,150 MT CO_2-e*

Category 11: Use of sold products

This category encompasses emissions associated with the end use of a good or service downstream of the reporting company. Since wood products are the final product made from Rayonier logs, and wood products do not emit in their useful lifespan, this category is not applicable to the company.

Category 12: End-of-life treatment of sold products

This category includes the waste disposal and treatment of products sold by the reporting company after their useful life. It differs from Category 5 in that it relates to products sold and not waste generated by the reporting company. This category consists of landfilling, combustion, and recycling of the wood products that result from the milling of Rayonier logs. Like category 10, there is little granularity in data for end-of-life treatment, so the average data method is applied across products sold by Rayonier.

Unlike most other categories, this category does not use a traditional emissions factor but rather uses the proportion of a product in an end-use category (combusted, recycled, or landfilled) after 100 years. The primary data available is the dry metric tonnes of harvested volume by species group (hardwood vs softwood) and product type (sawlog vs pulpwood; Table 28). The secondary data needed is the carbon content of wood (assumed to be 50% on a dry weight basis across species) and the average proportion of a product in each end-use category over 100 years.[35] The dry metric tonnes of timber no longer in use is calculated by multiplying the in-use average by the harvested volume and subtracting that from the total harvested volume. This volume is then converted to carbon by multiplying by 0.50 (half the mass of dry timber is considered carbon). The mass of carbon no longer in use is then multiplied by the proportion in each end-use category. Finally, the mass of carbon transferred to landfills is then multiplied by the proportion of said mass remaining in landfills, which is subtracted from the total mass transferred to landfills to estimate the carbon that has been emitted from wood products decomposing in a landfill. This mass is converted into CO_2 equivalents (CO_2-e) by multiplying by the ratio of the atomic weight of CO_2 to the atomic weight of carbon or 44/12 (Example 38). Recycled material is considered still in use, so emissions are considered negligible and beyond the company's control; combusted material is added to the biogenic emissions described in the section below.

Table 28: Data sources for end-of-life treatment of logs sold by Rayonier.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
End-of-life treatment of logs sold by Rayonier	Dry metric tonnes harvested	Production statistics warehouse	Proportion of products in end use	USDA Entity Scale Guidelines[35]	Not applicable	Not applicable

Example 38: *End-of-life emissions from landfilling hardwood pulp in the Southeast*

*Fp = (Dt * 0.5 * Cp)*

Where Fp = mass of final product (dry metric tonnes carbon), Dt = harvest volume (dry metric tonnes), and Cp = fraction of log converted to final product.

*Fp = (10,000 tonnes * 0.5 * 0.85) = 4,250 tonnes carbon*

AND

*Iu = FP * IUA*

Where Iu = mass of product in use over 100 years, Fp = mass of final product (dry metric tonnes carbon), and IUA = In use average (5)

*Iu = 4,250 tonnes C * 0.114 = 484.5 tonnes C*

AND

*Tl = (Fp – Iu) *Fl*

Where Tl = mass of product transferred to landfill, Fp = mass of final product (dry metric tonnes carbon), Iu = mass of product in use over 100 years, and Fl = fraction of product in landfill at end of life (%).

*Tl = (4,250 tonnes C – 484.5 tonnes C) * 0.26 = 979 tonnes C*

AND

*Ml = Tl *Fr*

Where Ml = mass of product remaining in landfill 100 year average, Tl = mass of product transferred to landfill, and Fr = fraction remaining in landfills 100 year average (%).

*Ml = 979 tonnes C * 0.41 = 401.4 tonnes C*

AND

*Le = (Tl – Ml) * (44/12)*

Where Le = landfill emissions (MT CO2-e), Ml = mass of product remaining in landfill 100 year average, and Tl = mass of product transferred to landfill

*Le = (979 tonnes C – 401.4 tonnes C) * (44/12) = 2,118 tonnes CO2-e*

Category 13: Downstream leased assets

This category includes emissions from the use of assets owned by the reporting company but leased by other entities. The only licenses that Rayonier grants are those related to land use. Since the asset being leased is land, emissions associated with this category are accounted for in reduced carbon stocks through a change in land use, if appropriate.

Category 14: Franchises

This category is not applicable to Rayonier, as we do not grant licenses to other entities to sell or distribute our goods or services in return for payments, such as royalties for the use of trademarks and other services.

Category 15: Investments

This category is not applicable to Rayonier as it primarily relates to investors and/or companies that provide capital or financing as a service.

Outside of scopes: Biogenic emissions

Emissions occurring due to the combustion of biomass are considered carbon neutral by the GHG Protocol and thus are reported outside of the Scopes. The CO_2 emissions from prescribed burning are the only biogenic emissions that need to be considered for Rayonier. Emissions from prescribed burning do not use a traditional emissions factor, rather than the mass of the harvest residues or understory vegetation determines the CO_2 emissions. The biomass of the residues is converted to a mass of carbon, and then the volume of CO_2 released by combustion (Table 29).

The emissions from prescribed burning in the South are based on the number of acres with prescribed burns based on data from LMS. It is assumed that approximately 10 short green tons of biomass per acre are consumed during prescribed burning based on published data for the South. The total short green tons (SGTs) burned are calculated by multiplying the acres by 10 tons per acre. SGTs are then converted to metric green tonnes and green tonnes are converted to dry tonnes using the moisture content for the dominant species in the region, which is assumed to be loblolly pine.[8] The oven-dry metric tonnes are converted to weight of carbon by multiplying 0.5, assuming that 50% of the weight of dry wood is carbon. It is then assumed that 50% of the logging debris and fuel is consumed by the prescribed fires. Finally, the carbon is converted to CO_2 by multiplying by the ratio of the molecular weight of CO_2 to the molecular weight of carbon, or 3.67 (Example 39).

The primary data for the PRU is the SGTs contained in burn piles. This data is determined from the burn permits required by state forestry agencies to burn piles in Oregon and Washington. It is assumed that 85% of the biomass in piles is consumed. The carbon content is determined assuming 50% of the SGT is carbon. The average moisture content of wood is used to calculate the dry tonnes of carbon which are then converted to CO_2 using the ratio of the molecular weight of CO_2 to the molecular weight of carbon, or 3.67.

Table 29: Data sources and emissions factors for Scope 3 prescribed burning emissions.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Prescribed burning	SE - Acres treated	Land Management System (LMS) database	Moisture content	Miles et al 2009[8]	Not applicable	Not applicable
Prescribed burning	PNW – SGTs from burn permits	Burn permits	Moisture content	Miles et al 2009[8]	Not applicable	Not applicable

Example 39: *Prescribed burning in mid-rotation stands in the Southeast*

t = (a x f) x 0.907

Where t = tonnes burned, a = acres burned, f = fuel load (tons/ac)

(341 ac x 10 tons/ac) x 0.907 tons/tonne = 3,093 tonnes

AND

D = g – (MC x g)

Where D =Dry tonnes, g = green tonnes, and MC = moisture content

D = 3,093 – (3,093 x 0.43) = 1,763 tonnes

AND

T = D x C x w x c

Where T = tonnes CO_2 emissions, D = OD tonnes, w = carbon content, w = ratio of molecular weights, and c = amount consumed

1,763 x 0.5 x 0.5 x 44/12 = 1,616 tonnes CO_2

In addition to the prescribed burning biogenic emissions, there is a large component of biogenic emissions from the combustion of both spent liquor and hog fuel in sawmills and pulp mills in category 10 processing, as well as the combustion of final products from category 12 end of life treatment. The calculations for both of these categories follow the same approach outlined in the respective categories, but the emissions factors are different for carbon dioxide (Table 30).

Table 30: Data sources and emissions factors for biogenic emissions from category 10 processing.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Spent liquor	Dry metric tonnes harvested	Production statistics warehouse	Spent liquor energy output; Conversion efficiency from logs to chips; Conversion efficiency from chips to spent liquor	Orr 2009[34], Bratkovich and Fernholz 2012[27]; Toberlin et al 2020[31]	94.4 kg CO_2-e/million BTU	EPA GHG Emission Factors Hub[7]
Hog fuel	Dry metric tonnes harvested	Production statistics warehouse	Conversion efficiency from logs to hog fuel	Bratkovich and Fernholz 2012[27]	1,640 kg CO_2-e/SGT material	EPA GHG Emission Factors Hub[7]

Carbon in harvested timber

It is important to account for harvest removals because trees that are harvested no longer remove (sequester) carbon. However, carbon continues to be stored in wood products manufactured from harvested timber, storing it well into the future depending on what the wood will be used for, which is covered in the next section.

Note: Carbon removed in harvests IS NOT INCLUDED IN TOTAL ECOSYSTEM CARBON STORAGE OR REMOVALS presented in the Carbon Report since this carbon has already been accounted for by setting the stand age to 0. Thus, carbon in harvested timber SHOULD NOT BE SUBTRACTED from total ecosystem carbon storage or removals. Carbon removed during harvest is presented as data to calculate the carbon stored in harvested wood products through time.

To calculate harvest removals, data is extracted from the Production Statistics Warehouse that has information on the SGTs harvested by species group throughout the year. The SGTs are summarized by species group for the two major regions where Rayonier operates (the Pacific Northwest and Southeast). Moisture contents are then calculated from USFS Research Note NRS-38 by taking the proportion of the average green and oven-dry weights (lbs/ft^3) of each species.[8] Some groups are composed of multiple species, which are averaged across the species in the group (i.e. whitewood in the Pacific Northwest). This proportion is then multiplied by the SGTs to calculate the weight of the water in wood, which is then subtracted from the SGTs to obtain the oven-dry weight of wood. Imperial tons are then converted to metric tonnes using the conversion rate of .90718474 metric tonnes/ton (Equation 40). Finally, the carbon content is calculated by multiplying the metric tonnes by .5, assuming that 50% of wood is carbon. The CO_2-e is calculated by multiplying the tonnes of carbon by 44/12 (ratio of the molecular weight of CO_2 divided by the molecular weight of carbon). The results are summed across species groups and regions to determine the final value for CO_2-e removed in harvest as the metric reported on page 11 of the Carbon Report.

Equation 40: *Convert short green tons (SGTs) to OD metric tonnes*

*OD = (t – (t * MC)) * 0.907*

Where OD = oven-dry metric tonnes, T = short green tons, MC = moisture content (%) of species/species mix

AND

*T = OD * 0.5 * (44/12)*

Where T = metric tonnes CO_2-e, OD = oven dry metric tonnes

Example 40: *CO_2 equivalents of Douglas-fir harvest removals in the PRU*

*OD = (1,000,000 SGT – (1,000,000 * 0.298)) * 0.907 = 636,714 tonnes*

*T = 636,714 tonnes * 0.5 * (44/12) = 1,617,309 tonnes CO_2-e*

Carbon stored in wood products

The carbon stored in wood products in use is an important way that forests serve as natural climate solutions. Because carbon continues to be stored in products following harvest, the long-term storage must be included to provide a complete picture of the carbon stored from forestry activities. If it is excluded, one is left with an incomplete picture of the benefits of managing forests and using wood.

To calculate the long-term storage of carbon in harvested wood products in use, the longevity of each product in use must be determined. This should include the product in use and storage in landfills after the useful life of the product. The longevity of carbon in harvested wood products is determined based on measured decay rates for specific products such as paper and lumber. The decomposition and release of carbon from harvested wood products back into the atmosphere is calculated as the half-life of each product. The half-life of domestic wood products is calculated based on data in GTR-343 (Table 31). The half-life of carbon in exported wood products is calculated based on data compiled for export timber by destination country in Manly and Evison[36].

Table 31: Excerpt from GTR-343 showing the different proportions of products in use, in landfills, and emitted with and without energy capture for Southeast Softwood Saw log and Pulpwood products. Rayonier's calculations include both "In use" and "Landfill" categories in our products in use calculations.

Table 6.—continued

	Southeast, Softwood							
	Saw log				Pulpwood			
Year after production	In use	Landfill	Energy	Emitted without energy	In use	Landfill	Energy	Emitted without energy
0	0.636	0.000	0.260	0.104	0.553	0.000	0.276	0.171
1	0.601	0.017	0.270	0.112	0.482	0.024	0.300	0.193
2	0.570	0.032	0.279	0.119	0.422	0.044	0.323	0.211
3	0.541	0.045	0.288	0.125	0.370	0.061	0.342	0.227
4	0.516	0.057	0.296	0.131	0.327	0.074	0.359	0.241
5	0.493	0.068	0.303	0.136	0.290	0.085	0.373	0.252

Data on the volume of harvested timber in domestic and export categories is extracted from the production statistics warehouse. The CO_2-e in each domestic or export product (pulp or sawtimber) is determined at the time of harvest. It is assumed that all export volume is sawtimber. The initial loss of CO_2-e during primary processing (conversion efficiency) of each product is then used to determine the carbon in each product remaining in the first year of use. The carbon remaining in the products in use and in landfills through time is calculated based on the exponential decay of each product based on the half-life equation for each product. The CO_2 equivalents remaining in use each year is determined by multiplying the total tonnes CO_2-e for a species and product class by the corresponding proportion in use at time X (Examples 41 and 42).

The total carbon stored in products in use through time is determined by summing domestic and export carbon stored in products in use. The results can be found on page 11 of the Carbon Report, which summarized results 5, 10, 25, 50, 75, and 100 years in the future.

Equation 41: *Domestic C stored in use*

$S_t = (U_t + L_t) * T$

Where S_t *=* CO_2 *equivalents stored at time t,* U_t *= proportion of products in use at time t,* L_t *= proportion of products in landfill at time t, T = total harvest removals*

Example 41: *Southern hardwood pulp in use after 15 years*

$S_t = (0.161 + 0.126) * 100{,}000$ *tonnes = 28,700 tonnes*

Equation 42: *Exponential decay in HWP for export*

$T_t = C * (e^{\wedge}((ln(0.5) \div h) * t))$

Where T_t = metric tonnes CO_2-e at time t, C = metric tonnes of CO_2-e for total export volume, e = Euler's number, ln = natural log, h = half life of product, and t = time period (years in future)

Example 42: *Southern exports to China in use after 15 years*

$T_{15} = 10{,}000 \text{ MT } CO_2\text{-e} * (e^{\wedge}((ln(0.5) \div 2.5 \text{ yrs}) * 15))$

$T_{15} = 156 \text{ tonnes}$

Carbon stored over multiple cycles

The data on carbon stored in harvested wood products demonstrates that significant carbon remains in the products in use for periods of time that exceed the normal rotation length of both southern and western species. Thus, the cumulative effect of sustainable forest management over time can be demonstrated by examining the long-term storage of carbon in wood products in use over multiple rotations. This is illustrated using 25-year rotations for southern pine and 50-year rotations for southern hardwoods and western conifers and hardwoods, assuming the harvest volumes remain constant over multiple rotations.

The carbon stored in wood products through time is summed for these multiple rotations over a 100-year period. For example, the carbon stored from the first harvest declines with time for the first 25 years. At age 25, the carbon stored in wood products from the second rotation of southern pine is added to the remaining carbon in products from the first rotation. The carbon stored in products from these two harvests then decreases through time until 50 years, when the carbon in harvested wood products forms the 3rd 25-year southern pine rotation, and the 2nd 50-year rotation of southern hardwoods and western conifers and hardwoods is added to the carbon remaining from wood products in previous rotations. This process continues with the 4th rotation of southern pine at 75 years, and the 3rd rotation of hardwoods and 5th rotation of southern pine at 100 years. The cumulative effect of the multiple rotations is illustrated in the graph on page 12 of the Carbon Report.

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Matariki Forests Calculations

Carbon storage

The calculation of total stored carbon quantifies the total stock of carbon on Matariki Forests' land at the 31st December of the reporting year. This is made up of two parts 1) a calculation of standing carbon and 2) a calculation of carbon remaining in harvest residuals. The calculation of carbon removed quantifies the change in carbon stock that has occurred between the start and end of the calendar year.

The data sources for these calculations are New Zealand forest carbon lookup tables[1] and the Matariki Forests area statement, taken 31st December of the reporting year. The latter provides stand species, area and age information for productive forest areas. Productive areas are defined as either stocked or fallow in the Geomaster Stand Record System (Geomaster).

Standing carbon across productive areas

Carbon lookup tables for carbon storage in above and below ground forest biomass are provided in the Climate Change (Forestry) Regulations 2022.[1] The lookup tables provide a species, age, and region-specific measure of carbon stock per hectare of forest land (tonnes CO_2-e/ha). These are used to calculate the total volume of standing carbon across the *Pinus radiata* (radiata pine) and *Pseudotsuga menziesii* (Douglas fir) areas of the Matariki Forests area statement (Example 1).

Harvest residue carbon across productive areas

Following harvest, a level of stored carbon is assumed to remain in above and below-ground biomass. This carbon is termed 'harvest residuals' and is assumed to decay in a linear fashion over ten years post-harvest. Carbon lookup tables for harvest residuals are provided in the Climate Change (Forestry) Regulations 2022.[1] The per hectare stock of harvest residuals is harvest age specific. Radiata pine is assumed to be harvested at 26 years and Douglas fir at 40 years. For both, a one-year delay is assumed between harvesting and replanting. Harvest residual carbon is excluded across areas that are removed from the Matariki Forests Estate post-harvest and included across acquisition forests that are second rotation (Example 2).

Soil carbon and non-productive areas

Soil carbon and carbon stored in non-productive (natural) areas have been assumed at a steady state based on the quantification of carbon stocks across these areas by Sweeney in 2020.[2]

__Equation 1:__ Carbon storage

$a = \sum (h \times c_{ijk})$

Where a = total carbon stock (tonnes CO_2-e), h = area (hectares), c_{ijk} = carbon stock (tonnes CO_2-e/hectare) from the carbon lookup tables for i^{th} species, j^{th} region, k^{th} age.

__Example 1:__ Two-hectare 24-year-old radiata pine in Glenbervie forest. Carbon region = Auckland, Species = Pinus radiata, age = 24 years

$2 \times 685 = 1{,}370$ *tonnes CO_2-e*

Equation 2: Harvest residual carbon

$a = \sum (h \times (c_{ijk} \div 10 \times (10-t)))$

Where a = total carbon stock (tonnes CO_2-e), h = area (hectares), c_{ijk} = residual carbon stock (tonnes CO_2-e/hectare) from the carbon lookup tables for i^{th} species, j^{th} region, k^{th} harvest age, and t = years since harvest (applicable for 10 years post-harvest)

__Example 2:__ Two-hectare radiata pine in Glenbervie forest, two years post-harvest. Carbon region = Auckland, Species = Pinus radiata, harvest age = 26 years

$2 \times (328 \div 10 \times (10-2)) = 525$ *tonnes CO_2-e*

Carbon removals

Annual carbon increment (CO_2-e tonnes/ha/year) has been calculated from the carbon lookup tables provided in the Climate Change (Forestry) Regulations 2022.[1] Carbon increment is age, species, and region-specific. The calculated increments are applied to stocked areas of *Pinus radiata* (radiata pine) and *Pseudotsuga menziesii* (Douglas fir) in the December area statement to calculate a total for the estate (Example 3).

__Equation 3:__ Carbon removals

$b = \sum ((c_{ijk\,t} - c_{ijk\,t-1}) \times h)$

Where b = carbon increment (tonnes CO_2-e/hectare/year), c_{ijk} = carbon stock (tonnes CO_2-e/hectare) from the carbon lookup tables for i^{th} species, j^{th} region, k^{th} age, h = area (hectares) and t = age (years)

__Example 3:__ Two-hectare 24-year-old radiata pine in Glenbervie forest. Carbon region = Auckland, Species = Pinus radiata, age = 24 years

$2 \times (685 - 653) = 64$ *tonnes CO_2-e*

Scope 1, 2, and 3 carbon emissions

Carbon emissions are released into the atmosphere as a result of the combustion of fossil fuels. All carbon units are reported in metric tonnes of carbon dioxide equivalents (tonne CO_2-e) using the global warming potentials set out in the IPCC Fifth Assessment Report (AR5). All emissions factors sourced from the Ministry for the Environment (MFE) can be found in Appendix B.

The following section outlines carbon emissions by three scopes, as outlined by the GHG Protocol Corporate Value Chain (Scope 3) Standard.3

- Scope 1 emissions pertain to emissions which originate directly from assets owned or controlled by Matariki Forests.
- Scope 2 emissions pertain to indirect emissions resulting from the production of purchased energy in the form of electricity, steam, heating, and cooling.
- Scope 3 emissions pertain to the timber value chain.

Scope 1: Direct emissions

Scope 1 direct emissions are from fuel usage across vehicles owned by Matariki Forests. These are predominantly fire appliances. To calculate the emissions associated with operating these vehicles, fuel usage is sourced from company purchase records in litres, and emissions factors for petrol and diesel are sourced from the Ministry for the Environment (Table 1; Example 4).[4]

Table 1: Data sources and emissions factors for Scope 1 emissions.

Type	Primary Data	Source	Emissions factor	Source
Fuel	Litres (petrol and diesel)	Company fuel and expense card records	Range 2.46-2.71 kg CO_2-e/litre	MFE NZ[4]

Equation 4: *Fuel*

$$T = \sum (l_i \times e_i) \div 1{,}000$$

Where T = carbon (tonnes CO_2-e), l_i = fuel (litres) for i^{th} fuel type, e_i = emissions factor for i^{th} fuel type (kg CO_2-e/litre)

Example 4: *2,000 litres of diesel consumed*

$$2{,}000 \times 2.71 \div 1{,}000 = 5.4 \text{ tonnes } CO_2\text{-e}$$

Scope 2: Indirect emissions from purchased electricity

Scope 2 indirect emissions are associated with purchased electricity across six offices. Electricity usage in kilowatt-hours (kwh) is sourced from company purchase records. This is prorated where required to ensure full-year coverage. An emissions factor based on the annual grid average for purchased electricity is sourced from the Ministry for the Environment (Table 2; Example 5).[4]

Table 2: Data sources and emissions factors for Scope 2 emissions.

Type	Primary Data	Source	Emissions factor	Source
Electricity	Kilowatt hours (kwh)	Electricity invoices	0.074 kg CO_2-e/kwh	MFE NZ[4]

Equation 5: *Electricity*

$T = (d \times e) \div 1{,}000$

Where T = carbon (tonnes CO_2-e,), d = electricity used (kilowatt hours), e = emissions factor for electricity (kg CO_2-e/kilowatt hour)

Example 5: *20,000 kilowatt hours of electricity used*

$20{,}000 \times 0.07 \div 1{,}000 = 1.5$ tonnes CO_2-e

Scope 3: Indirect emissions in the value chain

Most of Matariki Forests' forestry operations are conducted as contracted services and are therefore included as Scope 3 emissions. In addition to this, emissions associated with upstream and downstream activities along the value chain are included as Scope 3 emissions. The Corporate Value Chain (Scope 3) Accounting and Reporting Standard categorizes Scope 3 emissions into 15 categories to provide a systematic framework to report emissions. To align with this, the following section outlines Matariki Forests' Scope 3 emissions by these categories. For further information on the scope or specific categories, refer to the GHG Protocol.[5]

Category 1: Purchased goods and services

This category includes emissions associated with the products and services purchased or acquired by Matariki Forests in the reporting year but excludes products reported in the other Scope 3 categories. Most of Matariki Forests' forestry operations are contracted services, so they are purchased services and included in Category 1.

These are grouped into four categories: forest establishment, forest management, roading operations, and harvesting operations.

Forest establishment & management

Forest establishment and management activities include planting, site preparation, crop protection, thinning, and measurement activities. In 2010 actual emissions associated with these operations were quantified for the calendar year. From this, emission factors were calculated for forest establishment and forest management, both based on total estate area. In 2020, a review determined it would be more appropriate to base emission intensities for these categories on the annual area planted and area thinned, respectively. The resulting emissions factors from this review are shown in Table 3 and are used to calculate 2023 emissions (Examples 6 & 7).

Table 3: Data sources and emissions factors for Scope 3, Category 1 silviculture and establishment.

Type	Primary Data	Source	Emissions factor	Source
Silviculture	Area thinned (ha)	Geomaster Stand Record System	0.111 tonnes CO_2-e/ha	Actual emission intensity data from 2010
Establishment	Area planted (ha)	Geomaster Stand Record System	0.123 tonnes CO_2-e/ha	Actual emission intensity data from 2010

Equation 6: *Forest establishment*

$T = h \times e$

Where T = carbon (tonnes CO_2-e), h = area planted (hectares), e = emissions factor (tonnes CO_2-e/hectare)

Example 6: *2,000 hectares planted*

$2{,}000 \times 0.12 = 246$ tonnes CO_2-e

Equation 7: Forest management

$T = h \times e$

Where T = carbon (tonnes CO_2-e), h = area thinned (hectares), e = emissions factor (tonnes CO_2-e/hectare)

Example 7: *2,000 hectares thinned*

$2{,}000 \times 0.11 = 222$ tonnes CO_2-e

Roading operations

The emissions associated with road and landing construction are based on diesel fuel consumption across these operations. Diesel fuel usage is inferred from total expenditure on capital roading using a fuel usage factor (litres/NZD spent). This is calculated based on actual data from the 2010 calendar year, collected as part of a KPMG Carbon Footprint Study for Matariki Forests.[6] This is rebased to 2023 using the Consumer Price Index (CPI).[7] An emissions factor for diesel is sourced from MFE and applied to the result (Table 4).

A provision is made for the emissions associated with road construction for volume procured from third parties. An estimate of diesel fuel consumption is calculated for this volume. This is based on an inferred fuel usage factor derived from the total fuel usage and volume harvested across the Matariki Forests Estate (litres/tonne harvested). An emissions factor for diesel is sourced from MFE and applied to the result (Example 8).

Table 4: Data sources and emissions factors for Scope 3, Category 1 roading & landing construction.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Matariki Forests' volume	Expenditure on capital roading (NZD)	Company Enterprise Resource Planning Software (SAP)	Diesel fuel use	Fuel usage factor (litres/NZD) based on 2010 actuals	2.71 kg CO_2-e/litre	MFE NZ[4]
Third party sourced volume	Volume sourced (tonnes)	Company Enterprise Resource Planning Software (SAP)	Diesel fuel use	Fuel usage factor (litres/tonne) based on calculated Matariki litres/tonne	2.71 kg CO_2-e/litre	MFE NZ[4]

***Equation 8:** Roading*

Matariki Forests

T = (f × g × e) ÷ 1,000

Where T = carbon (tonnes CO_2-e), f = Matariki Forests' total expenditure on roading (NZD), g = fuel usage factor (litres/NZD), e = emissions factor for diesel (kg CO_2-e/litre)

Third party

m = (f × g) ÷ v

T = (j × m × e) ÷ 1,000

Where m = fuel usage factor (litres/tonne), f = Matariki Forests' total expenditure on roading (NZD), g = fuel usage factor (litres/NZD), v = Matariki Forests' harvest volume (tonnes), T = carbon (tonnes CO_2-e), j = third party harvest volume (tonnes), e = emissions factor for diesel (kg CO_2-e/litre)

***Example 8:** Matariki Forests: $2.0 million roading expenditure and 300,000 tonnes harvested. Third party volume: 100,000 tonnes. Fuel usage factor 0.127 litres/NZD*

2,000,000 × 0.127 × 2.71 ÷ 1,000 = 691 tonnes CO_2-e

(2,000,000 × 0.127) ÷ 300,000 = 1.18 litres/tonne

100,000 × 1.18 × 2.71 ÷ 1,000 = 319 tonnes CO_2-e

691 + 319 = 1010 tonnes CO_2-e

Harvesting operations

The emissions associated with harvesting are based on diesel fuel consumption. For volume harvested from Matariki Forests' estate, fuel usage is calculated based on harvested volume by harvest type (ground-based or swing-yarder).

A NZ industry study of fuel usage by harvest system was completed by Shepherd, Smith and Visser in 2022.[8] Fuel usage factors for ground-based and swing yarder harvesting systems are sourced from this publication in litres/m^3 harvested. The published factors include an allowance for oil use and a well to tank factor for processing and delivery. The factors are converted to litres/tonne using an average conversion of 0.95 m^3/tonne. An emissions factor for diesel is sourced from MFE and applied to the total volume of diesel calculated (Table 5).

A provision is made for the emissions associated with harvesting volume procured from third parties using the same methodology. For this volume, the harvest type split between ground-based and swing-yarder volume is assumed to be the same as the split across Matariki Forests' volume (Example 9).

Table 5: Data sources and emissions factors for Scope 3, Category 1 harvesting activities.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Matariki Forests volume	Volume by harvest type (tonnes)	Company Enterprise Resource Planning Software (SAP)	Diesel fuel use	Fuel usage factor (litres/tonne) from Shepherd, Smith & Visser[8]	2.71 kg CO_2-e/litre	MFE NZ[4]
Third party sourced volume	Volume sourced (tonnes)	Company Enterprise Resource Planning Software (SAP)	Diesel fuel use	Fuel usage factor (litres/tonne) from Shepherd, Smith & Visser[8]	2.71 kg CO_2-e/litre	MFE NZ[4]

Equation 9: *Harvesting*

$$T = \sum (v_i \times c_i \times e) \div 1{,}000$$

Where T *= carbon (tonnes* CO_2*-e),* v_i *= harvest volume for* i^{th} *harvest type (tonnes),* c_i *= fuel consumption for* i^{th} *harvest type (litres/tonne),* e *= emissions factor for diesel (kg* CO_2*-e/litre)*

Example 9: *200,000 tonnes harvested with a swing yarder*

$$200{,}000 \times 4.12 \times 2.71 = 2{,}235 \text{ tonnes } CO_2\text{-e}$$

Category 2: Capital goods

No new capital goods were purchased in the reporting year.

Category 3: Fuel- and energy-related activities

This category provides an allowance for the upstream emissions associated with purchased fuel and electricity, as well as an allowance for electricity transmission and distribution losses. The primary data for this category is fuel and energy usage, in litres and kilowatt hours, respectively, which is reported in Scope 1, Scope 2, and Scope 3, Category 8.

An emissions factor for transmission and distribution losses is sourced from MFE (Table 6).[4] New Zealand does not publish emissions factors for the upstream emissions associated with purchased fuel and electricity. For these sub-categories, 2023 emissions factors are sourced from the U.K. Government's Department for Environment, Food, and Rural Affairs (DEFRA; Examples 10-12).[9]

Table 6: Data sources and emissions factors for Scope 3, Category 3 activities.

Type	Primary Data	Source	Emissions factor	Source
Fuel	Litres (reported in Scope 1 and Scope 3, Category 8)	Company fuel and expense card records	Range 0.60664-0.62409 kg CO_2-e/litre	UK DEFRA[9]
Electricity	Kilowatt hours (reported in Scope 2)	Electricity invoices	0.0459 kg CO_2-e/kwh	UK DEFRA[9]
Electricity	Kilowatt hours (reported in Scope 2)	Electricity invoices	0.0086 kg CO_2-e/kwh	MFE NZ[4]

***Equation 10:** Upstream emissions for fuels*

$T = \sum (l_i \times e_i) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), l_i = fuel for i^{th} fuel type (litres), and e_i = emissions factor for i^{th} fuel type (kg CO_2-e/litre)

***Example 10:** 2,000 litres of diesel consumed*

$2{,}000 \times 0.60 \div 1{,}000 = 1.2$ *tonnes CO_2-e*

Equation 11: Upstream emissions for electricity

$T = (d \times e) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), d = electricity used (kilowatt hours), and e = emissions factor (kg CO_2-e/kilowatt hour)

***Example 11:** 20,000 kilowatt hours of electricity used*

$20{,}000 \times 0.04 \div 1{,}000 = 0.8$ *tonnes CO_2-e*

Equation 12. Transmission and distribution losses

$T = (d \times e) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), d = electricity used (kilowatt hours), and e = emissions factor (kg CO_2-e/kilowatt hour)

Example 12: *20,000 kilowatt hours of electricity used*

10c. 20,000 × 0.008 ÷ 1,000 = 0.16 tonnes CO_2*-e*

Category 4: Upstream transportation and distribution

This category includes emissions associated with the upstream transportation of purchased products as well as purchased third-party transportation and distribution services. The latter includes both inbound and outbound logistics. For Matariki Forests, this includes cartage associated with delivered log sales and purchased third-party volumes.

The emissions associated with cartage are based on diesel fuel consumption. For this calculation, the primary data source is regional production volume (tonnes). Average fuel usage in litres per tonne delivered is calculated for each region. This is inferred using average cartage rate ($/tonne), volume-weighted average contract fuel proportion (%), and a national annual average fuel price ($/litre). For 2023, the average contract fuel proportion is 27% and the average fuel price $1.768 NZD excluding GST. An emissions factor for diesel is sourced from MFE and applied to the result (Table 7).

A provision is made for the emissions associated with carting volume procured from third parties. The regional fuel usage factors in litres/tonne, derived using the methodology above, are applied to the procured volumes. An emissions factor for diesel is sourced from MFE and applied to the result (Example 13).

Table 7: Data sources and emissions factors for Scope 3, Category 4 activities.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Matariki Forests volume	Volume (tonnes)	Company Enterprise Resource Planning Software (SAP)	Diesel fuel use	Fuel usage factor (litres/tonne) using cartage contract data.	2.71 kg CO_2-e/litre	MFE NZ[4]
Third party volume	Volume (tonnes)	Company Enterprise Resource Planning Software (SAP)	Diesel fuel use	Fuel usage factor (litres/tonne) using cartage contract data.	2.71 kg CO_2-e/litre	MFE NZ[4]

Equation 13: *Cartage*

$T = \sum (v_i \times n_i \times o \times p \times e) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), v_i = harvest volume for i^{th} region (tonnes), n_i = average cartage rate for i^{th} region (NZD/tonne), o = contract average fuel proportion (%), p = average truck stop fuel price (NZD/litre excl. GST), and e = emissions factor for diesel (kg CO_2-e/litre)

Example 13: *200,000 tonnes, average cartage rate $25.00/tonne, contract fuel proportion 25%, fuel price $1.50/litre*

200,000 × 25.00 × 25% × 1.50 × 2.71 ÷ 1,000 = 2,258 tonnes CO_2-e

Category 5: Waste generated in operations

This category accounts for emissions associated with the disposal and treatment of waste.

The primary data for this category is an estimate of the volume (litres) of waste generated across six office locations based on waste container size and frequency of pickup (Table 8). This volume is annualised and converted to tonnes using a factor of 0.13 tonnes/m^3 for small loads of general waste, published in Schedule 1 of the Waste Minimisation (Calculations and Payment of Waste Disposal Levy) Regulations 2009.[10] An emissions factor for waste disposal is sourced from MFE and applied to this volume (Example 14).

Table 8: Data sources and emissions factors for Scope 3, Category 5 activities.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Waste	Annual volume (litres)	Regional estimates	Annual volume (tonnes)	Waste Minimisation Regulations factor[10] (tonnes/m^3)	0.666 kg CO_2-e/kg	MFE NZ[4]

Equation 14: *Waste*

$T = \sum (q_i \times r_i) \times 0.13 \times e$

Where T = carbon (tonnes CO_2-e), q_i = weekly waste volume for i^{th} region (litres), r_i = pickups per annum for i^{th} region, 0.13 = waste ratio[10] (tonnes/cubic metre) and e = emissions factor (tonnes CO_2-e/tonne)

Example 14: *240 litres waste per week, one pickup per week*

240 × 52 × 0.13 × 0.66 = 1.1 tonnes CO_2-e

Category 6: Business travel

This category accounts for emissions associated with the transportation of employees for business-related activities in vehicles owned or operated by third parties, including aircraft, trains, buses, and cars. This category is calculated including company use of taxis and rideshare services, air travel (domestic and international), and hotel accommodations (Table 9).

For emissions associated with air travel, the primary data source is distance (kilometres) travelled domestically and internationally. This information is sourced from the company's travel provider. Domestic travel is classified by aircraft size (large or small). International travel is classified by distance (short haul or long haul) and class (economy, premium, and business). Emissions factors for each travel type, size, distance, and class combination are sourced from MFE and applied to the distance travelled (Example 15 & 16).

For emissions associated with taxis and rideshares the primary data source is expenditures for these services. This is sourced from company records. An emissions factor sourced from MFE is applied to this spend (Example 17).

For emissions associated with hotel accommodations, the primary data source is the count of traveller nights spent in each country. This information is sourced from the company's travel provider. Country-specific emissions factors are sourced from MFE and applied to the number of nights spent (Example 18).

Table 9: Data sources and emissions factors for Scope 3, Category 6 activities.

Type	Primary Data	Source	Emissions factor	Source
Taxi & rideshare	Expenditure (NZD)	Company expense reporting software	0.05 kg CO_2-e/NZD	MFE NZ[4]
Air travel	Distance travelled by type (kilometres)	Company travel provider records	Range 0.148-0.429 kg CO_2-e/km	MFE NZ[4]
Accommodation	Nights spent away by country	Company travel provider records	Range 9.4-60.7 kg CO_2-e/night	MFE NZ[4]

Equation 15: *Domestic air travel*

$T = \sum (s_i \times e_i) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), s_i = total distance travelled by i^{th} aircraft size (kilometres) and e_i = emissions factor for domestic air travel for i^{th} aircraft size (CO_2-e/kilometre)

Example 15: *200,000 kilometres travelled in a medium aircraft*

$200{,}000 \times 0.239 \div 1{,}000 = 47.8$ *tonnes CO_2-e*

Equation 16: International air travel

$T = \sum (s_{ij} \times e_{ij}) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), s_{ij} = total distance travelled by i^{th} distance category and j^{th} class (kilometres) and e = emissions factor for international air travel for i^{th} distance and j^{th} class (CO_2-e/kilometre)

Example 16: *200,000 kilometres travelled long haul in economy*

$200{,}000 \times 0.148 \div 1{,}000 = 29.6$ *tonnes CO_2-e*

Equation 17: Taxi and rideshare travel

$T = (u \times e) \div 1{,}000$

Where T = carbon (tonnes CO_2-e), u = spend on taxi and rideshare services (NZD) and e = emissions factor for taxi travel (CO_2-e/NZD)

Example 17*: $20,000 spent on taxi and rideshare services*

$20{,}000 \times 0.05 \div 1{,}000 = 1$ *tonne CO_2-e*

Equation 18: Accommodation

$T = \sum (w_i \times e_i) \div 1{,}000$

Where T = metric tonnes CO_2-e, w_i = count of nights spent away for i^{th} country and e_i = emissions factor for i^{th} country (CO_2-e/night)

Example 18: *200 nights spent in USA*

$200 \times 19.8 \div 1{,}000 = 3.96$ *tonnes CO_2-e*

Category 7: Employee commuting

This category includes emissions associated with employee commuting from home to work. It also includes an allowance for emissions associated with working from home (WFH).

Commute distance, frequency, and type (bus, rail, car) is self-reported to the People & Culture Advisor by employees that do not have a company owned lease vehicle (n = 59). This is used to calculate the company's total annual distance by commute type (kilometres).

An emissions factor for each is sourced from MFE and applied to the calculated distances (Table 10; Example 19).

Total working-from-home days are calculated for the number of employees who have a working-from-home agreement (n = 66). A weekly average of 1.7 days working from home is calculated based on survey results from Auckland office employees. An emissions factor for working from home is sourced from MFE and applied to the annual days calculated (Example 20).

Table 10: Data sources and emissions factors for Scope 3, Category 7 activities.

Type	Primary Data	Source	Emissions factor	Source
Commute	Distance by commute type (kilometres)	Employee reporting	Range 0.02-0.25 kg CO_2-e/NZD	MFE NZ[4]
WFH	Days	Auckland employee staff survey	0.37 kg CO_2-e/km	MFE NZ[4]

Equation 19: *Commute*

$T = \sum (y_i \times z \times 48 \times e_i) \div 1{,}000$

Where T *= carbon (tonnes* CO_2*-e),* y_i *= weekly commute days by* i^{th} *travel type,* z *= commute distance (kilometres), 48 = annual weeks worked, and* e_i *= emissions factor for* i^{th} *travel type (kg* CO_2*-e/kilometre)*

Example 19: *20-kilometre commute by car three days per week*

$3 \times 20 \times 48 \times 0.25 \div 1{,}000 = 0.72$ *tonnes* CO_2*-e*

Equation 20: WFH

$T = (a \times b \times 48 \times e) \div 1{,}000$

Where T *= carbon (tonnes* CO_2*-e),* a *= number of employees,* b *= average days working from home per week, 48 = annual weeks worked, and* e *= emissions factor (kg* CO_2*/working day)*

Example 20: *20 employees working from home two days per week*

$20 \times 2 \times 48 \times 0.37 \div 1{,}000 = 0.71$ *tonnes* CO_2*-e*

Category 8: Upstream leased assets

This category includes emissions associated with the operation of leased assets. To calculate the emissions associated with operating Matariki Forests' leased vehicles, fuel usage is sourced from company purchase records in litres. Emissions factors for petrol and diesel are sourced from MFE and applied to the totals (Table 11; Example 21).

Table 11: Data sources and emissions factors for Scope 3, Category 8 activities.

Type	Primary Data	Source	Emissions factor	Source
Fuel	Litres (petrol and diesel)	Company fuel and expense card records	Range 2.46-2.71 kg CO_2-e/litre	MFE NZ[4]

Equation 21: Fuel

$T = \sum (l_i \times e_i) \div 1{,}000$

Where T = carbon (metric tonnes CO_2-e), l_i = fuel for i^{th} fuel type (litres), e_i = emissions factor for i^{th} fuel type (kg CO_2-e/litre)

***Example 21:** 2,000 litres of diesel consumed*

$2{,}000 \times 2.71 \div 1{,}000 = 5.4$ tonnes CO_2-e

Category 9: Downstream transportation and distribution

This category includes emissions associated with the transportation and distribution of sold products along the value chain in vehicles and facilities that are not owned or controlled by Matariki Forests. This includes export shipping, marshalling, and stevedoring (Table 12).

Export volume is sourced from AVA Timber's 2023 carbon report in Japanese Agricultural Standard units (JAS). This includes Matariki Forests' export volume and additional third-party volume purchased by Matariki Forests Trading and exported by AVA Timber. The total carbon emissions associated with shipping this volume is also sourced from the AVA Timber report. The primary data for this calculation is fuel consumption in tonnes by voyage and fuel type (IFO and MGO). Emissions factors for these fuel types are sourced from the International Marine Organisation (IMO) and applied to the result (Example 22).

Emissions from marshalling and stevedoring are based on diesel fuel consumption. The primary data source for this calculation is volume exported. Fuel usage is inferred from total export volume using a fuel usage factor (litres/JAS). This is calculated based on actual data from the 2010 calendar year, collected as part of a KPMG Carbon Footprint Study for Matariki Forests.[6] An emissions factor for diesel is sourced from MFE and applied to the volume calculated (Example 23).

Table 12: Data sources and emissions factors for Scope 3, Category 9 activities.

Type	Primary Data	Source	Secondary Data	Source	Emissions factor	Source
Shipping	Fuel usage (IFO & MGO)	AVA Timber	Not applicable	Not applicable	Range 3.151-3.206 kg CO_2-e/litre	IMO
Marshalling & stevedoring	Exported volume (JAS)	AVA Timber	Diesel fuel use	Fuel usage factor (litres/JAS) based on 2010 actuals	2.71 kg CO_2-e/litre	MFE NZ[4]

***Equation 22:** Shipping*

$T = \sum (c_{ij} \times e_i \times d_j)$

Where T = carbon (metric tonnes CO_2-e), c_{ij} = fuel usage for i^{th} fuel type and j^{th} voyage (tonnes), e_i = emissions factor for i^{th} fuel type (tonnes CO_2-e/tonne), d_j = Matariki Forests proportion of AVA cargo share for j^{th} voyage

***Example 22:** 500 tonnes IFO fuel consumed, 50% cargo share*

$500 \times 3.151 \times 50\% = 788$ *tonnes* CO_2*-e*

Equation 23: Marshalling and stevedoring

$T = \sum (v \times f \times e) \div 1{,}000$

Where T = carbon (metric tonnes CO_2-e), v = exported volume (JAS), f = diesel usage factor (litres/JAS), e = emissions factor for diesel (kg CO_2-e/litre)

***Example 23:** 200,000 JAS exported*

$200{,}000 \times 0.25 \times 2.71 \div 1{,}000 = 135.5$ *tonnes* CO_2*-e*

Category 10: Processing of sold products

This category includes emissions associated with the downstream processing of sold intermediate products. The primary data source for this category is production volume (tonnes), converted to dry tonnes. An average moisture content of 55% for radiata pine was assumed to convert from green to dry tonnes.[11]

Product pathways were determined based on domestic log deliveries and Manley & Evison's material flow for NZ log exports.[12] Emissions factors for downstream processing were calculated for each product pathway based on average processing conversions and published emissions data. These have been applied to the corresponding annual dry production volumes.

Emissions were categorised into three types: process emissions, biogenic emissions and non-biogenic emissions. Process and non-biogenic emissions have been included as Scope 3 Category 10 emissions while biogenic emissions associated with burning are out of scope and have been excluded. For further detail refer to the United States methodology for this category.

Category 11: Use of sold products

This category is not applicable to Matariki Forests. There are no lifetime emissions associated with timber products sold.

Category 12: End-of-life treatment of sold products

This category includes an allowance for the future emissions associated with the end-of-life disposal of sold products. Emissions associated with end-of-life treatment were estimated based on sold dry volume (tonnes) classified by final product type and market type. These were converted to carbon mass assuming 50% wood carbon content and final product carbon mass using conversions of 50% for sawn lumber, 52% for plywood, 38% for MDF and 11% for pulp/paper (volume weighted NZ average: 48.5%). The resulting carbon dry mass of the final products were then apportioned across four end of life categories as shown in Table 13.

Carbon mass assumed to incur end-of-life emissions was converted to carbon dioxide equivalents by multiplying by a factor of 3.67 (44/12). For further detail refer to the United States methodology for this category.

Table 13: End-of-life treatment assumptions to determine Scope 3 Category 12 emissions.

Type	End of life type	Volume weighted split (NZ)	Assumption
1	Remaining in use after 100 years	47%	No end-of-life emissions.
2	Burnt at end of life	9%	End of life emissions are biogenic and out of Scope.
3	Recycled at end of life	10%	No end-of-life emissions.
4	Landfilled at end of life	34%	End of life emissions included in scope for 62% of landfilled product (13% of total). This excludes the mass expected to be remaining in landfill/not yet decomposed in 100 years.

Category 13: Downstream leased assets

Matariki Forests currently has no downstream leased assets.

Category 14: Franchises

This category is not applicable to Matariki Forests.

Category 15: Investments

This category is not applicable to Matariki Forests.

Carbon stored in wood products

Carbon in harvested timber

The total amount of carbon removed via harvest is calculated from total harvest volume (m^3) and assuming a basic wood density of 42% and wood carbon content of 50%.

Equation 24: *Carbon in harvested timber*

$C = v \times 0.96 \times 0.42 \times 0.5 \times (44 \div 12)$

Where C = carbon removed through harvest (cubic metres), v = harvest volume (tonnes), 0.96 = volume conversion (cubic metre/tonne), 0.42 = wood basic density, 0.5 = wood carbon content, and (44/12) = CO_2/C ratio

Example 24: *200,000 tonnes harvested*

$200{,}000 \times 0.96 \times 0.42 \times 0.5 \times (44 \div 12) = 147{,}840\ m^3$

Carbon stored in wood products

Carbon is stored in harvested wood products over time. Carbon decay curves are quantified for volume harvested in 2023 by export and domestic product.

For both export and domestic product, a conversion of 0.96 tonnes/m^3 is used to convert from wood volumetric tonnes to cubic metres. Wood volume is converted to carbon volume assuming a basic wood density of 0.42 tonnes/m^3, wood carbon content of 50% and CO_2/C ratio of 3.667 (Example 25).[13]

The calculation of carbon stored in domestic wood products follows the framework set out by Wakelin et al. in 2020 (Example 26).[14] Domestic volume is categorized by customer in four IPCC product categories (saw timber, panels, paper & paperboard or other (firewood)). A 60% conversion is assumed to convert harvested volume (cubic metres) to harvested wood products (based on MFE National Inventory Carbon Reporting). Residue volume is excluded. IPCC half-lives, reflecting measured decay rates, are applied to processed product volumes by type to calculate a weighted average half-life. A decay function based on the weighted average half-life is applied to the calculated domestic carbon volume (Equation 28).

The average half-life for export products is calculated for each destination country based on the product pathways outlined in Manley & Evison (Example 27).[12] A decay function based on the destination-weighted average half-life is applied to the calculated export carbon volume (Equation 29).

Equation 25: *Carbon stored in harvested wood products:*

Domestic conversion to harvested wood products

$w = v \times 0.96 \times 0.6$

Where w = total wood product (cubic metres), v = harvest volume (tonnes), 0.96 = volume conversion (cubic metre/tonne), and 0.6 = processing conversion

Example 25*: 200,000 tonnes harvested*

$200{,}000 \times 0.96 \times 0.6 = 115{,}200\ m^3$

Equation 26: *Determination of domestic half life*

$Dh = \sum(v_i \times hl_i) \div v$

Where Dh = average half-life (years), v_i *= domestic harvest volume for* i^{th} *IPCC product type (cubic metres),* hl_i *= half-life for* i^{th} *IPCC product type, and v = total harvest volume (cubic metres)*

Example 26*: 200,000* m^3 *harvested for sawn lumber, 100,000* m^3 *harvested for panels*

$((200{,}000 \times 35) + (100{,}000 \times 25)) \div 300{,}000 = 31.7$ *years*

Equation 27: *Determination of export half life*

$Eh = \sum(v_i \times hl_i) \div v$

Where Eh = average half-life (years), v_i *= export harvest volume for* i^{th} *destination country (cubic metres),* hl_i *= half-life for* i^{th} *destination country, and v = total harvest volume (cubic metres)*

Example 27*: 200,000* m^3 *exported to China, 100,000* m^3 *exported to India*

$((200{,}000 \times 6.6) + (100{,}000 \times 2.5)) \div 300{,}000 = 5.2$ *years*

Equation 28: *Exponential decay of stored wood product for domestic product*

$T_t = (C \times (e^{\wedge}((\ln(0.5) \div h) \times t))$

Where T_t = carbon (tonnes CO_2-e) at time t, C = carbon removed through harvest (cubic metres) converted to , e = Euler's number, ln = natural log, h = half-life of product, and t = time period (years in future)

Equation 29: *Exponential decay of stored wood product for export product*

$T_t = (w \times 0.42 \times 0.5 \times (44 \div 12)) \times (e^{\wedge}((\ln(0.5) \div h) \times t))$

Where T_t = carbon (tonnes CO_2-e) at time t, w = total wood (cubic metres), 0.42 = wood basic density, 0.5 = wood carbon content, (44/12) = CO_2/C ratio, e = Euler's number, ln = natural log, h = half-life of product, and t = time period (years in future)

Carbon stored over multiple cycles

Carbon storage increases across multiple rotations because of the cumulative effect of long-term carbon storage in harvested wood products. To calculate this cumulative carbon storage a rotation of 25 years is assumed for Matariki Forests.

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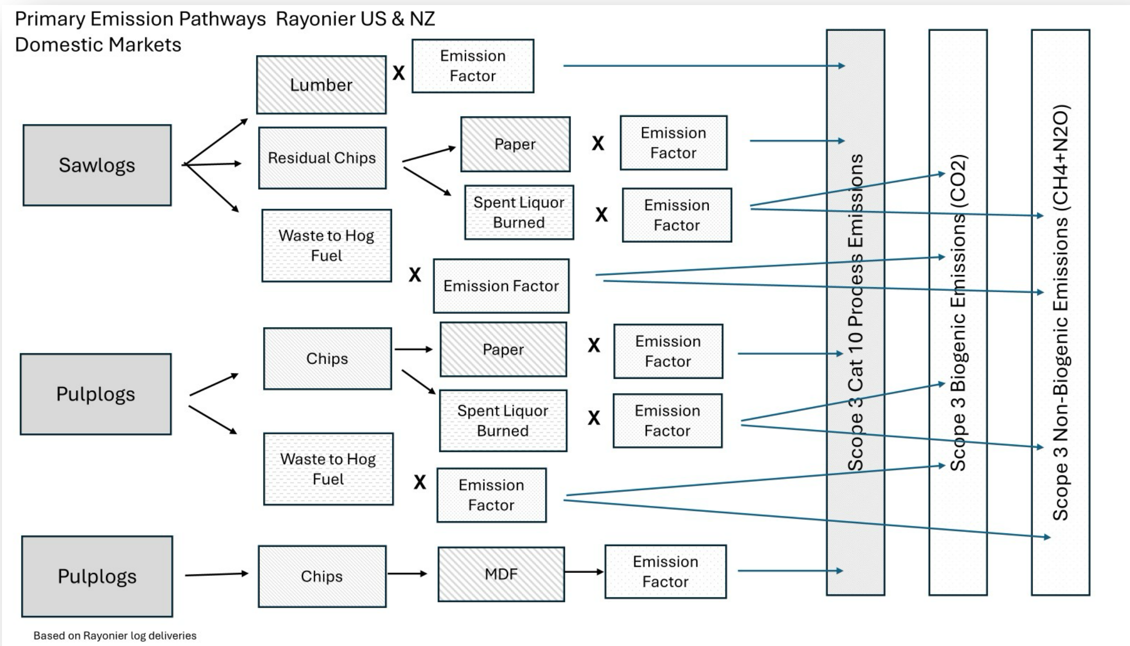
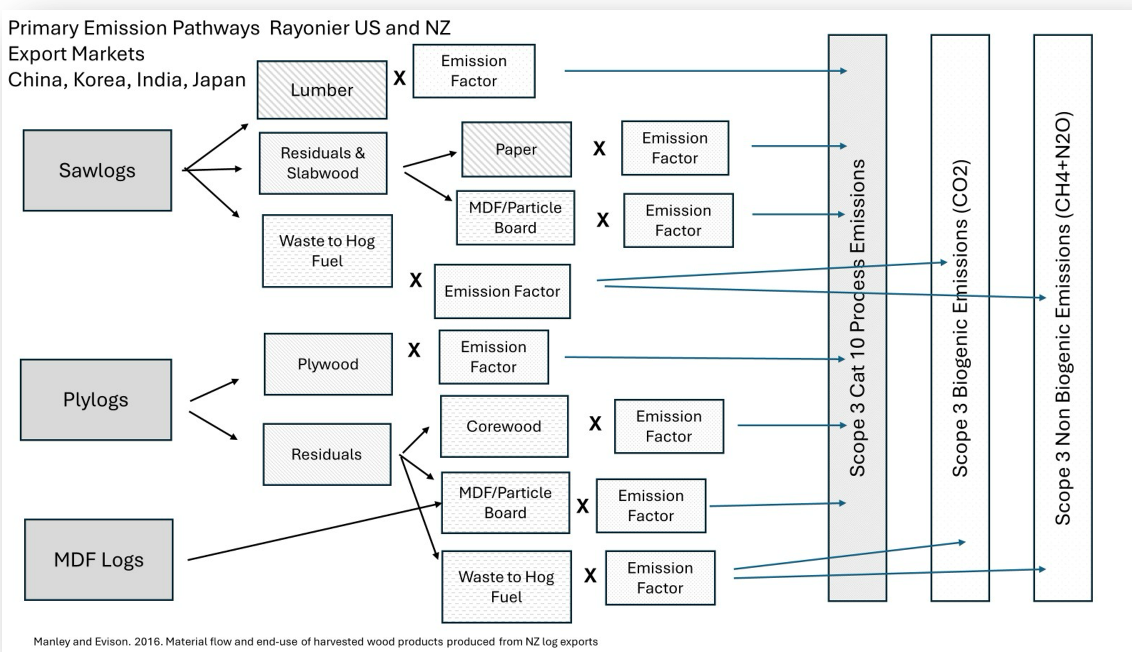
Appendix A:

Product pathways from processing of sold goods





Appendix B

MFE emissions factors sourced

Category	Factor	MFE Reference	Emission Factor Description
S1	Fuel	Table 4	Transport fuel per litre regular petrol and diesel.
S2	Purchased electricity	Table 9	Purchased grid-average electricity – annual average 2022.
S3, Cat 3	Transmission losses	Table 12	Transmission and distribution losses for electricity consumption 2022.
S3, Cat 5	Waste	Table 73	Waste disposal to municipal (class 1) landfills with gas recovery for office waste (unknown composition).
S3, Cat 6	Taxi and uber travel	Table 22	Taxi travel – regular.
S3, Cat 6	Domestic air travel	Table 37	Domestic aviation with a radiative forcing multiplier for medium and large aircrafts.
S3, Cat 6	International air travel	Table 42	International aviation with radiative forcing multiplier short hall and long hall, economy, premium economy, and business.
S3, Cat 7	Working from home	Table 14	Working from home default.
S3, Cat 7	Employee commute	Table 20	Public transport national average for bus and metropolitan average for rail.
S3, Cat 7	Employee commute	Table 27	Default private car for default age of petrol vehicle and <3,000 cc engine size.