Manufacturing and Industrial Processes sector: Chemicals and Pulp (Paper) Emissions

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1. Introduction

The chemical and pulp and paper industries underpin modern life yet come with significant climate costs. Ammonia-based fertilizers enable nearly half of the world's food supply (Boerner, 2019), while pulp and paper remain central to packaging, publishing, and hygiene products. Combined, these two sectors produce about 2.5% of global CO_2 emissions—four-fifths from the chemical industry and one-fifth from pulp and paper (IEA, 2024a; 2024b). Both sectors have made progress toward efficiency—pulp mills, for instance, often generate power from their own by-products—but overall emissions have risen with rapid demand growth. Since 2000, pulp and paper production has risen by a quarter while chemical production has doubled, driven especially by growth in production of the three primary chemicals covered in this dataset, namely methanol, ammonia, and soda ash.

Poorly understood facility level emissions limit the ability of policymakers, companies, and researchers to design credible decarbonization pathways. This paper addresses that gap by laying the foundation for robust, plant-level emissions estimates across the chemical and pulp and paper industries. Furthermore, beginning November 2025, Climate TRACE is providing potential emission reduction solutions (ERSs) to understand how sector specific mitigation strategies can reduce emissions for this sector.

2. Materials and Methods

We investigated each major processing route independently using publicly available data. Currently there is no comprehensive asset or emissions inventory for either the production of chemicals or pulp and paper. The Spatial Finance Initiative has published a Global Pulp and Paper Mill database (SFI, 2024), yet significant data gaps made it incomplete for our use case. To address these issues, we developed a large language model to collect asset metadata from online sources. We quantified emissions using a standardised "bottom-up" approach by applying an emissions factor to estimated plant-level production. Plant-level production is estimated by disaggregating publicly available national-level data amongst plants in that country. In the case of missing annual data, we forward or backfill production from the closest available year. For countries where national production data was unavailable throughout the entire dataset time period, we used regional or global average capacity utilization rates to estimate plant production.

2.1 Datasets employed

2.1.1 Asset inventory datasets

Climate TRACE has collected and compiled a global asset inventory containing important production characteristics (capacity, type, location). We developed a large language model to collect all chemical assets source data, and to complete data gaps found in SFI's Global Pulp and Paper Mill Database (2024). Where the results of this model fell well below expected global capacity in the chemicals subsectors, residual capacities sourced from Industrial Info Resources (2025) data were used on an aggregated geographical level. The totals for each sector are provided below:

- Ammonia: 258 emission sources (includes GADM-2 regions) in 41 countries (of which 137 are assets across 30 countries)
- Methanol: 140 emission sources (includes GADM-2 regions) in 31 countries (of which 42 are assets across 20 countries)
- Soda Ash: 61 emission sources (includes GADM-0 level) in in 34 countries 36 plants in 16 countries
- Pulp: 354 assets in 49 countries

2.1.2 Production datasets

National-level production data was utilized in all our models. For pulp and paper, this information was sourced from FAO (2024). For ammonia and soda ash, national production data was retrieved from USGS (2024a, 2024b). We were unable to source an equivalent dataset for methanol production. A description of the steps taken to estimate national production is outlined in Table 1.

2.1.3 Emissions factor dataset

Emissions factors were sourced separately for each material with ammonia from Climatiq (2025), methanol from the Methanol Institute (2022), soda ash from US EPA (2024) and from Gutierrez *et. al* (2025), and pulp and paper from Tomberlin *et. al* (2020).

2.2 Methods

2.2.1. Methodology for completing data gaps

Our asset production and emissions estimates rely on information about asset capacities and national production in each country. Where data gaps existed across our data sources, we used various methods to complete them determined by the data available for each country. The steps taken are detailed below in Table 1.

Table 1 Descriptions of the steps taken to assign missing asset capacities and estimate national production where raw data is unavailable.

National production data available	National capacity data available	At least some asset capacities available	Method for assigning missing asset capacities	Method for estimating national production	Relevant sector(s)
Yes	Yes	Yes	(1) Assign average of known asset capacities across assets missing capacities. (2) If (1) brings the national total in excess of national capacity, scale each asset proportionally to match official figures. This is preferred over assigning residual national capacity to avoid assigning unrealistically high or low capacities in light of a high degree of uncertainty in our source data.	N/A	Soda Ash, Ammonia, Pulp & Paper
Yes	Yes	No	(3) Equally distribute national capacity among all assets.	N/A	Soda Ash, Ammonia, Pulp & Paper
Yes	No	Yes	(4) Estimate national capacity using a global average capacity factor, derived from countries with available production and capacity data. Then follow steps (1) and (2)	N/A	Soda Ash, Ammonia, Pulp & Paper
Yes	No	No	Estimate national capacity as in (4), then equally distribute among all assets.	N/A	Soda Ash, Ammonia, Pulp & Paper
No	No	Yes	N/A	Use known and available asset-level capacity as national capacity. Apply a global average capacity factor, derived from countries with available production and capacity data, to estimate production. If no production data is available, as for methanol, derive capacity factor from literature review.	Methanol, Pulp & Paper

2.2.2. Production methodology

The subsequent step in quantifying emissions for each facility was estimating the associated activity in each time period. To do this, a disaggregation method was applied: for each facility, its share of national capacity was computed before multiplying this number by the national production to derive the facility's contribution. An illustrative example is shown below where a country has two plants A and B (with capacities C_A and C_B respectively) and a total production P_m for a given month m, the capacity-based production estimates for these two plants are (respectively $P_{A,m}$ and $P_{B,m}$):

- $P_{A,m} = \frac{C_A}{C_A + C_B} \times P_m$
- $P_{B,m} = \frac{C_B}{C_A + C_B} \times P_m$

In cases where national production exceeds the maximum realistic utilization rate of 95% national capacity, our asset capacity data was deemed to be incomplete. For pulp assets, production was estimated by applying an average global capacity factor calculated from countries indicating higher data quality. Due to indications of significantly lower capacity coverage across our assets in the chemical sector, we aggregated residual capacities from Industrial Info Resources (2025) to the smallest possible geographical level to estimate residual production.

2.2.3. Emissions methodology

With the production estimates generated for each asset or region, the emission estimates were derived by multiplying the production by the relevant emission factors. The high-level process is summarised in Figure 1.

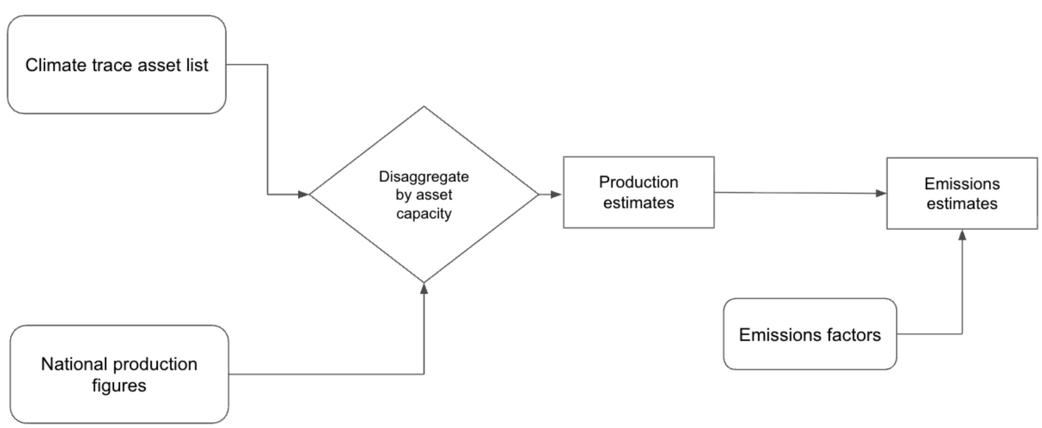

Figure 1 Methodology to calculate asset level emissions.

2.3 Uncertainty and Confidence Methodology

Uncertainty and confidence levels were assigned to activity estimates, emission factors, and CO_2 emissions following the framework detailed in the sections below.

2.3.1 Activity Estimation

Uncertainty in activity estimates arises from both the source of capacity data and the method used to determine capacity factors. When capacity information comes from reliable sources -such as independent organizations with asset-level data- and production is assessed at the national level, uncertainty is relatively low, and confidence is relatively higher. In contrast, when capacity is derived from less certain sources, such as large language model (LLM) outputs, uncertainty increases. The level of confidence further depends on the geographical resolution used to calculate capacity factors, with coarser resolutions generally leading to higher uncertainty.

The following rules apply:

- Reliable source for capacity (independent organizations with asset-level data), and capacity factor by using national level production: 0.12 (low confidence)
- Low confidence source for capacity (large language model outputs), and capacity factor estimated by using world production: 0.30 (very low confidence)
- Low confidence source for capacity (large language model outputs), and capacity factor estimated by using regional production: 0.25 (very low confidence)
- Low confidence source for capacity (large language model outputs), and capacity factor estimated by using national level production: 0.20 (very low confidence)

2.3.2 Emissions Factor

Uncertainty and confidence depends on the IPCC Tier of the emissions factor applied. In the pulp and paper sector, soda ash subsector, and most countries in the methanol subsector, a single global emission factor (Tier 1) is applied to all assets. Since this factor is not differentiated by region, technology, or process, the associated uncertainty is 0.15, corresponding to low confidence. Country-specific emissions factors (Tier 2) are used in the ammonia subsector, and for China in the methanol subsector, considered medium confidence and lower uncertainty (0.1-0.12).

2.3.3 CO2 emissions

The total CO_2 emissions uncertainty is calculated through propagation of uncertainties in both activity and emission factors. The relative uncertainty of emissions determined as:

$$\sigma_A = \sqrt{(\sigma_B)^2 + (\sigma_C)^2}$$

Where:

- σ_A = relative uncertainty of emissions
- σ_B = relative uncertainty of activity
- σ_A = relative uncertainty of emission factor

Confidence levels are then classified according to the resulting uncertainty value:

- > 0.25 - very low confidence
- 0.15 – 0.25 - low confidence
- < 0.15 - medium confidence

2.4 Emissions Reduction Solutions Overview and Application

Emissions Reduction Solutions (ERSs) for the chemicals sector are two strategies: carbon capture and renewable-driven solvay process. For pulp and paper, one strategy is applied: conversion to biomass fuels and optimization of equipment. All are discussed below. *Note: Only rank 1 strategies are provided for assets on the Climate TRACE website and additional strategies will be made available in future releases.*

Chemicals - Carbon capture and storage

The proposed strategy is the integration of carbon capture and storage (CCS) systems to capture CO_2 from process and/or fuel combustion emissions in ammonia and methanol production. CCS involves capturing CO_2 before it is released into the atmosphere and securely storing it, reducing the overall greenhouse gas footprint of production operations. Implementing CCS can reduce emissions and emissions factors by approximately 78% for the targeted processes. This reduction is achieved by capturing the majority of CO_2 emissions produced during chemical synthesis and energy generation in ammonia and methanol plants.

The IEA has conducted a detailed study evaluating the cost, effectiveness, and deployment potential of CCS in ammonia and methanol production. While CCS is recognized as an industry goal, current deployment is limited, and the report primarily provides technical and economic projections rather than evaluations of existing full-scale operations (IEA, 2017). Factors such as technology readiness, capital costs, and integration into existing facilities influence adoption.

Chemicals - Renewable-driven Solvay process

The chemicals sector includes emissions from ammonia, methanol, and soda ash production. Soda ash, used in many household and industrial products, is traditionally produced from salt (NaCl) and limestone ($CaCO_3$) using an ammonia-based loop. Ammonia acts as a catalyst, enabling the conversion of raw materials into soda ash and is regenerated and reused to improve process efficiency. However, the lime kiln in this process is fueled by fossil energy, generating substantial CO_2 emissions (EPA, 2015a; EPA, 2015b).

The strategy applied here is based on a pilot-scale module developed by Solvay, a European chemical company (https://www.solvay.com/en/). They have developed "e.Solvay", a technology that reduces emissions. The approach, applied to soda ash production, begins by replacing the fossil-fueled lime kiln with a low-energy electrochemical system powered by decarbonized, renewable electricity. Ammonia is still recovered and reused in a circular loop, but the process no longer generates CO_2 in the calcination step. In addition to eliminating CO_2 emissions from lime calcination, the process improves resource efficiency, using 20% less brine, 30% less limestone, and 20% less energy while maintaining production output (Solvay, 2024; We Soda, 2024). Overall, this results in a 50% reduction in CO_2 emissions compared to the traditional process.

Implementing the Solvay process can potentially reduce the sector's emissions while simultaneously improving material and energy efficiency, thereby translating process improvements into quantifiable emissions reductions. Following full validation, the company plans deployment across all European soda ash plants by 2050, reflecting the technology's readiness and potential for scale (Solvay, 2024; We Soda, 2024). Adoption is supported by both emissions reduction potential and process efficiency improvements, though global deployment may be influenced by regional electricity decarbonization levels.

Pulp-and-paper- Conversion to biomass fuels and optimization of equipment

GHG emissions from the pulp and paper manufacturing primarily arise from fuel combustion in boilers and lime kilns, which generate steam and process heat, as well as from chemical pulping processes that release CO_2 and sulfur compounds. These emissions occur directly at the mill during the conversion of wood or recycled fiber into pulp and finished paper products, contributing roughly 0.2% of global CO_2e emissions. Emissions can be mitigated by converting the fuel used for steam and process heat from fossil fuels to biomass, alongside overall equipment optimization to improve efficiency. Implementing biomass fuel conversion and equipment optimization is estimated to reduce plant-level emissions by approximately 40%. These measures are widely applied across the sector and have been demonstrated as effective in recent decarbonization reviews (Sciencedirect, 2025).

3. Results

Figure 2 presents the total global annual CO_2 emission estimates for the chemicals and pulp and paper industries. Among the four sub-sectors, ammonia production is the largest emitter, with emissions exceeding 350 Mt CO_2. Methanol ranks second, with emissions showing a slight decline in recent years from 150 Mt CO_2 to 138 Mt CO_2. The pulp and paper industry is the third largest contributor, releasing around 130 Mt CO_2 annually. Finally, soda ash production accounts for relatively lower emissions, remaining stable at approximately 26 Mt CO_2 in recent years.

Tables 1 to 4 list the largest emitters in the ammonia, methanol, soda ash, and pulp and paper industries. Across all three primary chemical subsectors, China is the largest emitter, particularly for methanol where production is coal-dominated as opposed to using natural gas used more extensively elsewhere. In the pulp sector, China comes second to the U.S., followed closely by Brazil.

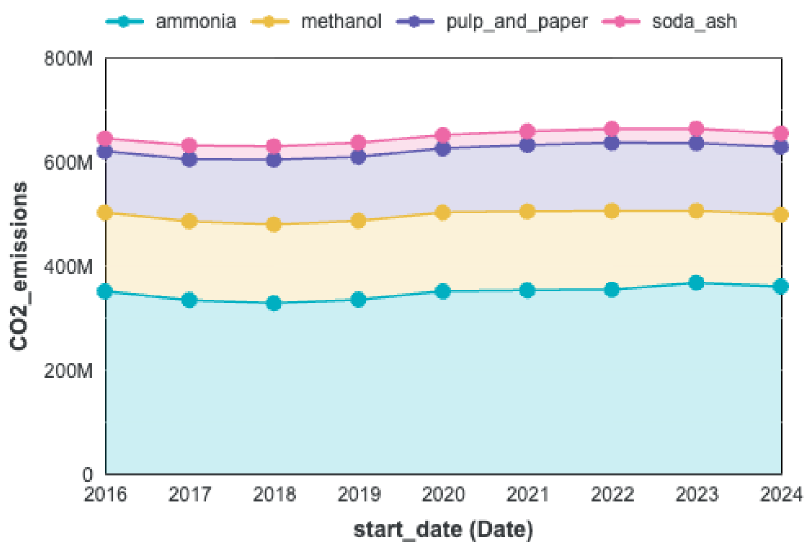

Figure 2 Global annual Climate TRACE estimated CO_2 emissions (stacked by year) for Ammonia, Methanol), Soda Ash, and Pulp and Paper for years 2016 to 2024.

Table 1 Top 10 emitters in the ammonia sector in 2024

Country	CO_2 Emissions ($MtCO_2$)
China	182.4
India	42.3
Russia	29.5
U.S.A.	20.2
Iran	11.8
Egypt	10.4
Pakistan	9.9
Canada	7.16
Germany	6.5
Nigeria	4.8

Table 2 Top 10 emitters in the methanol sector in 2024

Country	CO_2 emissions ($MtCO_2$)
China	118.2
Iran	3.6
U.S.A	3.6
Russia	2.22
Saudi Arabia	1.79
Malaysia	1.56
Egypt	1.1
Oman	0.7
Canada	0.7
New Zealand	0.7

Table 3 Top 10 emitters in the soda ash sector in 2024

Country	CO_2 Emissions ($MtCO_2$)
China	11.8
U.S.A.	5.1
Russia	1.5
Turkey	1.3
India	1.1
Germany	1.1
Bulgaria	0.5
Poland	0.5
France	0.4
Iran	0.3

Table 4 Top 10 emitters in the pulp sector in 2023

Country	CO_2 emissions ($MtCO_2$)
U.S.A.	25.7
China	15.79
Brazil	14.11
Indonesia	6.49
Finland	5.36
Canada	4.86
Sweden	3.53
Chile	2.92
Japan	2.04
Russia	1.55

4. Discussion & Conclusions

In this work, asset-level CO_2 emissions are provided on a monthly basis for the chemicals and pulp and paper sectors, with residual production and emissions aggregated to the GADM-2 level for certain chemical subsectors where public asset data was unavailable.

To estimate emissions at the facility-level, our methodology disaggregates national production numbers to assets based on the share of their capacity to the total national production capacity. Consequently, the accuracy of these estimates can be considered limited. Nevertheless, this work serves as a foundational piece for the estimating CO_2 emissions in the pulp and paper and chemical sector and may be utilised to develop more detailed estimates in the future as more data becomes available.

5. Supplementary metadata section

5.1 Chemicals

The chemicals sector CO_2 emissions were reported for individual assets for the years 2021 to 2024. The emissions described here represent a subset of specific country-level emissions estimates from the Climate TRACE manufacturing sector. All data is freely available on the Climate TRACE website (https://climatetrace.org/). A detailed description of what is available is described in Tables 5 to 7.

Table 5 Details on the chemical assets metadata

General Description	Definition
Sector definition	*Emissions from chemicals production*
UNFCCC sector equivalent	*2.B.1 (Ammonia), 2.B.8.a. (Methanol), 2.B.7. (Soda ash)*
Temporal Coverage	*2021 - 2024*
Temporal Resolution	*Monthly*
Data format	*CSV*
Coordinate Reference System	*None. ISO3 country code provided*
Number of emitters available for download	*221 ammonia sources and 114 methanol sources*
What emission factors were used?	*global emission factors*
What is the difference between a "0" versus "NULL/none/nan" data field?	*"0" values are for true non-existent emissions. If we know that the sector has emissions for that specific gas, but the gas was not modelled, this is represented by "NULL/none/nan"*
total_CO2e_100yrGWP and total_CO2e_20yrGWP conversions	*Climate TRACE uses IPCC AR6 CO_2e GWPs. CO_2e conversion guidelines are here: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport_small.pdf*

Table 6 Definition of the fields in the chemicals asset dataset

Data attribute	Definition
sector	manufacturing
source_sub-sector_name	chemicals
source definition	emissions from chemicals production
start_date	start date for time period of emissions estimation (YYYY-MM-DD format)
end_date	end date for time period of emissions estimation (YYYY-MM-DD format)
asset_identifier	internal identifier
asset_name	name of the facility
iso3_country	ISO 3166-1 alpha-3 country code
location	well-known text (WKT) point location
type	chemicals type (ammonia, methanol, soda ash)
capacity	monthly plant capacity (tons)

Data attribute	Definition
capacity_factor	utilisation rate of plants
CO2_emissions_factor	direct emissions factor (t-CO_2/ton of chemicals)
CH4_emissions_factor	not used; N/A
N2O_emissions_factor	not used; N/A
CO2_emissions	Direct emissions (t-CO_2)
CH4_emissions	not used; N/A
N2O_emissions	not used; N/A
total_CO2e_100yrGWP	100 years global warming potential (t-CO_2e)
total_CO2e_20yrGWP	20 years global warming potential (t-CO_2e)
other1	not used; N/A
model_number	version of the model (e.g. 1,2...)

Table 7 Definition for confidence and uncertainty in emissions.

Data attribute	Confidence Definition	Uncertainty Definition
type	● *Very low:* Based on highly speculative or obsolete information. Very low level of confidence in the accuracy of asset classification. ● *Low:* Limited or somewhat outdated data. Low level of confidence in the classification's correctness. ● *Medium:* A mix of historical and more recent data. A medium level of confidence in its accuracy. ● *High:* Grounded in comprehensive and recent data. A high level of confidence in the precise classification of the asset. ● *Very high:* Extensive, up-to-date, and verified data. A very high level of confidence in the accurate and detailed identification of the asset.	Not used; N/A
capacity	● *Very low:* Limited or outdated data, and significant uncertainties exist. ● Low: Outdated and/or incomplete data. ● *Medium:* A mix of historical and recent data. ● *High: Comprehensive* and recent data updates. High level of certainty. ● *Very high:* Extensive, up-to-date, and verified data. Very high level of certainty.	Not used; N/A
capacity_factor	● *Very low:* Data is sparse or highly unreliable. Considerable uncertainty in capacity factor estimations. ● *Low:* Moderate uncertainty in capacity factor calculations.	Not used; N/A

Data attribute	Confidence Definition	Uncertainty Definition
	• *Medium:* Data is sufficiently available, though not comprehensive. No absolute accuracy in capacity factor estimations. • *High:* High confidence in the accuracy of capacity factor calculations. • *Very high:* Derived from thorough and validated data sources. Very high precision of capacity factor estimations.	
activity	• *Very low:* Largely speculative or based on outdated information. A very low level of confidence in activity assessments. • *Low:* Limited or somewhat outdated sources. A low level of confidence in the activity assessments. • *Medium:* A mix of historical and more recent data. Medium level of confidence in activity insights. • *High:* Detailed and current operational data ensures a high level of confidence in the accuracy of activity assessments. • *Very high:* Extensive, verified, and up-to-date data. A very high level of confidence in their accuracy.	±12 to 30% of production estimates (based on IPCC)
CO2_emissions_factor	• *Very low:* Highly uncertain due to insufficient or unreliable data. • *Low:* Estimated from incomplete data. Low confidence level in its precision. • *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy. • *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. • *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	±15% of assumption (based on IPCC)
CH4_emissions_factor	Not used; N/A	Not used; N/A
N2O_emissions_factor	Not used; N/A	Not used; N/A
CO2_emissions	• *Very low:* Based on very rough estimations or outdated information. A very low level of confidence in its accuracy. • *Low:* Estimated from incomplete data. Low confidence level in its precision. • *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy. • *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. • *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	±19 to 34% of emissions estimates

Data attribute	Confidence Definition	Uncertainty Definition
CH4_emissions	Not used; N/A	Not used; N/A
N2O_emissions	Not used; N/A	Not used; N/A
total_CO2e_100yrGWP	• *Very low:* Based on very rough estimations or outdated information. A very low level of confidence in its accuracy. • *Low:* Estimated from incomplete data. Low confidence level in its precision. • *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy. • *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. • *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	±19 to 34% of emissions estimates
total_CO2e_20yrGWP	• *Very low:* Based on very rough estimations or outdated information. A very low level of confidence in its accuracy. • *Low:* Estimated from incomplete data. Low confidence level in its precision. • *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy. • *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. • *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	±19 to 34% of emissions estimates

5.2 Pulp and paper

Pulp sector CO_2 emissions were reported for the individual emitting sources for the years 2021 to 2024. The emissions described here represent a subset of specific country-level emissions estimates from the Climate TRACE manufacturing sector. All data is freely available on the Climate TRACE website (https://climatetrace.org/). A detailed description of what is available is described in Tables 8 to 10.

Table 8 Details on the pulp and paper assets metadata

General Description	Definition
Sector definition	*Emissions from pulp and paper production*
UNFCCC sector equivalent	*2.H.1 Pulp and paper*
Temporal Coverage	*2021 - 2024*

General Description	Definition
Temporal Resolution	*Annual*
Data format	*CSV*
Coordinate Reference System	*None. ISO3 country code provided*
Number of emitters available for download	*354 pulp and paper sources*
What emission factors were used?	*global emission factors*
What is the difference between a "0" versus "NULL/none/nan" data field?	*"0" values are for true non-existent emissions. If we know that the sector has emissions for that specific gas, but the gas was not modelled, this is represented by "NULL/none/nan"*
total_CO2e_100yrGWP and total_CO2e_20yrGWP conversions	*Climate TRACE uses IPCC AR6 CO_2e GWPs. CO_2e conversion guidelines are here: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_FullReport_small.pdf*

Table 9 Definition of the fields in the pulp and paper asset dataset

Data attribute	Definition
sector	manufacturing
source_sub-sector_name	pulp and paper
source definition	emissions from pulp production
start_date	start date for time period of emissions estimation (YYYY-MM-DD format)
end_date	end date for time period of emissions estimation (YYYY-MM-DD format)
asset_identifier	internal identifier
asset_name	name of the facility
iso3_country	ISO 3166-1 alpha-3 country code
location	well-known text (WKT) point location
capacity	monthly plant capacity (tonnes of pulp)
capacity_factor	utilisation rate of plants
activity	production of pulp (tonnes)
CO2_emissions_factor	direct emissions factor (t-CO2/tonnes of pulp)
CH4_emissions_factor	not used; N/A
N2O_emissions_factor	not used; N/A
CO2_emissions	direct emissions (t-CO_2)
CH4_emissions	not used; N/A
N2O_emissions	not used; N/A
total_CO2e_100yrGWP	100 years global warming potential (t-CO_2e)
total_CO2e_20yrGWP	20 years global warming potential (t-CO_2e)
other1	not used; N/A
model_number	version of the model (e.g. 1,2...)

Table 10 Pulp and paper sector description for confidence and uncertainty in emissions.

Data attribute	Confidence Definition	Uncertainty Definition
type	• *Very low:* Based on highly speculative or obsolete information. Very low level of confidence in the accuracy of asset classification.	Not used; N/A

Data attribute	Confidence Definition	Uncertainty Definition
	● *Low:* Limited or somewhat outdated data. Low level of confidence in the classification's correctness. ● *Medium:* A mix of historical and more recent data. A medium level of confidence in its accuracy. ● *High:* Grounded in comprehensive and recent data. A high level of confidence in the precise classification of the asset. ● *Very high:* Extensive, up-to-date, and verified data. A very high level of confidence in the accurate and detailed identification of the asset.	
capacity	● *Very low:* Limited or outdated data, and significant uncertainties exist. ● *Low:* Outdated and/or incomplete data. ● *Medium:* A mix of historical and recent data. ● *High:* Comprehensive and recent data updates. High level of certainty. ● *Very high:* Extensive, up-to-date, and verified data. A very high level of certainty.	Not used; N/A
capacity_factor	● *Very low:* Data is sparse or highly unreliable. Considerable uncertainty in capacity factor estimations. ● *Low:* Moderate uncertainty in capacity factor calculations. ● *Medium:* Data is sufficiently available, though not comprehensive. No absolute accuracy in capacity factor estimations. ● *High:* High confidence in the accuracy of capacity factor calculations. ● *Very high:* Derived from thorough and validated data sources. Very high precision of capacity factor estimations.	Not used; N/A
activity	● *Very low:* Largely speculative or based on outdated information. A very low level of confidence in activity assessments. ● *Low:* Limited or somewhat outdated sources. A low level of confidence in the activity assessments. ● *Medium:* A mix of historical and more recent data. Medium level of confidence in activity insights. ● *High:* Detailed and current operational data ensures a high level of confidence in the accuracy of activity assessments. ● *Very high:* Extensive, verified, and up-to-date data. A very high level of confidence in their accuracy.	±12 to 30 % of production estimates
CO2_emissions_factor	● *Very low:* Highly uncertain due to insufficient or unreliable data. ● *Low:* Estimated from incomplete data. Low confidence level in its precision. ● *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy.	±15% of assumption

Data attribute	Confidence Definition	Uncertainty Definition
	● *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. ● *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	
CH4_emissions_factor	Not used; N/A	Not used; N/A
N2O_emissions_factor	Not used; N/A	Not used; N/A
CO2_emissions	● *Very low:* Based on very rough estimations or outdated information. A very low level of confidence in its accuracy. ● *Low:* Estimated from incomplete data. Low confidence level in its precision. ● *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy. ● *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. ● *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	±19 to 34 % of emissions estimates
CH4_emissions	Not used; N/A	Not used; N/A
N2O_emissions	Not used; N/A	Not used; N/A
total_CO2e_100yrGWP	● *Very low:* Based on very rough estimations or outdated information. A very low level of confidence in its accuracy. ● *Low:* Estimated from incomplete data. Low confidence level in its precision. ● *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy. ● *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. ● *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	±35% of emissions estimates
total_CO2e_20yrGWP	● *Very low:* Based on very rough estimations or outdated information. A very low level of confidence in its accuracy. ● *Low:* Estimated from incomplete data. Low confidence level in its precision. ● *Medium:* A mix of historical and more recent data. Medium level of confidence in their accuracy.	±35% of emissions estimates

Data attribute	Confidence Definition	Uncertainty Definition
	• *High:* Derived from comprehensive and recent data. A high level of confidence in their precision. • *Very high:* Based on extensive and validated data, providing a very high level of confidence in their precision.	

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Disclaimer: The emissions provided for this sector are our current best estimates of emissions, and we are committed to continually increasing the accuracy of the models on all levels. Please review our terms of use and the sector-specific methodology documentation before using the data. If you identify an error or would like to participate in our data validation process, please contact us.

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