NAICS Code: 322110 - Pulp mills (Recycling/finishing variation)

SUMMARY INFO: Some pulp plants conduct specialized finishing processes to prepare pulp for commercial paper and paperboard production, as well as more direct uses. These can include drying, cutting, and wrapping the pulp before it is transported to paper mills, which is usually stored in dried bales.[1] In particular, the moisture of pulp is controlled to minimize any potential dust or curling in subsequent paper production. Finishing processes are dependent on the end use of pulp products, including for printed paper, food containers, tissue, and more.[2] Some pulp is molded more directly into packaging products, including for egg and fruit cartons and tableware.[3]

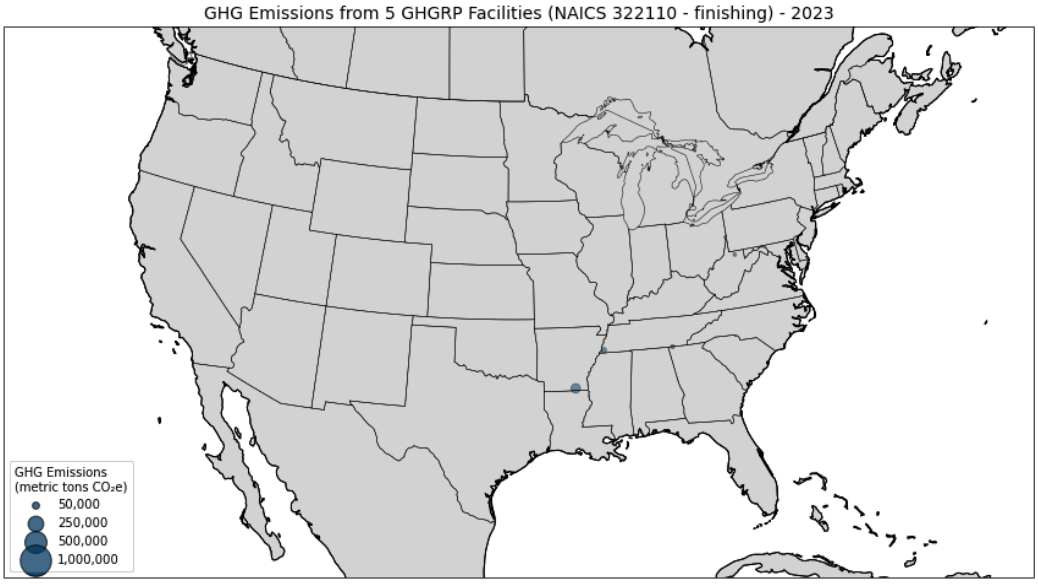
Date Updated: 1/7/2026

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Link to archetype code:
https://github.com/ISALGroup/archetypes/blob/main/archetypes_list/market_pulp_recycling.py

Archetype Name: Pulp mill finishing

Emissions and facility overview: According to the United States Census Bureau, there are 35 establishments associated with NAICS 322110 in the United States in 2023, 26 of which report annual GHG emissions in the GHGRP.[4] According to the criteria outlined in the Technical Appendix (i.e. no presence of a recovery boiler and no lime kiln onsite in the GHGRP dataset), five of the 26 pulp mills have been classified as mills using a finishing process. Reported emissions from GHGRP amounted to 33.3 Mt CO_2e in 2023 for all plants with the 322110 NAICS code, including biogenic emissions. The five plants classified as finishing mills account for 0.2 Mt CO_2e, or 0.5% of the emissions reported in the GHGRP. The majority of these plants are concentrated in the Southeast U.S., as summarized in the map below.



[1] AXA XL Risk Consulting. Pulp and Paper Manufacturing.
[2] Leo Chan. The Lifecycle of a Molded Pulp Product. BonitoPak. October 2024.
[3] Sodaltech. 10 Reasons Why Molded Pulp Packaging Is the Future. February 2025.
[4] U.S. Census Bureau. 2023: ECNSVY Business Patterns County Business Patterns CB2300CBP. 2023; U.S. Environmental Protection Agency. Greenhouse Gas Reporting Program (GHGRP). 2025.

Sector outputs: Pulp mills manufacture pulp without producing end products such as paper or paperboard.

Process pathways: Pulp manufacturing consists in extracting cellulose fibers to make pulp. These fibers come from two main sources:

- Recovered paper
- Virgin fibers

Recovered fibers come from used paper that gets cleaned, de-inked, and re-pulped and dried to make market pulp. The U.S. has a fairly high rate of recovered paper of 65.8% in 2017, and this means that pulp recycling cannot be ignored and will be included for all models for pulp and paper production.

When fibers come from virgin sources (i.e., wood cut for the express purpose of manufacturing paper products), there are several pathways available to recover cellulose from the wood matrix, which contains cellulose, lignin, and hemicellulose. These pathways are typically classified into mechanical processes, which rely on grinding wood to release the fibers, and chemical processes, which rely on chemical reactions to dissolve lignin to free the fibers. According to FAO,[5] the use of recovered paper for paper and paperboard production represents 46.4% of the 2023 production. According to Ek et al.,[6] the majority (75%) of virgin paper produced worldwide is obtained through chemical processes, while the mechanical and semi-chemical (which includes both chemical separation and mechanical grinding) methods are responsible for around 20% and 5% of global production respectively. Among the chemical methods, the Kraft process is responsible for the vast majority of the production (~90%), while the main other production route is the sulfite method. Tran and Vakkilainnen[7] also support that assessment, stating that ⅔ of the global virgin fiber production comes from the Kraft process among all processes, and 90% of the chemical processes. This specific document focuses on the production process from recycled materials.

Process Overview: Figure 1 represents the process flow diagram of a pulp production mill that uses the Kraft process. A large part of the present process overview section is based on the "Pulp and Paper Chemistry and Technology" series.[8]

[5] Food and Agriculture Organization of the United Nations. Pulp and Paper Capacities Survey 2023-2025. 2024.
[6] Monica Ek et al. Pulp and Paper Chemistry and Technology Volume 2: Pulping Chemistry and Technology. 2009.
[7] Honghi Tran and Esa K. Vakkilainnen. The Kraft Chemical Recovery Process. 2008.
[8] Monica Ek et al. Pulp and Paper Chemistry and Technology Volume 1: Wood Chemistry and Wood Biotechnology. 2009; Monica Ek et al. Pulp and Paper Chemistry and Technology Volume 2: Pulping Chemistry and Technology. 2009; Monica Ek et al. Pulp and Paper Chemistry and Technology Volume 3: Paper Chemistry and Technology. 2009; Monica Ek et al. Pulp and Paper Chemistry and Technology Volume 4: Paper Products Physics and Technology. 2009.

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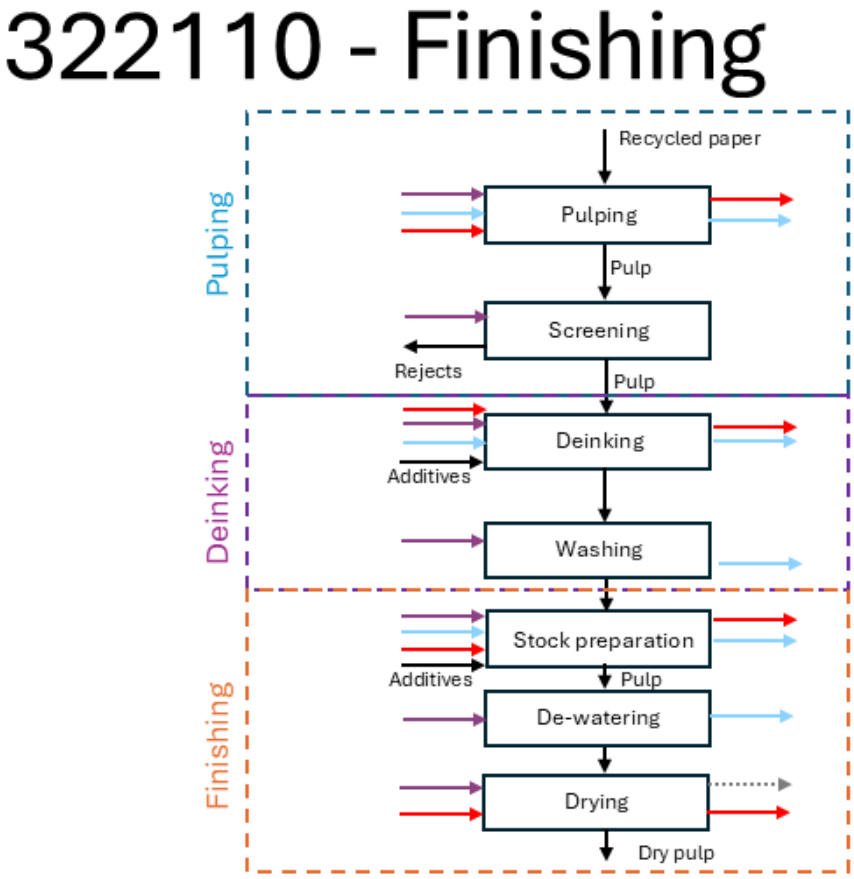


Figure 1: Recycled Pulp Mills Archetype Process Flow Diagram

Pulp is sourced from recycling paper at its end-of-life by re-pulping the waste paper and treating it to remove impurities. This is broadly divided into three steps: pulping, de-inking, and finishing.

Pulping Production Line: Pulping typically takes place in drum pulpers or high-consistency batch pulpers which have a consistency of 12%-18%.[9] They run at higher temperatures than ambient and require electricity to circulate the pulp

Pulp is screened, and 2% is assumed rejected. Screened pulp is then sent for de-inking.

De-inking Production Line: De-inking is a flotation process typically at 1%-2% consistency at 40-45°C.[10]

Finally, a washing step takes place to remove impurities separated from the fibers in the de-inking step.

Finishing Production Line: Pulp is then re-pulped, de-watered, dried, and packaged. In integrated plants, pulp would be kept at low consistency to form paper, but to produce market pulp it needs to be

[9] Pratima Bajpai. Recycling and Deinking of Recovered Paper. 2024.
[10] Pratima Bajpai. Recycling and Deinking of Recovered Paper. 2024.

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dewatered. De-watering is typically done in a screw press, though other technologies like belt presses or centrifuges can also be used.

De-watered pulp is then sent to pulp dryers, where the market pulp moisture content is 10%.

Archetype Unit Process Assumptions: The model used is depicted in Figure 1, and Table 1 contains the assumptions made in each process unit of the model.

Limitations and future work: Types of dryers and variations of other equipment could not be identified just from GHGRP datasets, so generic units were modeled. Additives-use modeling lacks some details. At the time of report production, numbers from DOE[11] were used in order to supplement energy demand per process unit as the recycled paper line was not yet included in the models.

Table 1: Finishing Pulp Mill Archetype Unit Process Assumptions

Unit Process Name	Assumptions	Parameter Basis	Source
Pulping	Pulping temperature: 80°C	Literature-derived	Jerry Aue et al. Fiber Recovery from Waste Paper: A Breakthrough in Re-Pulping Technology. 2004.
	Electricity use: 28kWh	Literature-derived	Pratima Bajpai. Pulp and Paper Industry: Energy Conservation. 2016.
De inking	Consistency: 1.5%	Literature-derived	Pratima Bajpai. Recycling and Deinking of Recovered Paper. 2024.
	Temperature: 42.5°C	Literature-derived	Pratima Bajpai. Recycling and Deinking of Recovered Paper. 2024.
Dewatering	Electricity: 1.2 kWh/ton dry pulp	Literature-derived	Bouchaib El Idrissi et al. Dewatering parameters in a screw press and their influence on the screw press outputs. 2019.
	Moisture change: 10% or up to total of 78% moisture	Literature-derived	Bouchaib El Idrissi et al. Dewatering parameters in a screw press and their influence on the screw press outputs. 2019.
Pulp dryer	Market pulp moisture content: 10%	Engineering judgment	
	Air temperature: 110℃	Engineering judgment	
	Exhaust temperature: 100℃	Engineering judgment	

[11] U.S. Department of Energy. Bandwidth Study on Energy Use and Potential Energy Saving Opportunities in U.S. Pulp and Paper Manufacturing. 2015.

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