Life Cycle Assessment and calculation of CO_2 removal for biochar

Version 1.1

24st May 2021

accend

Important information

 Accend has prepared the report to ascertain the net CO2 sequestration of biochar produced by Freres Lumber. The report contains a carbon footprint calculation for the biochar product using the life cycle assessment approach in accordance with ISO 14067, where applicable.

Disclaimer: The author has taken every reasonable care to ensure that the contents are an accurate and fair representation of the product's carbon footprint, based upon the received production data and using industry best practice. However, the author disclaims all responsibility for the consequences of actions taken by any third party, directly or indirectly, based on the information in this report. The report has not been 3rd party verified.

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Abbreviations

Cubic meter	m^3
EPDs	Environmental Product Declarations
GHG	Greenhouse gases
GWP	Global Warming Potential
GWP_{Bio}	Carbon dioxide only released from the combustion of biogenic materials (eg wood)
ISO	International Organization for Standardization
kg	kilogram
KWh	Kilowatt hour
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LVL	Laminated Veneer Lumber
m	meters
m^3	cubic meters
MC	moisture content
MJ	megajoule
MPP	Mass ply panels
tonkm	metric ton – kilometers

Glossary of terms

Allocation – A way of dividing emissions and resource use among the different products of a process. The partitioning can be made on weight basis, energy content, or economic value.

Cradle-to-gate – LCA model which includes upstream part of the product life cycle, i.e. all steps from raw material extraction to product at factory gate.

Declared Unit - Quantity of a wood building product for use as a reference unit, e.g. mass, volume, for the expression of environmental information needed in information modules.

Functional unit – expresses the function of studied product in quantitative terms and serves as basis for calculations. It is the reference flow to which other flows in the LCA are related. It also serves as a unit of comparison in comparative studies.

Life cycle assessment (LCA) – Method for the environmental assessment of products covering their lifecycle from raw material extraction to waste treatment

Life cycle inventory (LCI) – LCA study that goes as far as an inventory analysis but does not include impact assessment.

Life cycle impact assessment (LCIA) – Phase of an LCA study during which the environmental impacts of the product are assessed and evaluated.

System boundary – A set of criteria that specifies which processes are part of a product.

1. Introduction

Established in 1922, Freres Lumber produces finished plywood products, lumber, veneers, structural composite lumber, and mass ply panels (MPP) with around 450 employees. The company operates two veneer plants, a veneer drying facility, plywood plant, co-generation facility, a stud mill, their own log and highway trucks, and the MPP production facility located in Lyons, Oregon on the westside of the Cascade Mountains.

Figure 1 Freres Lumber facility at Lyons, Oregon.

The co-generation facility is a 100% biomass-fired rotary bed boiler that runs 24/7 producing steam to use in the manufacturing of lumber-based products and for electricity generation. The biochar is a by-product of steam production. The boiler is fed with a wide range of biomass feedstocks sourced from the local region, including bark and waste from the on-site production of timber products.

During the period of this study, biochar output represented 9.8 % of the total captured energy output of the boiler. The char is either shipped to a landfill, where it becomes a carbon sink or is used for material purposes. The company has plans to produce soil amendments by combing biochar.

The period of this study is 1st October 2019 – 31st March 2021. During this period, the company produced and shipped 3525 dry metrics ton of biochar.

This report is concerned only with the lifecycle greenhouse gas emissions attributable to the production of the biochar and the biochar's CO2 sequestration potential. Data sources are the Ecoinvent 3.6 database for upstream emissions factors, Bionova's LCA tool, LCA data from comparable operations, sales and feedstock data from the company and chemical analyses of the biochar by independent third-party laboratories.

The facility maintains a Title V operating permit from the State of Oregon Department of Environmental Quality.

2. Compliance with Puro methodology

The production of biochar by Freres Lumber is performed in accordance with the eligibility requirements for the Puro biochar methodology. Paragraph references to the requirements detailed in Puro CO_2 removal marketplace general rules, version 2.0, annex 1 are included in parentheses.

- The produced biochar is not used for energy purposes. Biochar produced during the period was either landfilled at Coffin Butte, Corvallis, OR 97330 or used for material recycling purposes by Construction Materials Recycling at Woodburn or Forest Grove, Oregon. (§1.1.1)
- The feedstock comes from multiple sources. Categorized under the EBC guidelines positive list[1], 62% of the feedstock is waste wood such as pallet grindings, ply trim and sawdust. 10% is agricultural waste, 0,3% is food processing residues, and 28% forestry residues (Bark) from Freres' own operations. See chapter 4 for detailed feedstock analysis. No timber qualities that could have been used for construction purposes are used as feedstock. (§1.1.2-4)
- The facility does not have an EBC certificate. Compliance with comparable conditions is outlined in this report, and all process emissions have been calculated in the LCA. Using the Cradle-to-gate approach, the following emissions have been accounted for: Harvesting, transport and grinding of feedstock, pile emissions, stack emissions, transport and handling of the biochar on site.
- The power plant is 100% biomass-fired. Fossil fuels are not employed. Pyrolysis gases are captured and combusted within the reactor for the generation of steam and electricity. (§1.1.6-8)
- The produced biochar has a high, stable carbon content. The lab analysis demonstrated a carbon content of 81,1% in the dry state, which corresponds to the gross capture of 2,974 Kg/Kg (§1.1.9)
- The produced biochar has a H/Corg molar ratio of 0.33, well below the 0.7 threshold (§1.1.10)
- The O/Corg molar ratio is calculated to be 0.09, well below the 0.4 threshold. (§1.1.11) and below 0.2, meaning that the 2,5% buffer is used in the CORC Calculation.
- Freres Lumber has implemented appropriate measures to ensure the safe storage and transport of the biochar. They can provide a material safety data sheet for transport and storage. (§1.1.12)
- The potential for methane emissions from stockpiling of feedstock has been considered in accordance with the criteria of the EBC.[2] The site has a storage capacity of feedstock for 4-5 days, far below the one-month threshold.
- The potential for fugitive release of syngas from pyrolysis is considered negligible. It has been assumed that all emissions are included in the data that is delivered to the EPA, (a statutory

[1] https://www.european-biochar.org/media/doc/2/positivliste_en_2021.pdf
[2] https://www.european-biochar.org/media/doc/2/c_en_sink-value_2-1.pdf

requirement). Emissions of CH_4 and N_2O have been calculated using standard factors from the EPA.[3]

3. System diagram

Figure 2 shows the co-generation system Freres uses to convert the feedstock to outputs; steam for the electricity turbine, the veneer drying process and block conditioning process, and biochar. Fly ash, fugitive heat from the exhaust, and boiler rock are also system outputs. A precipitator separates fly ash from the exhaust stack. The boiler is a 7.5 MW rotary bed reactor where the bark and chipped biomass undergo a rapid pyrolysis process, resulting in syngas combustion. The ash/char combination is sieved through a trommel screen before storage and transportation.

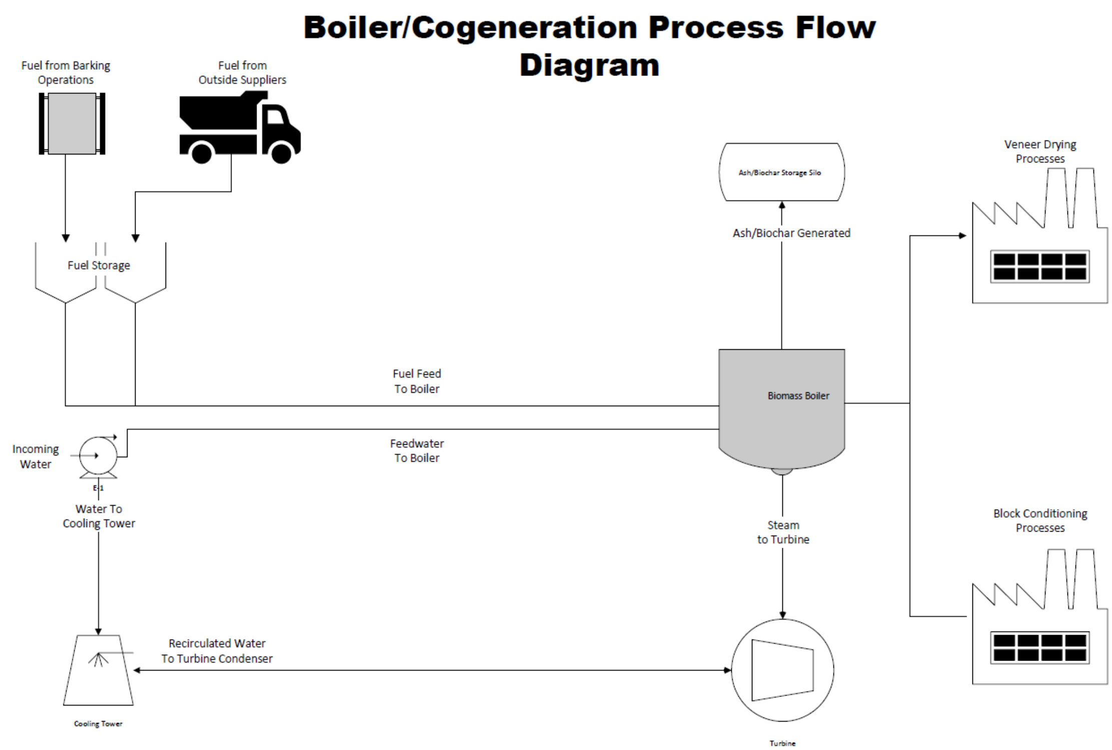

Figure 2 System diagram. Source: Freres Lumber inc.

Figure 3 (below) details the energy balance of the system during the period 1.10.19 – 31.3.21. Low-temperature heat cannot be captured and is exhausted.

[3] https://www.epa.gov/sites/production/files/2020-09/documents/1.6_wood_residue_combustion_in_boilers.pdf

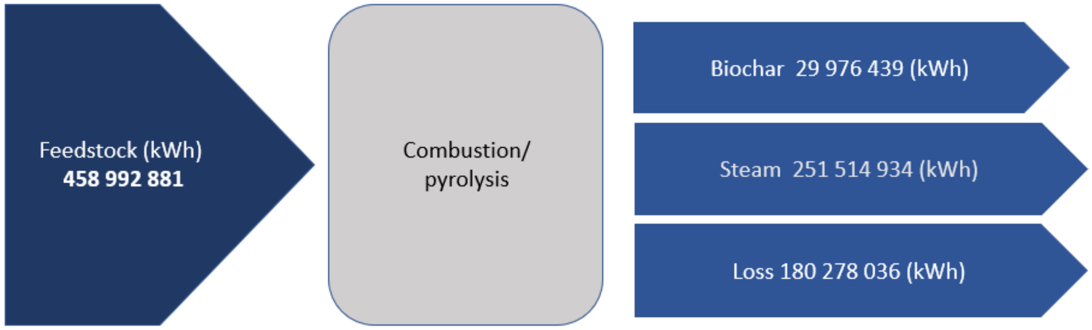

Figure 3 Energy inputs and outputs in KWh 1.10.2019 – 31.3.2021

4. Feedstock Analysis

Freres Lumber uses approximately 61 000 US tons of feedstock for the boiler per year. They use materials sourced from a wide range of local suppliers and bark and other waste from the on-site manufacture of timber products as feedstock.

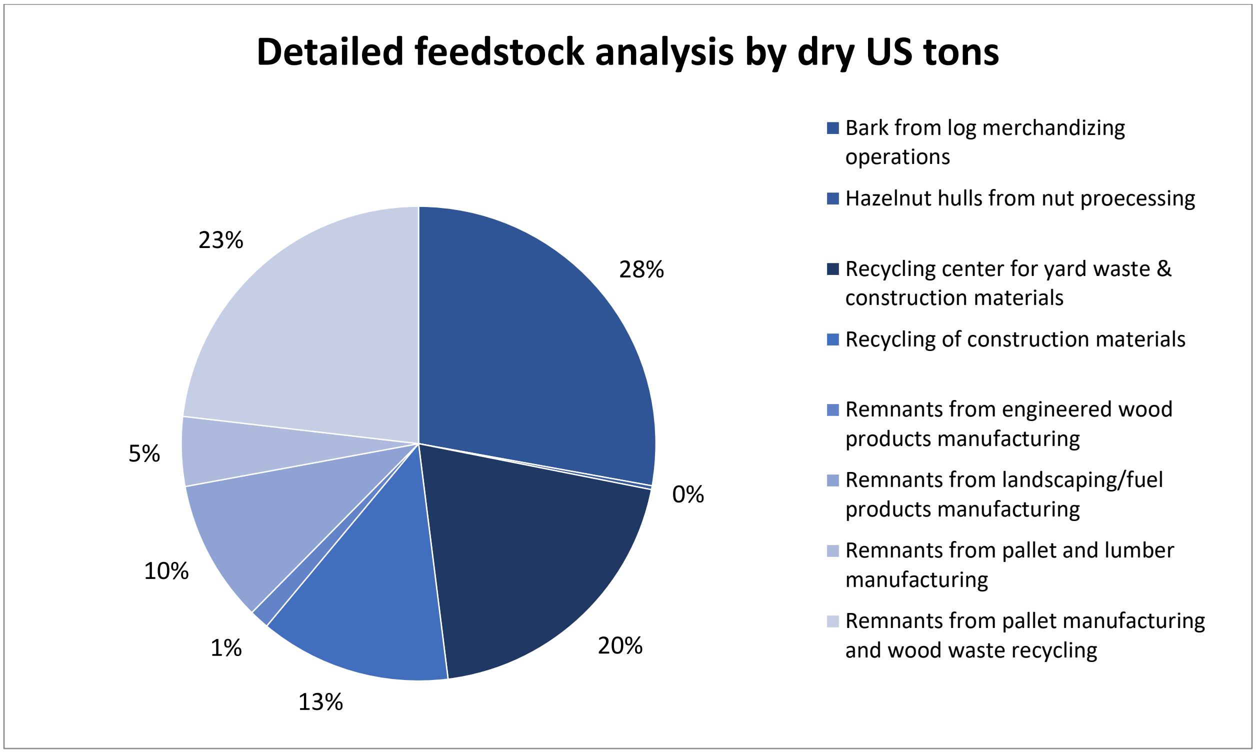

Figure 4 Detailed feedstock analysis. % share.

Figure 4 shows the distribution of feedstock during the period 1.10.2019-31.3.2021 organized by detailed categories. Except for bark from Freres Lumber's operations, the other feedstocks are waste from agriculture, food processes or recycling. Transport distances for external fuels are short. The weighted average transport distance for the external fuel suppliers is 44 km.

Figure 5 (below) shows the distribution of feedstock during the period 1.10.2019-31.3.2021, organized by the categories used by the EBC[4] to determine sustainable feedstock for biochar production.

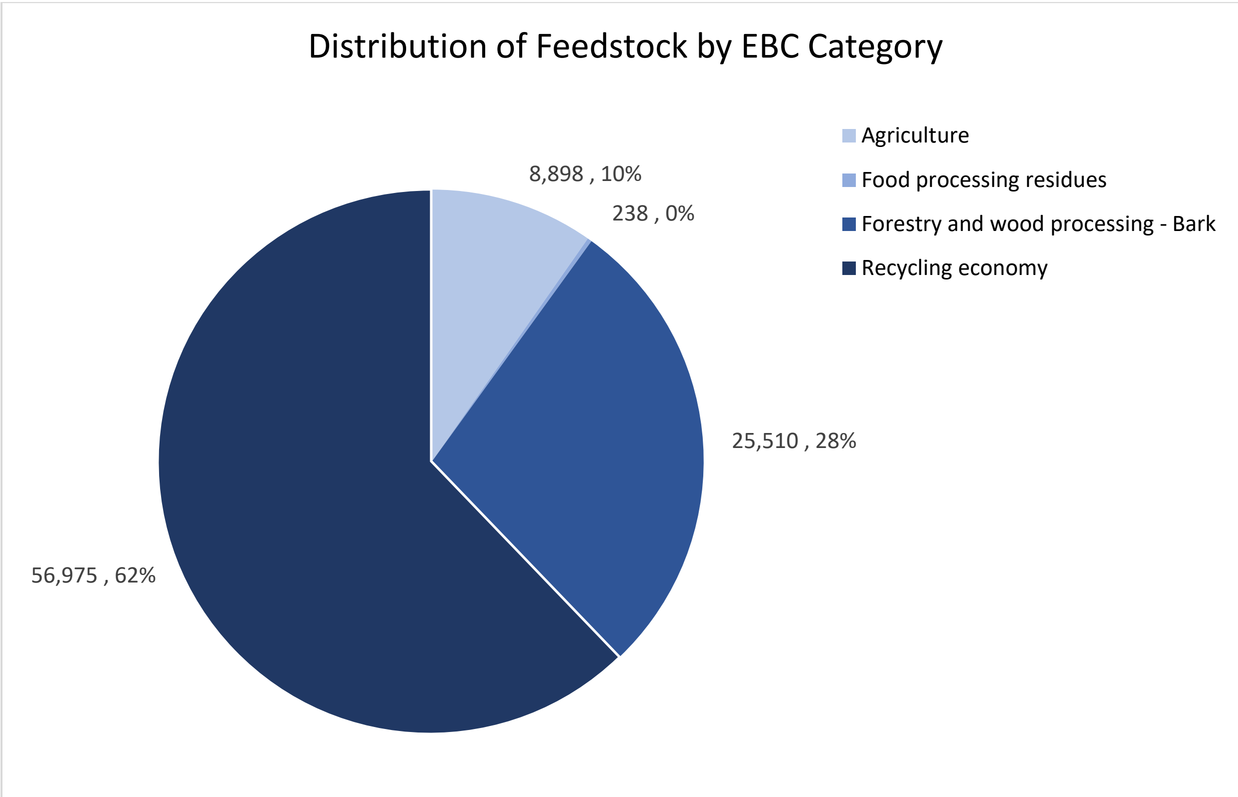

Figure 5 Feedstock categorized according to EBC feedstock positive list. Dry US tons and % share.

All food processing residues, such as nutshells, and all recycling economy categories such as pallet grindings and reprocessed construction materials are automatically eligible for CORC certificates, as is bark. As evident from figure 4, the other forestry and wood feedstocks are predominately waste products. 100% of the feedstock at Freres can be placed within an accepted category.

[4] https://www.european-biochar.org/media/doc/2/positivliste_en_2021.pdf

5. Life Cycle Assessment

Lifecycle assessment (LCA) is an internationally accepted method to analyze complex impacts and outputs of a product or process and the corresponding effects they might have on the environment. LCA is an objective process to evaluate a product's life cycle by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials uses and releases on the environment, and to evaluate and implement opportunities to effect environmental improvements. LCA studies can evaluate full product life cycles, often referred to as "cradle to grave", or incorporate only a portion of the products life cycle, referred to as "cradle-to-gate", or "gate-to-gate". This study can be categorized as a cradle-to-gate LCA as it considers the impacts from forestry to shipping of the biochar.

The LCIA process characterizes and assesses the effects of environmental releases identified in the LCI into impact categories such as global warming, acidification, carcinogenics, respiratory effects, eutrophication, ozone depletion, ecotoxicity, and smog.

a. Goal and scope

The Global warming impact category is the only one considered in this report. A calculation of the carbon footprint of the biochar has been carried out in accordance with ISO 14044 and 14067, where applicable. The declared unit is 1 metric ton (1000 Kg) of biochar. The primary goal is to generate a cradle-to-gate product global warming footprint, documenting the carbon capture of the biochar produced at Freres Lumber. The primary audience for the results of this report is Freres Lumber Company, Puro.Earth market place, third party auditors. The report does not include product use and end of life phases, which are required for comparative assertions relative to substitute products.

b. System Boundary

The system boundary is defined using the "cradle to gate" approach A1-A3, figure 6. Harvesting, transport and handling of feedstock, pile emissions, stack emissions, transport of biochar have been included in the system boundary. After production, emissions from the transport of the product to the destination are the customer's responsibility. Capital equipment, transportation of employees, construction, maintenance, use of the biochar have been excluded from the boundary. The system boundary of this study accords to the Puro earth requirements.

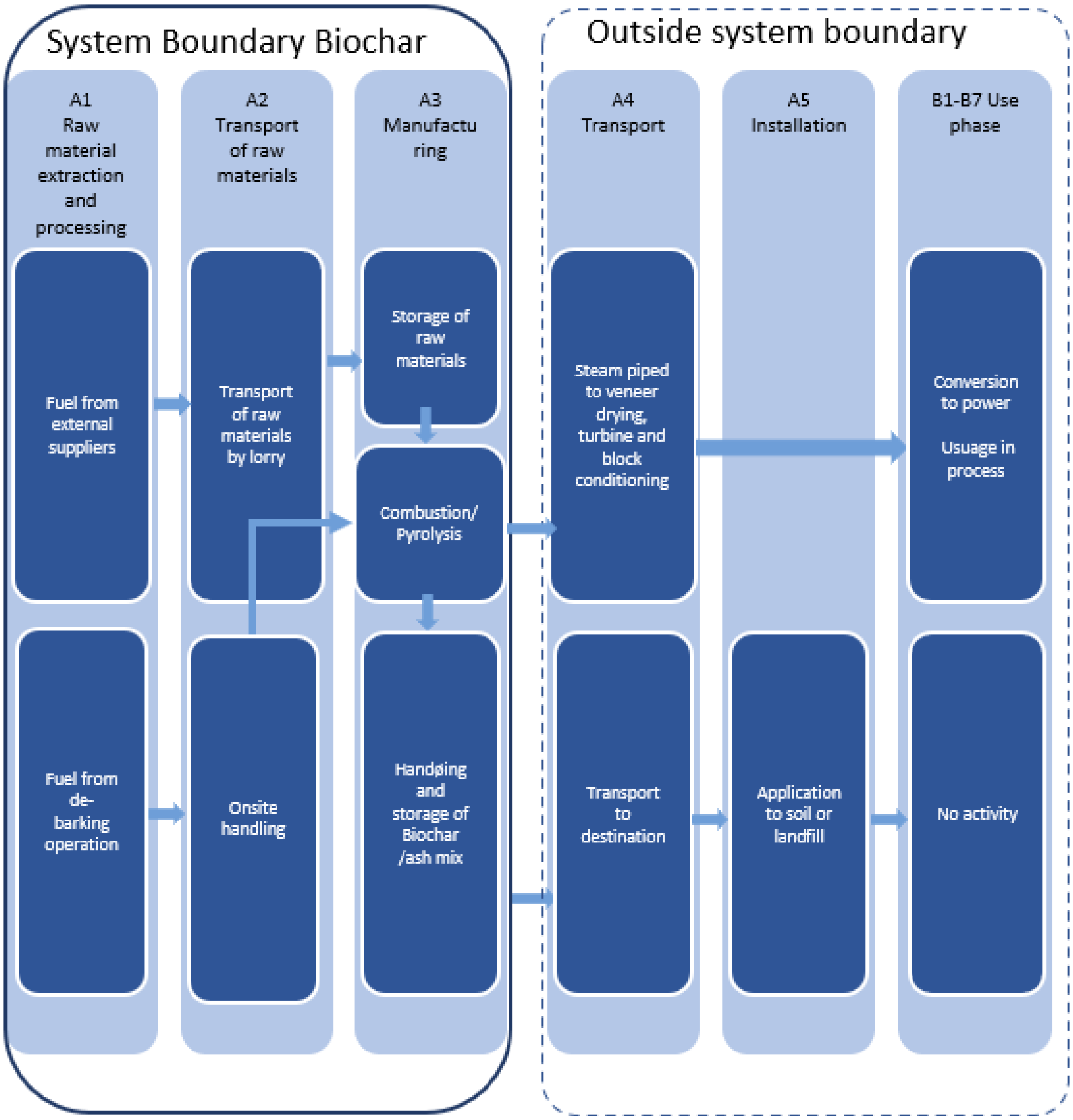

Figure 6 System boundary

c. Carbon content calculation

The CO_2 removal potential of the biochar is derived using the formula:

The quantity of biochar produced and sold to non-energy users is multiplied with the carbon content of the biochar, taking into account the buffer for uncertainty, from which we subtract the emissions from the biochar production.

Afterwards, from the production process variables, the emissions from harvesting the raw material, including the possible loss of sinks, and the emissions from the transport of the raw material(s) to the production facility are deducted. Finally, the result is the amount of available CORCs.

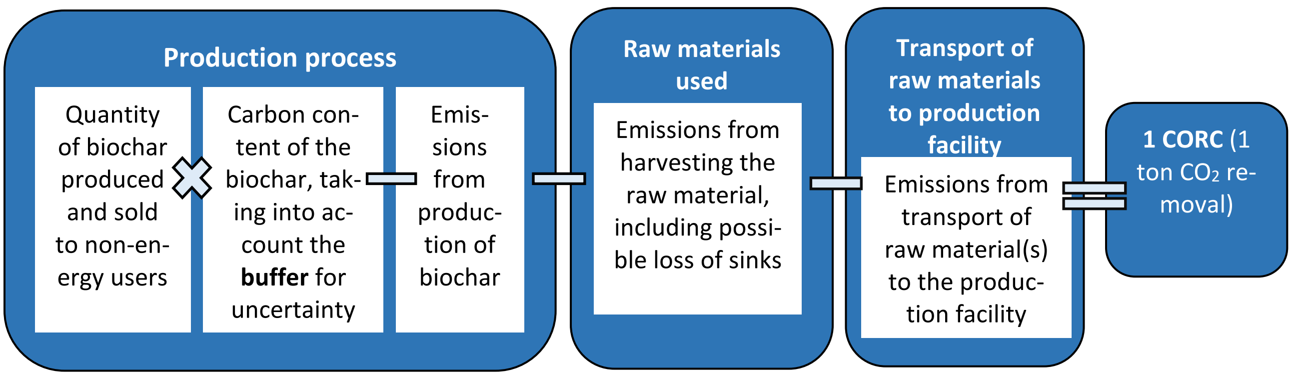

Figure 7 CO_2 removal formula[5]

d. Quantity of biochar

7059 metric tons of biochar/ash mix were produced and shipped from 1st October 2019 – 31st March 2021. The data source is Frere's "Ash Shipment" records, detailing the daily truck shipments and the destination. The trucks are weighed in and out to determine the mass transported. Biochar is shipped as-is from the combustion chamber. It contains both biochar and ash. The physical analysis of the biochar was performed on char that was sieved with ¼" inch mesh. This process removed 48,6% of the material is predominantly ash. The remaining 51.4% is the biochar that the laboratory tested. The total mass of shipped ash/biochar has been adjusted accordingly, which means that the mass of ash has been deducted. Thereby, only 51.4% of the total shipped mass of ash/have been counted as biochar. The moisture content of the biochar was measured at 10.2%. To ascertain the dry weight of the biochar, the moisture content has been deducted. The remainder, 3252 metric tons of dry biochar, has been used for the purposes of this study.

e. Carbon content

The carbon content of the biochar, is 81,1% in the dry state. The stability of the carbon content can be ascertained using the molar O/Corg ratio. The maximum oxygen content was calculated by excluding other

[5] Puro CO_2 removal marketplace general rules, annex 1

elements, and the maximum molar O/C ratio of 0.09 determined. The lower safety buffer of 2.5% from the Puro methodology is therefore applied. The stable CO_2 content, taking into account the safety buffer, is 2,899 metric tons per ton (1 declared unit) of output.

f. Emissions from harvesting raw materials. (EPD Module A1)

Analysis shows that 28% of consumed feedstock is from forestry residues, in practice bark from the lumber operations. The remaining 72% are waste products. For raw forestry materials, the emissions from the forestry and harvesting of the materials have been calculated using the dataset "Bark chips production, softwood, at sawmill (Reference product: bark chips, wet, measured as dry mass) from Ecoinvent 3.6, 2021. According to the allocation principles of ISO 14067[6], emissions have *not* been allocated to waste products: As a consequence, for waste feedstocks such as nutshells, pallet grindings, and construction waste, emissions related to raw materials are not allocated (the transport emissions have been considered).

Using the allocation key of 28% for forestry residues, the total CO_2e emissions linked to the harvesting and extraction of feedstock has been calculated at 23 142 metric tons. The emissions allocated to *biochar* from feedstock harvesting is 53.5 metric tons Kg CO_2e.

The total for module A1 (raw materials) is **16.4** Kg CO_2e per unit of biochar.

g. Pile emissions (EPD Module A1)

The feedstock is either delivered in chipped or ground form or is de-barked on-site as part of the lumber production process. When such products are stored in moist conditions, uncontrolled self-heating occurs. In this process, the biomass is microbially degraded, similar to composting, which results in the loss of carbon as CO_2. Depending on the biomass and storage conditions, emissions of CH4 and N2O may also occur.[7]

The EBC, in their C-Sink guidelines, have published a methodology for approximating the pile emissions, which has been used in this study. Accordingly, for the storage of sawdust and wood chip with over 25% moisture content for over 1 month, 1.5% of the Carbon content is assumed to be released in the form of methane (CH4). All feedstock is ground, so this calculation is used for all feedstocks.

Inventory analysis confirms that the average feedstock holding time < 5 days. No pile emissions have therefore been calculated.

h. Transport emissions (EPD Module A2)

For the 72% of the boiler feedstock that gets transported to the site in ground form, greenhouse gases emissions from feedstock transport have been calculated using the factor 0.32 Kg CO_2e/tonkm. The factor

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[7] ISO 14067:2018 "Greenhouse gases – Carbon footprint of products -Requirements and guidelines for quantification"

[8] https://www.european-biochar.org/media/doc/2/c_en_sink-value_2-1.pdf

is from a GREET LCA from 2018/2019 from the Oregon lumber industry and is highly representative. The weighted average distance travelled from the suppliers is 44 km. In total, the feedstock transport emissions per unit of biochar are 143 metric tons of CO_2e.

Total transport emissions (EPD Module A2) are **44.2,4** kg CO_2e per unit of biochar.

i. Emissions from the manufacturing of the biochar (EPD Module A3)

The powerplant is 100% biomass-fired. From a life cycle perspective, biomass power production is considered to be carbon-neutral. CO_2 emissions are therefore not attributed to the biochar. Methane (CH4) and Nitrous dioxide (N2O) are powerful greenhouses gases, the emissions of which are included in biomass-based LCA calculations. The exhaust gases that are directly emitted from the boiler are measured are reported to the EPA in accordance with the Oregon Title V Operating Permit. Emissions of CO, NOx and particulate matter were within limits, according to the testing carried out by Bison Engineering, 1400 11th Avenue, Suite 200 Helena, MT an accredited emissions tester. Emissions of greenhouse gases are not in the scope of the testing required by the State. Emissions factors for greenhouse gases, CH4 and N20 are taken from the EPA standard air pollution factors for wood residue boilers[8]. The total exhaust emissions from the boiler is calculated to be 3421 metric tons CO_2e using the GWP 20-year values from the IPCC 2019 update of 56 for CH4 and 280 for N_20. These emissions have been allocated to the biochar using the allocation key for the biochar output. The direct emissions allocated to each unit of biochar is 103 kg CO_2e.

Emissions related to diesel and gas consumption of equipment used on the site has been calculated and allocated to the biochar output using the energy allocation key. Freres has considerable experience and can accurately estimate the hours of usage and fuel consumption to calculate GHG emissions. Emissions from equipment fuel consumption are 12 kg CO_2e per ton of biochar.

The boiler uses electricity from the grid for its operation. In total, 11.2 GWh during the study period. Using an emissions factor for the energy grid in the State of Oregon, the emissions from power consumption are 81 kg CO_2e per unit of biochar.

Total emissions related to the manufacturing of the biochar (EPD Module A3) are 196 kg CO_2e per unit of biochar.

[8] https://www.epa.gov/sites/production/files/2020-09/documents/1.6_wood_residue_combustion_in_boilers.pdf

j. List of emissions factors

Module	Inputs	LCI Data source	Geography	Year	Data Quality Assessment
A1	Bark Chips	Ecoinvent 3.6	Global	2019	Very good
A2	Transport of wood chips.	LCA study 2018	Oregon, USA	2019	Excellent
A3	Electricity. Oregon state mix	Ecoinvent 3.6	Oregon, USA	2018	Excellent
A3	Propane	Ecoinvent 3.6	Global	2019	Good
A3	Diesel	Ecoinvent 3.6	Global	2019	Good

k. Allocation and cut-offs

Allocation is the method used to partition the environmental load when several products or functions share the same process. The captured outputs from the boiler are steam and biochar. The relative energy content of the biochar (13 000 BTU/lb) has been used to allocate the feedstock and exhaust emissions to the multiple co-product outputs. Given that a large quantity of energy is lost as fugitive heat, the allocation to the biochar is conservative.

If the mass/energy of a flow is less than 1% of the model flow's cumulative mass/energy, it may be excluded, provided its environmental relevance is minor. All energy and mass flows from the primary data have been allocated to the LCA for biochar. Material and energy inputs related to the construction of the facility have been excluded from the system boundary.

Transport emissions for the timber that is de-barked and used for timber and lumber production have been allocated to the primary purpose, not to biochar.

6. Results

The emissions from the production process of one unit (one metric ton) of biochar are 0.257 metric tons. Figures 8 and 9 show the breakdown into the process stages.

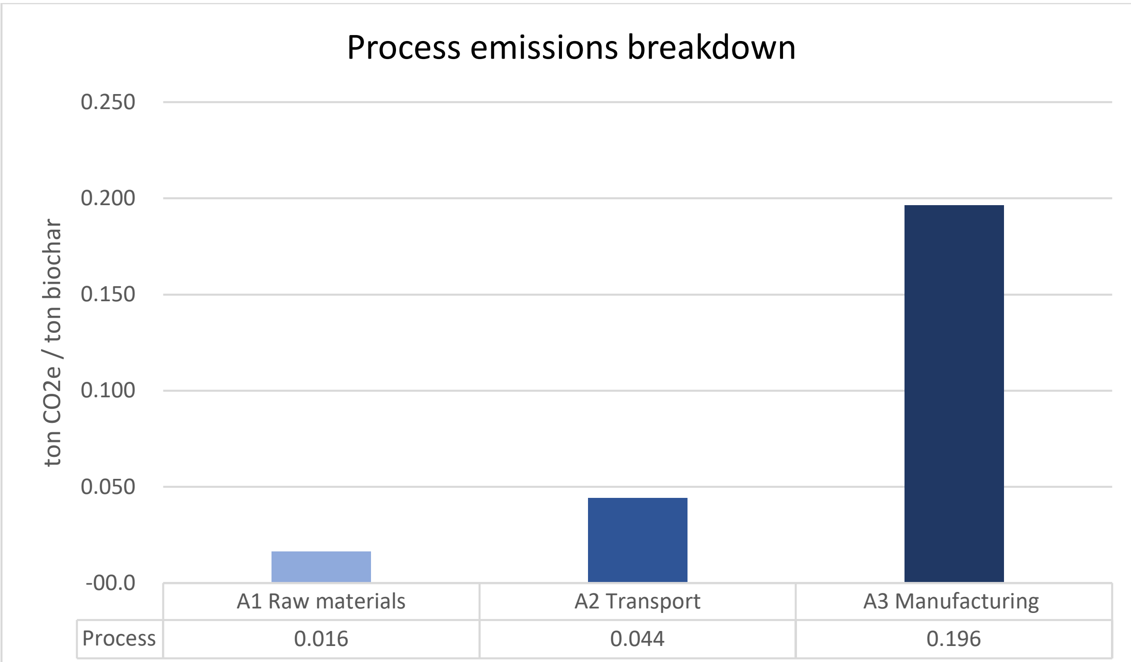

Figure 8 Process emissions in metric tons CO_2e from materials, transport and manufacturing A1-A3. Metric tons CO_2e

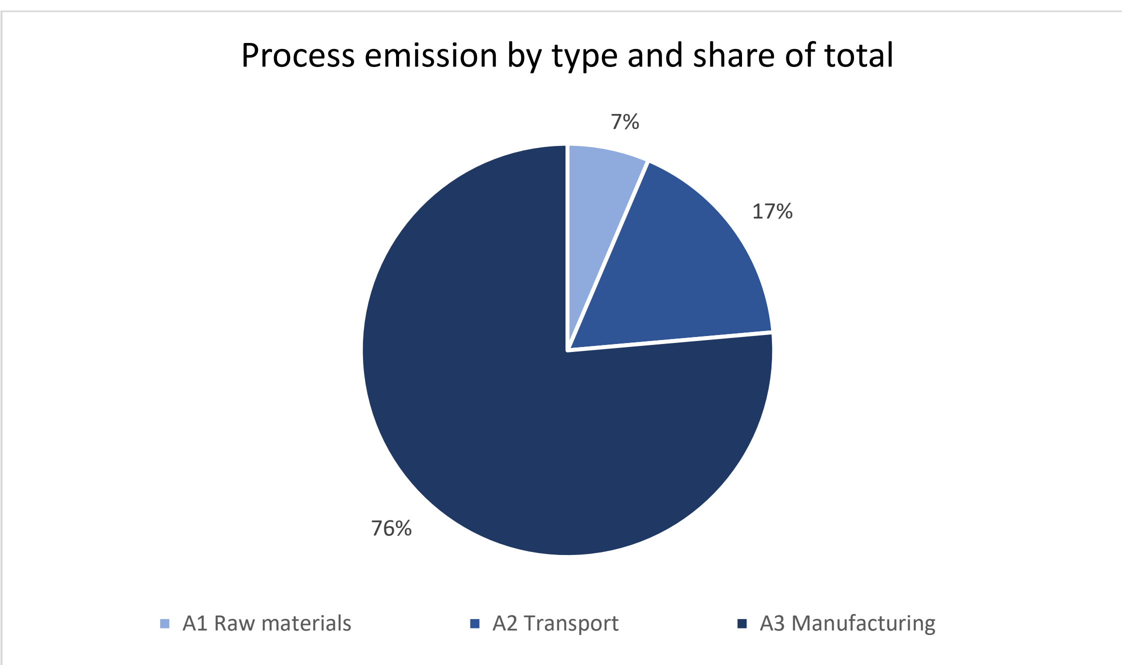

Figure 9 Process emissions by type and share of total.

From the laboratory analysis of the biochar's physical qualities, the gross sequestration of CO_2 is 2.899 metric tons/unit. Using the formula in figure 6, after the emissions from the process, 0.257 tons/unit has been deducted, the net CO_2 sequestration per metric ton of biochar, and the factor used to calculate Puro CO_2 removal certificates (CORCs) is 2.64.

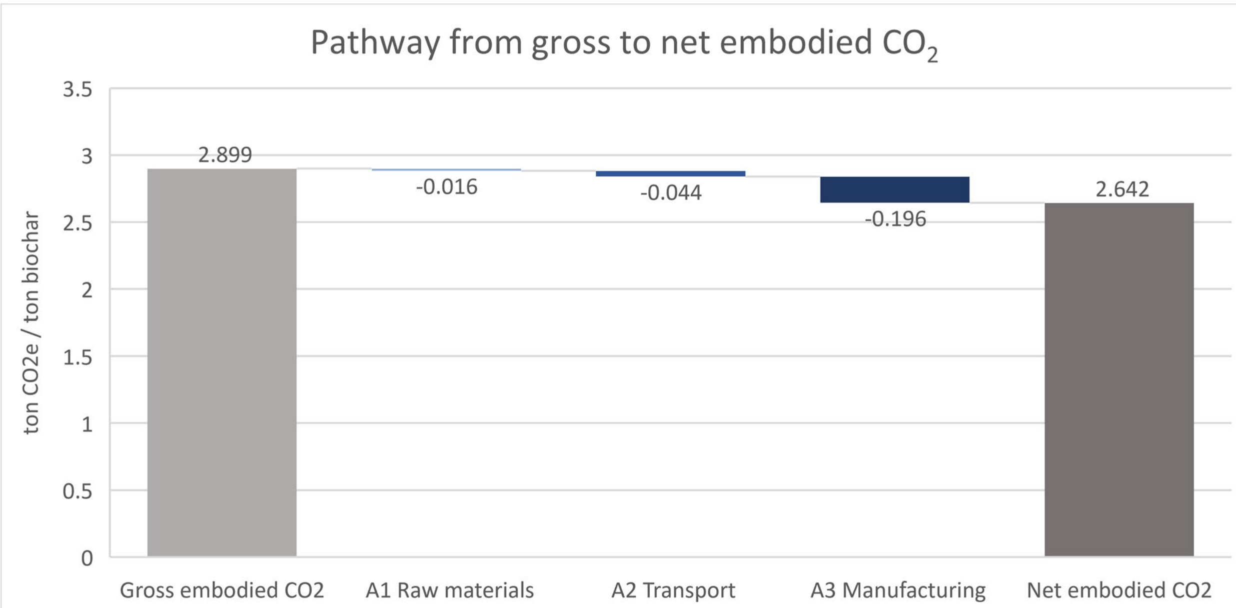

Figure 10 Pathway from gross to net embodied CO_2. Metric tons CO_2e

For the output of biochar for the period 1st October 2019 – 31st March 2021, 3252 dry metrics tons of biochar, Freres Lumber is eligible for the issuance of **8593** CORCs.

Due to uncertainty arising from the following factors: the use of an industry-standard value to allocate the energy content, interpolation of steam volumes for 2019, the potential impact of variance in moisture content and the relative masses of biochar and ash, an additional safety margin of 5% should be applied to the output volumes, reducing the number of CORCs for the period to **8163**.

7. References and links

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https://www.european-biochar.org/media/doc/2/positivliste_en_2021.pdf

ISO 14067:2018 "Greenhouse gases – Carbon footprint of products -Requirements and guidelines for quantification"

ISO 14064--:2019 "Greenhouse Gases Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gases and removals"

https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

https://ghgprotocol.org/sites/default/files/Stationary_Combustion_Guidance_final_1.pdf

https://www.epa.gov/sites/production/files/2015-07/documents/fugitiveemissions.pdf

https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-28-v1.pdf

Pelaez-Samaniego , Perez , Ayiania, Garcia-Perez, (2020) "Chars from wood gasification for removing H2S from biogas" Science Direct.

https://www.epa.gov/sites/production/files/2020-09/documents/1.6_wood_residue_combustion_in_boilers.pdf

8. Supporting Documentation

The following supporting documentation is available in digital format:

1. Excel spreadsheet "LCA Calculation Freres Lumber v1.0", Accend ©