Carbon Footprint Analysis of StalkMarket Bagasse Tableware

Executive Summary

The threat of global climate change has spurred developments in many new sectors, including development of renewable energy sources, sequestration of atmospheric carbon, and the creation of technologies to increase efficiencies for pre-existing processes. Concurrent with these shifts is the need for more accurate greenhouse gas (GHG) emission accounting. Proper accounting is required for any cap-and-trade or carbon tax system that aims to decrease GHG emissions.

While such regulatory action may not take effect for a few years, many companies now see the benefit of beginning to catalog the GHG emissions for their products and for their organization. The benefits of this accounting include being in-line with regulatory requirements when they take effect, taking proactive steps to decrease GHG emissions in the short term, and for many '*green*' products, to ensure that their claims are substantiated by measurable and transparent analysis.

The goal of this project is to catalog the carbon footprint of one such green product, StalkMarket's bagasse derived plates and bowls. Bagasse is traditionally a waste product in sugar manufacturing from sugarcane, but can now be used in a manner analogous to wood pulp for formation of paper products. Since these products utilize a secondary waste material instead of raw petrochemical feedstock, or virgin wood, they are inherently considered to be more environmentally friendly.

Asean Corporation, maker of StalkMarket Products, has contracted Blue Tree Strategies to complete this carbon footprint analysis. It is a completely voluntary effort that enables Asean Corporation and its customers to identify the carbon footprint of each bagasse item and subsequently compare that footprint to other similar products.

Finally, it is essential to note that the analysis and conclusions presented in this study are unique to the supply chain and manufacturing processes of StalkMarket Co. brand of bagasse products only. Blue Tree Strategies and StalkMarket Co. both support carbon labeling standards to advance climate change initiatives and a more sustainable economy; we encourage others to refer, share and build upon the methodologies and analysis used in this report.

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About the Author

Primary research and analysis for this report was performed by Professor Mike Marsolek. Mike holds a PhD in Chemical Engineering from Northwestern University, is currently a Professor of Civil and Environmental Engineering at Seattle University and serves as an adviser to Blue Tree Strategies.

About The Companies

For more information about Blue Tree Strategies, visit
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For more information about Asean Corporation, visit
http://www.stalkmarketproducts.com

1 – Background on Bagasse Utilization and Carbon Accounting

1.1 - Introduction

The carbon footprint (or carbon balance) analysis requires a detailed understanding of the production process for the bagasse products, together with specific data on inputs and outputs from each step therein. Examples include electricity requirements for manufacturing plants, as well as transportation distances and vehicle fuel economy. Once gathered, this information must be converted into useful units, namely equivalents as mass of carbon dioxide (CO_2) emitted. This is accomplished through standardized procedures utilizing emission factor (EF) data from reputable sources, including the Intergovernmental Panel on Climate Change (IPCC), Greenhouse Gas Protocol (GPG), the United States Environmental Protection Agency (USEPA), and the Department for Environment, Food, and Rural Affairs (DEFRA) of the UK. Finally the information can be compiled and expressed on a per product basis, providing the end goal of use to the consumer. Each of these steps is discussed in detail below.

1.2 - Bagasse Product Manufacture

Before any material balance can be accomplished the system boundaries must be defined. Defining system boundaries requires a clear understanding of the production process. This is important to ensure an accurate accounting of all CO_2 emissions in the process. There are standardized procedures for defining these boundaries for countries performing GHG Inventories via the IPCC, or for companies performing company-wide GHG inventories via the Greenhouse Gas Protocol. There are fewer standardized practices for carbon footprint analysis of an individual product (GHG Protocol is developing product line standards for 2010), however the general procedure used here is similar to a company-wide GHG inventory.

In order to define boundaries for bagasse product manufacture, the steps involved in turning atmospheric CO_2 into sugarcane, sugarcane into bagasse, and bagasse into tableware, must be understood. As with all plant-like photosynthetic processes, carbon dioxide is used as the carbon source. The environmental benefit of this process is obvious, since it removes CO_2 from the atmosphere and fixes it into plant biomass. Therefore the original carbon source for bagasse products is atmospheric CO_2, whereas for typical plastic tableware the original carbon source is petrochemicals, which transform carbon that was fixed back into atmospheric CO_2 without the concurrent sink of carbon associated with photosynthesis.

Sugarcane is a perennial grass grown in varying climates. The crop duration ranges from 12 to 18 months in tropical and sub-tropical regions (Liu And Bull, 2001). Sugarcane grows with typical yields of 66,000 kg cane/hectare·year (wet basis, Beeharry 2001). Of this sugarcane biomass, 30% is typically bagasse. The composition of raw bagasse is 49% moisture, 49% cellulose, pentosan, and lignin fibers, and 2% soluble solids (Chiparus 2004). The amount of sugar, lignin, and lignin-like compounds increases with plant age. After harvest, sugarcane is processed to extract the sugar and molasses fractions, and the waste biomass is called bagasse. Thus the bagasse fraction of sugarcane is responsible for some amount of carbon fixation, which must be accounted for in our analysis.

Conventional use of bagasse includes electricity generation through burning or re-application to the field (Mohee and Beeharry, 1999). When utilized for product manufacture, the accumulated bagasse is taken from the sugarcane plantation to the processing mill, where moisture is removed and it is pressed into fiberboard sheets. There is nearly 100% transformation of raw bagasse into fiberboard sheets, with any losses considered immaterial. The overall flowchart is shown in Figure 1.1. The mill utilizes electricity, direct burning of coal, and generates wastewater, all of which contribute to carbon dioxide emissions. Bleaching agents are also added and while they contribute to the environmental burden of the process, they are considered immaterial from a greenhouse gas point-of-view.

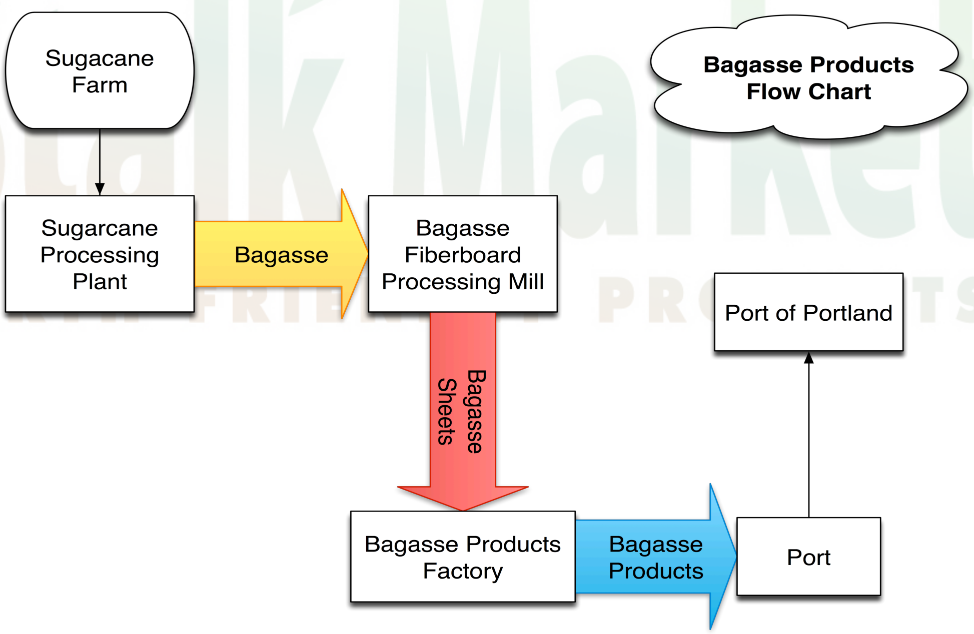

Figure 1.1: Operational flowchart for bagasse tableware production.

Upon production, the fiberboard sheets are transported by diesel truck to the processing factory (the 'factory'). This transportation contributes to carbon dioxide emissions. In the factory, fiberboard sheets are transformed into a variety of products, including plates and bowls. The fiberboard is combined with steam/water, forced into molds, pressed into the desired shape, and coated with a water-repellent surfactant (Zonyl 9434, DuPont, Wilmington, DE, USA). Any waste trimmings from the production are recycled back to the beginning of the process, resulting in nearly 100% transformation of the bagasse fiberboard into products. Carbon emissions come from electricity, coal or natural gas burning for steam generation, and wastewater treatment. The zonyl contribution is considered immaterial for this analysis.

The products are then packaged, trucked to a shipping port, and shipped to Portland, OR, or Los Angeles, CA. The production processes occur in China and Thailand, although only the Thailand process is reported here due to more rigorous reporting of information.

1.3 - Carbon Accounting Practices

The widespread use of GHG inventories is a relatively recent phenomenon, and as such the standards used to produce them are evolving as well. However the basis for these standards are conventional accounting principles, since the apportioning of ownership and responsibility is similarly applicable to the fluid movement of money and worth as it is to carbon.

National GHG inventories have existed the longest in common practice, and include national estimations of GHG sources such as electricity usage, fossil fuel consumption, transportation, and manufacturing, and sinks due to land uses such as forestry.

Because many companies sub-contract or purchase materials from other companies for use in their applications, the accounting of GHG emissions can be challenging. Establishing ownership of the emissions in a consistent manner to avoid double-counting is necessary to ensure an accurate representation of the entire process across different companies. In this context the proper allocation of carbon emissions becomes cumbersome, and traditional accounting practices are used. The guidelines in the Greenhouse Gas Protocol's Corporate Standard (the 'Standard', 2004) are used as the basis for this report.

Based on the Standard, operational boundaries and carbon sources and sinks are identified as shown in Figure 1.2. The emissions are grouped into three scopes as identified in the standard:

Scope one contributions to GHG emissions include "direct emissions from sources controlled by the company", such as boilers, furnaces, and vehicles. For StalkMarket products this includes the use of coal and natural gas directly burned during fiberboard and product manufacture, transport of materials and products via diesel trucks and marine shipping.

Scope two contributions arise from off-site electricity generation. This applies to the sugarcane mill where bagasse fiberboard is produced, and the factory where fiberboard is transformed into usable products.

Scope three contributions include indirect costs, such as transportation, carbon sequestration, and inefficiencies in electricity transfer. For this project tier three contributions include carbon sequestration into the bagasse fraction of sugarcane biomass, and subsequent treatment of wastewater at municipal treatment facilities.

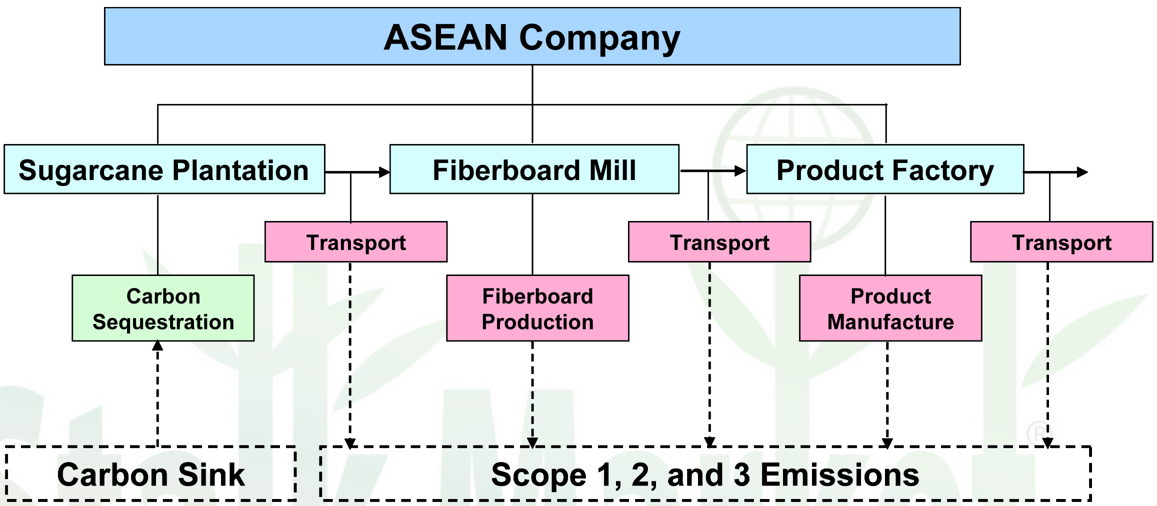

Figure 1.2: Carbon sources and sinks for bagasse tableware manufacturing

It should be noted that no emissions other than CO_2 were accounted for in this analysis because the contribution of the remaining five GHGs as identified by the Kyoto protocol -- CH_4, N_2O, SF_6, hydrofluorocarbons and perfluorocarbons -- do not contribute significantly to the gas emissions evaluated here. Therefore only CO_2 emission factor data is used in this analysis.

2 – Calculation Methods, Emission Factors, and Raw Data

2.1 - Emission Factor Determination

The use of accurate emission factors (EFs) is central to an accurate carbon footprint analysis. Emission factors are used to convert materials from conventional units, such as electricity in kWh or transport in km, to equivalents as CO_2. In this way, the contribution to the total GHG production from various different pieces of the production process can be added together to determine the total CO_2 footprint.

Emission factors will vary regionally, and on the technology used. For instance, a diesel truck in China may not produce the same amount of carbon dioxide per unit of fuel used as a diesel truck in the United States, due to regulatory or technological differences in the areas. Furthermore, the quality of the diesel fuel is not the same and so would affect the amount of carbon emitted. This is true for all different GHG emissions, including electricity generation and direct coal and natural gas burning for heat, which are included in this analysis. Thus it is best to have emission factors for your specific region, but when not possible global EFs can be used. As the regulation of GHGs evolves so too will the accuracy and reporting of quality EF data.

There are multiple sources of EFs available, with the predominant being the IPCC Emission Factor Database (EFDB). This database lists emission factors for many different GHG sources in a variety of units and from multiple geographic locations. A multitude of technical reports have been published by the USEPA and DEFRA, together with several different governmental agencies that measure and report emission factors, including the United States Department of Energy. The Greenhouse Gas Protocol also compiles EF data for many different corporate and industrial sectors, which was also used in this analysis. However, while the wide variety increases the opportunity to find an EF, it also results in there being a wide range of reported EFs for a single source. Therefore when possible several sources were identified to obtain the most representative factors. The EFs are listed in Table 2.1 with their sources, as well as the magnitudes of emissions for stationary combustion of coal and natural gas via the Greenhouse Gas Protocol worksheet, “Greenhouse Gas Emissions From Stationary Combustion”.

Table 2.1: Emission Factors Used in Thailand Analysis

Source	Magnitude	Units	Notes
Coal Electricity and Heat Generation - Thailand	0.729[a]	kg CO_2/kwh	2005 Reference
Wastewater Treatment	0.339[b]	kg CO_2/m^3	
Mobile Combustion - Diesel	2.75[c]	kg CO_2/L	Original value = 74100 kg CO2/TJ. Converted with factor from GHG Protocol Mobile Emissions Spreadsheet: 0.0371 GJ/L for diesel
Marine Shipping	0.0146[d]	kg CO_2/(short ton·miles)	
Coal Direct Burn	5335[e]	kg CO_2	Per 2 ton coal (amount used in fiberboard production)
Natural Gas Direct Burn	1938[e]	kg CO_2	Per 720 kg natural gas (amount used in product manufacture)

a – Greenhouse Gas Protocol, "Indirect CO2 Emissions from Purchased Electricity, Heat, or Steam". b – IPCC Emissions Factor Database (EFDB). c – 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2 – Energy, Chapter 3 – Mobile Combustion. d – Greenhouse Gas Protocol "CO_2 Emissions from Transport or Mobile Sources". e – Greenhouse Gas Protocol worksheet, "GHG Emissions from Stationary Combustion".

2.2 - Bagasse Production Information

Greenhouse gas reporting is still in its infancy for most companies worldwide. Therefore accurate accounting of emissions for greenhouse gases is challenging, particularly when subcontracting from multiple companies and when those companies are on a different continent. This can make independent validation impossible.

This is the reality for this project, and as such Asean Corporation attests to the accuracy and completeness of the Data used in this report. The information was gathered through an iterative process of formulating questions, sending those questions to representatives working with the mills or factories, and analyzing the answers. Gaps or inconsistencies were filled with another set of questions, until the answers were satisfactory. The necessary information on bagasse processing is presented below in Table 2.2.

Table 2.2: Raw data for bagasse tableware production used in this analysis.

Parameter	Magnitude	Units
Electricity in fiberboard production	60	kWh/ton bagasse
Wastewater Generated in Fiberboard Production	120	m^3/ton bagasse
Coal Directly Burned in Fiberboard Production	2	ton/ton bagasse
Transport to Factory from Mill - Diesel Truck	30	km (round trip, 30 ton bagasse per truck load)
Electricity in Product Manufacture	2418	kWh/ton bagasse
Natural Gas Directly Burned in Product Manufacture	720	kg LPG/ton bagasse
Wastewater Generated in Product Manufacture	3	m^3/ton bagasse
Transport to Port from Factory	440	km (round trip, 30 ton bagasse per truck load)
Transport to Port of Portland from Port in Thailand	12159	km

3 – Results and Discussion for Carbon Footprint Analysis

3.1 - Carbon Sequestration

Bagasse products are theoretically more environmentally friendly than their plastic counterparts because of the sequestration of atmospheric CO_2 by the sugarcane plants coupled with the use of an agricultural waste product as raw material, rather than petrochemicals or virgin wood. However, accounting for the amount of carbon fixed via photosynthetic processes can be difficult. The primary resource available is the *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 4, Agriculture, Forestry and Other Land Use*. This document outlines how to account for carbon sequestration into soils or forest biomass.

However, as with all carbon accounting, data specific to your individual process is preferred over general data. Fortunately there is significant work detailing the life cycle and energy requirements typical for sugarcane processing. Beeharry (2001) performed a detailed carbon balance for sugarcane bioenergy systems based on a sugarcane plantation on the island of Mauritius, and Mohee and Beeharry (1999) performed a life cycle analysis on the same system. These reports detail the carbon flows from sequestration to cultivation and harvesting, transportation, and conversion of the cane into products. The carbon content is broken down by fraction, and includes sugar, molasses, filter cake, cane tops and leaves, trash, root system, and bagasse. This research indicates 18,114 kg of CO_2 are sequestered into the bagasse fraction per hectare per year. The typical cane yield is 66,000 kg cane/(hectare·year), of which 30% is bagasse (or 19,800 kg bagasse/ha·yr) on a wet basis. The dry fraction of bagasse amounts to 9900 kg bagasse/(ha·yr). The dry fraction should be used in the analysis since water does not contribute to carbon sequestration, and all subsequent calculations are on a dry basis as well. Therefore, the mass of carbon sequestered per mass bagasse is 1.830 kg CO_2 sequestered/kg bagasse used.

The carbon emitted during sugarcane processing from natural gas, diesel, coal, and electricity usages is equivalent to 1191 kg CO_2/(ha·yr) (Beeharry 2001). Attributing the same 30% of this responsibility (357 kg CO_2/ha·yr) to bagasse (9900 kg bagasse/ha·yr) results in a CO_2 emission of 0.036 kg CO_2 emitted/kg bagasse used. Therefore, the net CO_2 uptake per kg of bagasse is 1.794 kg CO_2 sequestered/kg bagasse used (or ton CO_2/ton bagasse used). These results are summarized in Table 3.1.

Table 3.1: Carbon dioxide emitted and sequestered, attributable to bagasse during sugarcane growth and processing.

CO_2 Sequestered in Total per Hectare per Year	58,172 kg CO_2
CO_2 Sequestered in Bagasse per Hectare per Year	18,114 kg CO_2
CO_2 Emissions in Total per Hectare Processed per Year	1191 kg CO_2
CO_2 Emissions Attributable to Bagasse per Hectare Processed per Year	357 kg CO_2
Bagasse Produced per Hectare per Year	9900 kg Bagasse
Net CO_2 Sequestered per kg Bagasse	1.794 kg CO_2/kg Bagasse

3.2 - CO_2 Emissions From Product Manufacture

Using the emission factors in Table 2.1 and the process information in Table 2.2, the carbon dioxide emissions for each stage can be calculated. The total emissions are 9.254 tones of CO_2 per ton bagasse processed. The results are separated into sectors in Figure 3.1, divided into transportation, fiberboard production, and product manufacture. Each of these sectors is further broken down into their individual components. Numbers indicate tones of CO_2 per ton of bagasse (raw material or product, since approximately 100% of the raw material is converted into product). Percentages indicate the percent of total emissions for each chart.

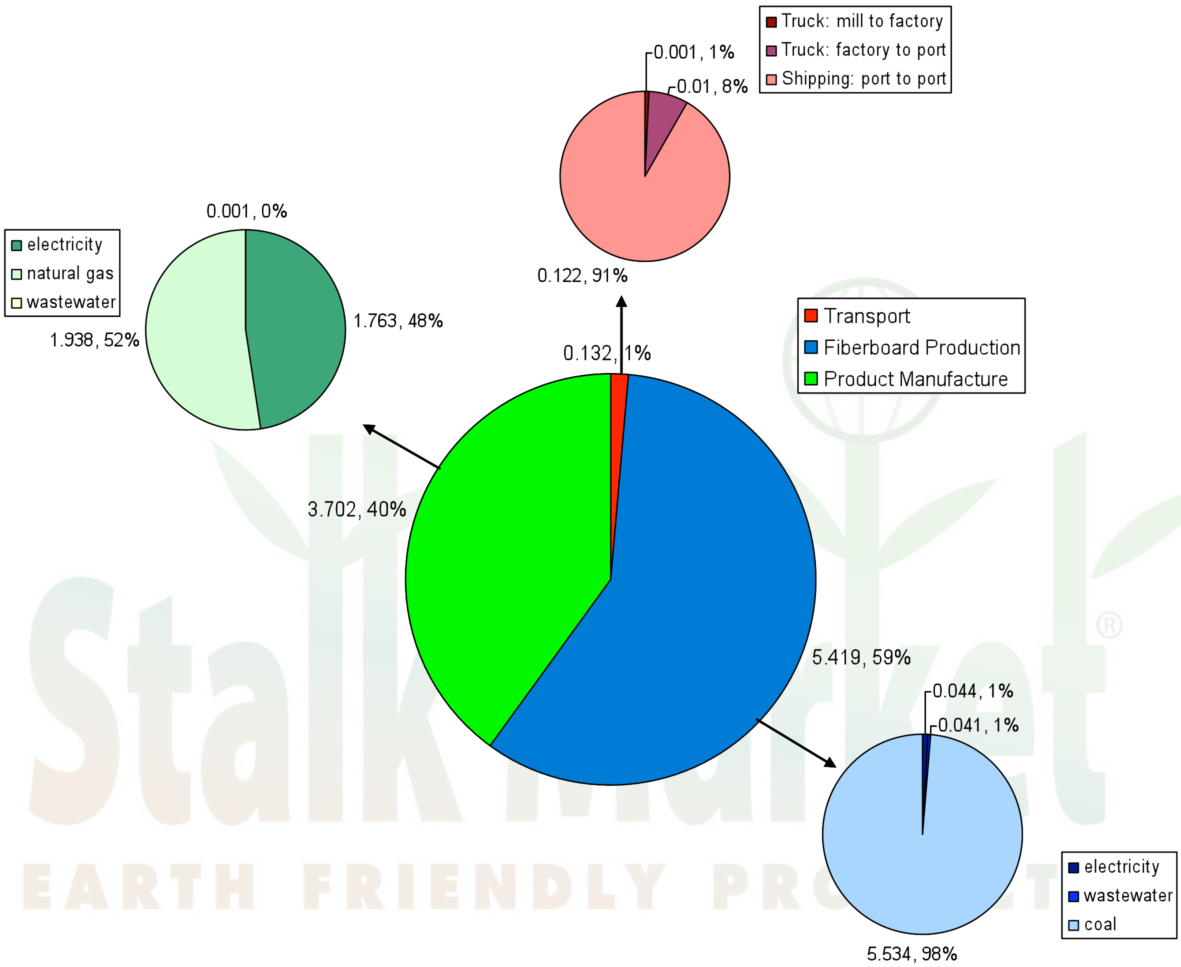

Figure 3.1: Carbon dioxide emissions for each sector of bagasse tableware production. The numbers indicate tones CO_2 per ton bagasse. The percentages are percent of total emissions for each chart.

3.3 – Net Carbon Footprint of Bagasse Tableware Production

Carbon sequestered must be combined with carbon emitted to determine the net carbon emissions for bagasse tableware. From section 3.1, the carbon sequestered per ton of bagasse is 1.794 ton CO_2/ton bagasse. The total carbon emitted from section 3.2 is 9.254 ton CO_2/ton bagasse, resulting in a net emission of 7.460 ton CO_2/ton bagasse. At the product level, a 10-inch bagasse plate, which weighs 22 grams, has a carbon footprint of 164 grams.

This report highlights the carbon emissions for production of bagasse based tableware for StalkMarket Co. Emissions are dominated by the direct burning of coal and natural gas for heat/steam in the fiberboard and product manufacturing processes respectively. Together they account for 79% of the total CO_2 emissions. Nineteen percent (19%) of the remaining 21% of emissions are due to electricity usage during product manufacturing.

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