Carbon Footprint Calculator for Rendering Operations

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Introduction

Two versions of a Carbon Footprint Calculator have been developed for rendering operations. Each uses an Excel® spreadsheet platform. One version requires the user to input data on raw materials entering a rendering plant. In the other the user enters data on products leaving the plant. If accurate data on both raw materials entering and products leaving a particular plant are available, the two versions should yield nearly identical results. The results can differ slightly because each spreadsheet uses default assumptions about raw material or product compositions that might not match actual plant data. These default compositions can be changed by the user to reconcile small differences between the two alternative versions and provide a more accurate indication of the carbon footprint.

Calculator Documentation

Data input requirements, calculations, and results from the Carbon Footprint Calculator are explained below.

Input Data on Raw Materials Consumed
Annual tonnage can be entered for 13 common categories of raw materials:

- Steer offal and bone
- Cow offal and bone
- Calf offal and bone
- Hog offal and bone
- Sheep offal and bone
- Poultry offal
- Poultry feathers
- Whole cattle
- Whole hogs
- Whole sheep
- Whole poultry
- Raw grease
- Blood

A placeholder row is provided for the user to include a feed that is not among the categories listed. Additional rows can be added easily to include other feeds, and the spreadsheet will adjust the calculated total to include the added rows. If any of the listed categories of feed is not rendered at the plant, the user should enter 0 (zero) in the ton/yr column.
The numbers currently in the raw material ton/yr column are merely for illustration and are meant to be replaced by the user. To the right of these data columns are provided for the weight % fat, protein, and water in each feed material. These columns contain default estimates derived from information on the Dupps Company web site (1, 2). The default values can be replaced if a renderer has more accurate data for a specific facility. At the bottom of the raw material table, the spreadsheet calculates the total ton/yr and the weighted average fat, protein, and water compositions.

**Alternative Input Data on Product Output**

In the Product version of the Carbon Footprint Calculator, data can be entered on the annual production of six specific products:

- BFT (animal fat)
- Meat and bone meal
- Poultry byproduct meal
- Feather meal
- Pork Meal
- Blood products

A placeholder row is provided for the user to include a product that is not among the categories listed. Additional rows can be added easily to include other products, and the spreadsheet will adjust the calculated total to include the added rows. If any of the listed categories of products is not produced at the plant, the user should enter 0 (zero) in the ton/yr column.

The illustrative numbers currently in the ton product/yr column are to be replaced by the user. To the right of the ton product/yr, a column is provided for the weight % carbon in each product. The default estimates shown were taken from an NRA white paper (3). These default values can be replaced if a renderer has more accurate data for a specific facility. At the bottom of the product table, the spreadsheet calculates the total ton/yr and the weighted average % carbon.

**Input Data on Transportation of Raw Materials to the Plant**

In this section the user must input data on the mode of transportation by which raw materials are received at the rendering plant. Two alternatives are currently set up in the table - integrated plants in which raw material is generated on site and no transportation is needed, and truck transportation. Rows could be added to accommodate other means of transportation. The total tonnage should match the total raw material input.
The Product Output version of the calculator is set up to back-calculate the total annual raw material input from the product rate using an estimated % conversion of raw material to product. The default conversion is 41%, but this estimate can be changed in the spreadsheet calculation (cell B22).

For truck transportation, the user must input the total ton/yr received by truck, the average size of the load, the average one-way distance traveled by the truck, and the average fuel economy of the truck. The numbers shown in the spreadsheet for illustration will be replaced when data are entered for a specific plant.

**Input Data on Commuting of Employees to the Plant**

This section is similar to the one above. The objective is to estimate total gallons of fuel burned annually by employees commuting to the plant. To arrive at this figure, the user inputs total number of employees, average number of days worked per year, average distance traveled from home to plant, average number of employees per car to account for car poolers, and average fuel efficiency. Again, the numbers shown in the spreadsheet for illustration will be replaced when actual data are entered for a specific plant.

**Input Data on Process Fuel Burned and Electric Power Purchased**

In this section the user must enter the annual consumption of several different types of fuel burned on site. Certain units of measure are specified. The numbers currently in the annual use column of the spreadsheet are for illustration only. Grease and fat produced and burned on site are entered along with other fuels and are handled appropriately in the calculations that follow. If methane is produced by anaerobic waste water treatment and burned on site, it is not entered here, but is accounted for later in wastewater calculations.

The two columns to the right of the fuel usage list typical lower heating values and weight % carbon for the various fuels. The % carbon in any fuel can be replaced if better data are available. The LHV values are for reference only and are not actually used in the calculations. They can be used to obtain fuel usage estimates from heat input data if necessary.

The total kWh of electricity purchased is also entered in this section. Generally, electricity generated on site by the rendering company should not be included here, but should be included by entering the fuel used to generate it. The amount of carbon dioxide emissions that results from power generation depends on the type of fuel. The default values shown under % generation are national averages. Local data can be substituted, if known. The spreadsheet references a web site...
where regional power generation data can be obtained (4). Default values are shown for lb CO₂/kWh resulting from each type of utility fuel. These estimates are based on typical fuel compositions and mass balance calculations. Renewable fuels are assumed to contribute zero net carbon dioxide to the environment though this may not be valid in every case.

**Output: Indicators of Carbon Footprint**

**CO₂ equivalents in raw materials.**
The first line in this section shows ton/yr of CO₂ equivalents in the raw materials that enter the plant. This figure is calculated from the total ton/yr of raw material input and the average % fat and % protein. The calculation is based on the following assumptions:

- Fat is 76 weight % carbon.
- Protein is 27 weight % carbon.
- All carbon entering the plant in raw materials would have been converted into carbon dioxide if it had not been rendered.

The assumed carbon contents of fats and proteins are typical numbers that can be changed by modifying the cell formula if needed. The assumption on the alternative fate of carbon in the raw material is hypothetical, and it deserves further attention. What would happen to this material if it were not rendered? Few studies have been conducted to quantify the chemical fate of buried or composted animals. It is likely that some dead stock left in the field would be eaten by scavengers, but most would be decomposed, primarily into carbon dioxide, water, and residual mineral matter. Nitrogen in the protein would be released primarily as N₂.

Buried animals and composted material decompose in an oxygen limited environment. Some carbon is converted into methane and some nitrogen into nitrous oxide. A comprehensive study conducted in western Canada (5) showed that for every 1000 lb (wet basis) of cattle composted, approximately 630 lb of carbon dioxide, 9 lb of methane, and 4 lb of nitrous oxide were emitted over a period of several months. The small amounts of CH₄ and N₂O emitted are highly significant because these gases are much more potent greenhouse gases than CO₂. On a mass basis, CH₄ is estimated to have 70 times the global warming potential or GWP of CO₂, and N₂O has a GWP that is nearly 300 times that of CO₂ (6). Thus, the total global warming potential of burying or composting could be several times the effect of CO₂ alone.
**CO₂ emissions due to on-site burning of purchased fuels, grease, and fat.**
The amount of each fuel burned per year is converted into tons, which is then multiplied by the weight % carbon in the fuel to get tons of carbon burned. This is then multiplied by the molecular weight ratio, 44 tons of CO₂ produced per 12 tons of carbon burned. Burning of grease and fat recovered from rendered materials is counted here because it results in CO₂ emissions just like burning any other fuel. But credit is also taken for the avoidance of the same amount of CO₂ emission when the raw material was brought into the plant rather than being left dead in the field or composted.

To avoid double counting, methane captured from anaerobic wastewater treatment and burned on site is not included in the fuel calculations. See the wastewater treatment section below for further explanation.

**CO₂ emissions due to wastewater treatment.**
The quantity and concentration of wastewater containing organic material varies considerably from one rendering plant to another. Carbon in the aqueous organic material that goes to wastewater treatment has three potential fates:

- Aerobic conversion into carbon dioxide
- Anaerobic conversion into methane
- Aerobic or anaerobic conversion into solid biomass

Most of the wastewater produced in rendering plants is treated aerobically, and the most common measure of organic material in wastewater is the BOD, or amount of oxygen consumed in the microbiological reactions; literally the Biological Oxygen Demand. A related quantity, carbonaceous BOD or CBOD, excludes oxidation of organic nitrogen, so CBOD is a more direct indicator of potential CO₂ emissions. Sindt (7) estimates that, on average, raw rendering plant wastewaters contain CBOD concentrations in the range of 4000 to 10,000 mg/L. Usually this must be reduced to 10 to 25 mg/L before discharge. Sindt further estimates that the amount of CBOD produced and treated in a typical rendering plant is 5000 lb CBOD per million lb of raw material rendered.

The molar ratio of hydrogen to carbon in fats and proteins is about 2:1, but 1 carbon atom combines with 2 oxygen atoms while 2 hydrogen atoms combine with only 1 oxygen atom. This means that about 1/3 of the oxygen consumed in the degradation of carbon in proteins and fats reacts with hydrogen and is converted into water, and about 2/3 reacts with carbon and is converted into carbon dioxide. When the molecular weights of oxygen and carbon dioxide are taken into account, the net result is that 1 lb of CBOD is equivalent to roughly 1 lb of CO2 released to
the environment. Combined with Sindt’s estimate, this means that about 0.005 tons of CO₂ are emitted/ton of raw material rendered if conventional aerobic wastewater treatment is used. Most of this CO₂ is released within a few days after the water reaches the treatment plant. Carbon converted to biomass may be sequestered for a longer period of time, depending on the method of sludge accumulation or disposal.

Anaerobic treatment plants use different microorganisms, which work in an oxygen-deficient environment to produce a mixture of CO₂ and CH₄. When this method of treatment is used, the gas is usually captured and burned on site, so that all of the carbon is released to the atmosphere as CO₂. Thus anaerobic and aerobic treatment facilities have the same effect on CO₂ emissions.

The Carbon Footprint Calculator uses Sindt’s estimate of the quantity of fats and proteins sent to wastewater treatment per ton of raw material rendered. It further assumes that all carbon sent to wastewater treatment is released to the environment as CO₂. This should be a reasonable estimate of the contribution of wastewater treatment to greenhouse gas emissions unless a significant quantity of methane is produced and released directly to the atmosphere. The estimate can be scaled up or down if a particular plant has data indicating that its lb CBOD/lb of rendered material is substantially different from Sindt’s approximation.

**CO₂ emissions attributed to purchase of electricity.**
To determine the CO₂ emissions attributable to the use of purchased electricity, the total kWh of electricity purchased is first apportioned out to different methods of power generation. These results are then multiplied by the lb CO₂ emissions/kWh that applies to each method of generation.

**CO₂ emissions due to raw material transport and employee commuting.**
The data entered for truck transport of raw materials and for commuting of employees to the rendering plant are used to calculate the total gallons of fuel used in each category annually. One-way mileage is doubled to account for the return trip of the vehicles, and a factor of 19.5 lb CO₂/gallon fuel is applied based on typical composition of diesel fuel and gasoline.

**CO₂ reduction ratio.**
CO₂ reduction ratio is a logical measure of the beneficial effect that a rendering plant has on greenhouse gas emissions. The ratio is obtained by dividing the CO₂ emissions that would occur if the plant did not exist by the CO₂ emissions that are attributed to operation of the plant. The Carbon Footprint Calculator currently
assumes that all of the carbon in the raw materials processed by the plant would otherwise be released to the atmosphere as carbon dioxide. With respect to global warming potential or GWP, this estimate is low compared to the more likely result that alternative methods of disposal would release substantial quantities of methane and nitrous oxide. As noted above, the most quantitative study reported to date (5) indicates that the GWP impact of composting dead stock and meat byproducts could be roughly four times higher than the result estimated by the current, conservative version of the carbon footprint calculator.

The denominator of the CO₂ reduction ratio is the carbon footprint of the rendering plant. Carbon footprints are discussed often in the popular press, but there is no universal agreement as to what should be included in this number; i.e., who is responsible for what emissions? Numerous organizations claim expertise in matters of greenhouse gases and climate change. Some have developed and published methodologies for quantifying GHG emissions and carbon footprints. Among these are The Greenhouse Gas Protocol Initiative (8) and The Climate Registry (9). According to information on its web site, the GHG Protocol Initiative seeks “to harmonize GHG accounting and reporting standards internationally” and to “ensure that different trading schemes and other climate related initiatives adopt consistent approaches to GHG accounting.” The GHG Protocol Corporate Standard “provides standards and guidance for companies and other organizations preparing a GHG emissions inventory.” The GHG Project Protocol claims to be “the most comprehensive, policy-neutral accounting tool for quantifying the greenhouse gas benefits of climate change mitigation projects.”

The GHG Protocol requires the reporting of Scope 1 and Scope 2 emissions. Scope 1 “comprises all direct emissions from company controlled sources.” For rendering plants this would normally include emissions that result from burning any kind of fuel on site, from wastewater treatment facilities operated on site, and from transportation of employees, raw materials, and wastes in company vehicles. Scope 2 emissions are those attributable to purchased energy.

The GHG Protocol recommends voluntary reporting of other indirect emissions designated as Scope 3. These emissions are related to company activities, but they originate from sources not controlled by the company. For rendering operations, this would normally include transportation of raw materials to the site, employee commuting and business travel, and transportation of products in contractor vehicles. The Climate Registry recommends a similar General Reporting Protocol. Neither the GHG Protocol nor the Climate Registry addresses GHG emission credits.
The Carbon Footprint Calculator developed in this work determines the CO₂ reduction ratio using Scope 1 emissions only, Scopes 1 and 2 emissions, and Scopes 1, 2, and 3 emissions, according to the definitions of the GHG Protocol. Transportation of raw material and commuting of employees are assumed to occur in vehicles not owned by the company so they are treated as Scope 3. Business travel and transportation of products are not covered in the calculator, but they could be added as additional Scope 3 emissions if a company has sufficient data to support their estimation.

Obviously, a smaller denominator results in a larger CO₂ reduction ratio. Any value of the ratio greater than 1 indicates that rendering processes have a net beneficial effect on CO₂ emissions. The estimates used for illustration in the Carbon Footprint Calculator show that a typical rendering process releases to the atmosphere only a small fraction of the carbon dioxide that would be released by alternative disposal methods. Most of this CO₂ can be attributed to fuel burning.

References

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