Thank you for the opportunity to comment on the 2013 update to the AB 32 Scoping Plan. These comments are submitted on behalf of the National Rendering Association (NRA), the Pacific Coast Rendering Association (PCRA) and the California Grain and Feed Association (CGFA).

The National Renderers Association is the international trade association for the industry that safely and efficiently recycles animal agriculture byproducts and recycled restaurant grease into valuable ingredients for the livestock, pet food, fertilizers, chemical and consumer product industries in a manner that is protective of our environment and public and animal health. PCRA and CGFA are the California based association of renderers and livestock and pet food companies that provide rendered products and feed input materials to California's livestock, pet food, organic fertilizer and biofuel industries. NRA represents its members' interests to Congress, regulatory and other government agencies, promotes greater use of rendered products, and fosters the opening and expansion of trade between North American exporters and foreign buyers. NRA's membership represents more than 98% of the rendering capacity in both the U.S. and Canada. PCRA and CGFA represent their members in California.

The functions performed by rendering plants are a critical behind the scenes component of our animal, environmental and public health infrastructure and key link in our animal agriculture production chain. It is important to us that the updated scoping plan recognize rendering as a carbon reduction strategy for <u>recycling</u> and handling organic material of animal and food origin including but not limited to animal mortalities, meat, bone, plate waste; fats, oils and grease and other food material.

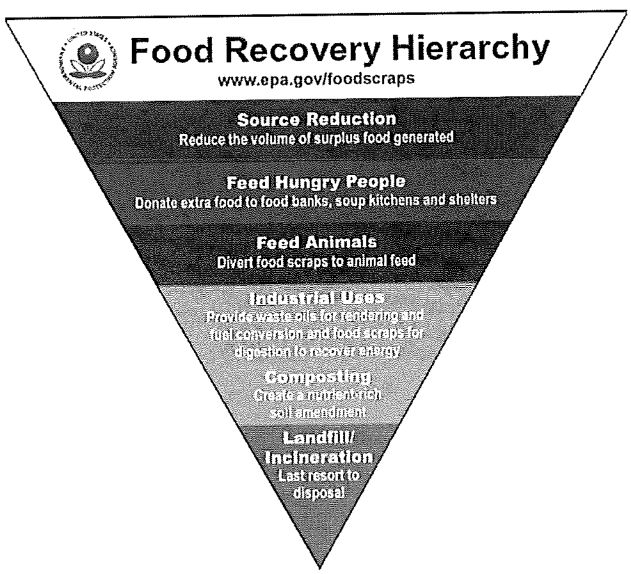
We also believe the scoping plan and any credits, regulations, incentives or any other benefits be applied technologically neutral by all agencies charged with implementing this plan. Finally, when implementing agencies at the state and local level provide direction on implementing this plan, they must be sure to not hinder our ability to perform our current recycling activities as profitable businesses and that any incentives or opportunities to trade carbon offsets be made available to renderers as essential industries.

Unintended Consequences. Our members believe that the state of California should very carefully weigh their policy decisions so they do not cause animal and food origin materials - that should be rendered - to be diverted to pathways that may not be entirely protective of animal, environmental and public health. Historically, rendering and landfills have very effectively shut the door regarding animal and human disease cycles where animal origin material serves as the disease vector. We are concerned that encouraging diversion of animal and food origin materials away from their historic pathways due to solid waste management or GHG policies – may allow diseases to spread if the material of animal or food origin was not properly handled, processed and directed to appropriate end uses.

Currently, only rendering provides a verified, repeatable and monitored process at sufficient time and temperatures to mitigate the risk of animal and human pathogens. Rendering facilities, processes and outputs are held to federal food safety standards on par with human food that are being currently formalized into regulation by the U.S. Food and Drug Administration's Food Safety and Modernization Act. Renderers are already obliged to license and register their facilities and perform risk assessment, mitigation, monitoring, verification, record keeping, recall planning, audit and inspections to ensure that downstream biological and chemical risks to the public, animals and the environment are addressed

Highest and Best End Use. Our members believe that the state of California in its scoping plan should also recognize and encourage those GHG reducing processes and technologies that make the highest and best end use of products of animal and food origin. It should be noted the rendering industry is the primary supplier of feed stock and major producer of California's Low Carbon biodiesel and renewable diesel.

The U.S. EPA has established a "Food Recovery Hierarchy" for food wastes:



Similarly, the California Department of Resources Recycling and Recovery recognized a hierarchy, "Californians throw away nearly 6 million tons of food scraps each year. Rather than throwing away excess food, manage it through source reduction, feeding people, feeding animals, industrial uses, and composting for soil restoration."

Rendering. Simply, rendering is the cooking and drying process used to convert materials of animal and food origin into fats and proteins. In the U.S., renderers recycle approximately 56 billion pounds of highly perishable organic materials. Through the rendering process, inedible wastes that are rich in carbon and nitrogen are recycled into re-useable materials. This process also averts the release of carbon dioxide and other greenhouse gas emissions that would otherwise be released into the air through the normal decomposition process or through other technologies. Rendering is the most efficient and environmentally sound disposal alternative for organic materials of animal origin.

Rendering, Carbon and Nitrogen. Recently, the NRA reported on select rendering outputs and the amount of carbon, nitrogen inherent in those products and avoided carbon and nitrogen emission potentials.

	Production (Tons)	% Carbon	Carbon, (metric ton)	CO_2 (metric ton)	CO_2 (US ton)
BFT (animal fat)	4,515,600	75.89%	3,426,889	12,566,516	13,852,070
Meat and bone meal	2,314,600	24.27%	561,661	2,059,629	2,270,329
Poultry by-product meal	1,153,500	28.68%	330,801	1,213,057	1,337,153
Feather meal	600,900	37.50%	225,350	826,364	910,901
Pork meal	720,711	25.59%	184,427	676,300	745,486
Blood products	102,512	37.50%	38,444	140,976	155,397
Total	**9,407,823**		**4,767,571**	**17,482,842**	**19,271,337**

Table 1. Annual U.S. Production of Select Rendered Outputs, Carbon and Avoided Carbon CO_2 Emission Potentials.

	Production (Tons)	% protein	N (metric ton)	N (US ton)
Meat and bone meal	2,314,600	55%	203,685	224,522
Poultry by-product meal	1,153,500	65%	119,964	132,236
Feather meal	600,900	85%	81,722	90,083
Pork meal	720,711	58%	66,882	73,724
Blood products	102,512	85%	13,942	15,368
Total protein meals	4,892,223		486,195	535,933

Table 2. Annual U.S. Production of Select Rendered Outputs, Nitrogen and Avoided Nitrogen Emission Potentials.

If all carbon in these waste products were expressed as CO_2, using the EPA estimate of 5.46 metric ton per car, failure to remove these products from the waste stream would be **the same as adding 3,201,986 cars to the nation's roads.**

However, if 20% of the carbon in decaying organic material is expressed as methane and 10% of the nitrogen is expressed as nitrous oxide, then removing these products from the waste stream would be **the same as removing 12,263,316 cars from the nation's roads** higher warming potentials of the nitrogen emissions.

Opportunities for Additionality. Based on GHG measurements taken from composting studies, one metric ton of cattle carcasses added to the compost pile results in 2 metric tons of CO2 equivalents produced over and above gases produced composting of manure, bedding or other organic material in the pile. If GHG production is similar when carcasses decomposes naturally in the environment, one adult dairy cow might be expect to add 1.2 metric tons of CO2 equivalents to the environment. Fortunately in California the majority of dairy cow mortalities are rendered due to statutory and regulatory requirements. However, there appears to be an opportunity to explore opportunities for additionality in regards to mortalities of other animal species and meat (other than mammalian) that are not currently entering the rendering pathway.

Carbon Footprint and Life Cycle Analysis. The most recent and best data regarding carbon footprint for rendering is Gooding, C.H. (2012). *Data for the Carbon Footprinting of Rendering Operations*. Journal of Industrial Ecology Volume 16(2): 223-230 (Attachment 1) which reported:

> This article presents a tool and data for calculation of the carbon footprint of rendering operations in North America, quantifying Scope 1 (direct) and Scope 2 (indirect) greenhouse gas emissions. Scope 3 (life cycle) emissions are not included.
>
> According to the sample data, in one year an average-size rendering plant in North America processes 100,000 tonnes (t) of meat by-products, fallen animals, and restaurant grease and produces 40,000 t of marketable fats and proteins. A plant of this size emits directly about 20,000 t of carbon dioxide (CO2), mostly by burning fuels to operate cookers that destroy pathogens, drive off moisture, and separate the fat and protein. Another 4,000 t of CO2 is emitted by utility companies to provide electricity for the rendering process.
>
> These direct and indirect emissions are equivalent to about 30% of the CO2 that would be released if all of the carbon in the rendered raw material were decomposed into CO2.

There is familiarity to the rendering process and lifecycle analysis at the board as two pathways have been modeled by California Greenhouse Regulated Emissions and Energy use in Transportation studies; *Detailed California-Modified GREET Pathway for Biodiesel Produced in California from Used Cooking Oil* and *Detailed California-Modified GREET Pathway for Co-Processed Renewable Diesel Produced from Tallow (U. S. Sourced).*

The NRA and PCRA would welcome the opportunity to collaborate with the board to establish a lifecycle analysis and method for estimating greenhouse gas emission reductions from rendering of inputs including but not limited to animal mortalities, meat, bone, plate waste; fats, oils and grease and other food material.

Pacific Coast Renderers Association. California Census of Incoming Raw Materials. For fiscal year 2011-12, fourteen processing plants reported they handled and processed 2,201,937,843 pounds of fat, meat and bone; slaughterhouse offal; used cooking oil; animal mortalities (ovine, bovine, porcine, & equine); poultry offal; fish & seafood by products; and trap/interceptor grease. The data here only represents 14 licensed rendering plants in California that are members of PCRA. The California Department of Food and Agriculture can report the total number of licensed rendering facilities in the state.

Rendering and Criteria Pollutants. As the board evaluates different GHG reduction pathways for the recycling and treatment of animal and food origin materials – it would be prudent to consider broader environmental goals if hierarchy or recognition of technologies is given. All rendering plants in California hold stationary air permits from local air pollution control districts – and are regulated under numerous district, state and federal rules. In brief and very generally, the rendering process begins when raw materials are delivered by truck to a load-in facility. The material is next ground/chopped into uniform pieces. The material is then moved to a cooking vessel where it is indirectly heated – through steam supplied by permitted natural gas fired boilers. Drying of the material produces vapors that are typically condensed and discharged to on-site or municipal water treatment. Non-condensed vapors are captured by venturi scrubbers then to thermal oxidizers that incinerate any remaining emissions prior to venting to the atmosphere. Output of the cooking process includes oils and meat and bone meals. Raw material receiving, handling, processing and storage of material produces insignificant amounts of particulate matter which are typically controlled further by room air scrubbers before venting. The thermal oxidizer serving the cooking process does produce emissions of NOx, SOx, PM10, CO, and VOC from the combustion of fuel. The current typical use of control technologies, permitted operational parameters and natural gas as fuel ensures that emissions from rendering are compliant with local, state and federal air standards – and can be further counted on to contribute to plans to reach attainment in non-attainment areas.

As rendering plants are permitted in each of California's major Air Pollution Control Districts we would encourage the board to review existing stationary source permits for rendering plants - their regulated and controlled emissions of NOx, SOx, PM10, CO, and VOCs and their role for ongoing and future attainment of state and federal clean air act goals – especially as it relates to moving animal and food origin material through different pathways that may be recognized for reduction of GHG.

Allowing the rendering industry to receive appropriate incentives and approaching them in a technology neutral manner would create financial incentives for restaurants, grocery stores and municipalities to properly dispose of organic waste while avoiding additional greenhouse gases, reducing concerns over the spread of disease and freeing up limited landfill space. Also, discriminating against products already recycled through rendering as "not new," but recognizing protocols for placing organic material such as plate waste, meat and bone meal, offal and other material in anaerobic digesters, composting or in landfills to trap and burn off the methane produced as "new" would put rendering at a competitive disadvantage and drive these organic materials to a much less productive and environmentally advantageous end. The result would be awarding offsets for shifting carbon from recycling to disposal with no net reduction (and a probable increase) in greenhouse gas emissions.

Thank you for considering our role in the current and future work to decrease greenhouse gas emissions. Please feel free to contact us any time for more information about the rendering industry.

In support, NRA, PCRA and CGFA provide the following list of references.

1) C.H. Gooding, 2012. Data for the Carbon Footprinting of Rendering Operations. Journal of Industrial Ecology, Vol 16: pp 223-230. Gooding reported that after offsetting the GHG emitted to collect, transport and process food materials, including fuel burned to generate steam, transportation fuel, waste water treatment and electricity, a typical rendering plant will recycle 7 out of every 10 carbons processed.
2) Meeker, Dr. David , Rendering and Its Role in Carbon Emissions. 2012, National Rendering Association
3) Hamilton, Dr. Ross, How Rendering Compares to Alternatives. 2012, Presentation to the National Rendering Association.
4) Hamilton, Dr. Ross, Value Pyramid for Waste Reduction Options. 2012, Presentation to the National Rendering Association
5) S. Xu, X. Hao, K. Stanford, T. McAllister and F. Larney. 2007. Greenhouse gas emissions during co-composting of cattle mortalities with manure. Nutrient Cycling and Agroecosysems. Vol 78. pp. 177-187. (Abstract of paper)
6) United Kingdom Department for Environment, Food and Rural Affairs. *Risk Assessment: Use of Composting and Biogas Treatment to Dispose of Catering Waste Containing Meat.* May 2002. Available on the Internet at: http://www.defra.gov.uk/animalh/by-prods/publicat/report5.pdf.
7) United Kingdom Department of Health. *A Rapid Qualitative Assessment of Possible Risks to Public Health from Current Foot and Mouth Disposal Options – Main Report*. June 2001. Available on the Internet at: http://www.doh.gov.uk/fmdguidance.

Data for the Carbon Footprinting of Rendering Operations

Charles H. Gooding

Keywords:

animal by products
fat
greenhouse gas (GHG)
industrial ecology
meat
protein

Summary

This article presents a tool and data for calculation of the carbon footprint of rendering operations in North America, quantifying Scope 1 (direct) and Scope 2 (indirect) greenhouse gas emissions. Scope 3 (life cycle) emissions are not included.

According to the sample data, in one year an average-size rendering plant in North America processes 100,000 tonnes (t) of meat by-products, fallen animals, and restaurant grease and produces 40,000 t of marketable fats and proteins. A plant of this size emits directly about 20,000 t of carbon dioxide (CO_2), mostly by burning fuels to operate cookers that destroy pathogens, drive off moisture, and separate the fat and protein. Another 4,000 t of CO_2 is emitted by utility companies to provide electricity for the rendering process. These direct and indirect emissions are equivalent to about 30% of the CO_2 that would be released if all of the carbon in the rendered raw material were decomposed into CO_2.

The Ancient Practice of Rendering

To sustain their existence, prehistoric humans required food, water, and shelter. They needed weapons to protect them from animals and each other, and to advance, they ultimately needed tools. Early humans found all of these essentials except water in the animals around them. In addition to eating meat, they used animal hides for clothing and shelter and animal bones and teeth for weapons and tools. At least two millennia ago several cultures advanced further, learning to cook mixtures of fat and ash to make soap, which improved health as well as comfort (Burnham 1978).

Candles made from tallow became an effective source of light as early as the 13th century. Roughly 100 years ago Peterson, Plumb, and others demonstrated that rendered animal protein was an effective feed supplement for swine, leading to accelerated rates of growth (Bisplinghoff 2006; Burnham 1978). Animal feeds are now the primary market for fats and proteins produced by the rendering industry, though significant quantities of rendered products are used to make biodiesel fuel and a variety of specialty chemicals (McGlashan 2006). Rendering industries now exist on all of the populated continents. In North America, roughly 30 million tonnes (t)[1] of meat by-products, fallen animals, and restaurant grease are processed annually in 300 rendering plants (Meeker and Hamilton 2006). Large packing and poultry companies process about 75% of this material in plants that are integrated with meat production. The remaining 25% is collected and rendered by independent companies (Bisplinghoff 2006).

A Primer on Modern Rendering Operations

Rendering plants process a variety of raw materials, including whole animals that die from disease and other miscellaneous causes; bone, feathers, blood, and offal (viscera and trimmings) from slaughterhouses; and grease from restaurants. On average,

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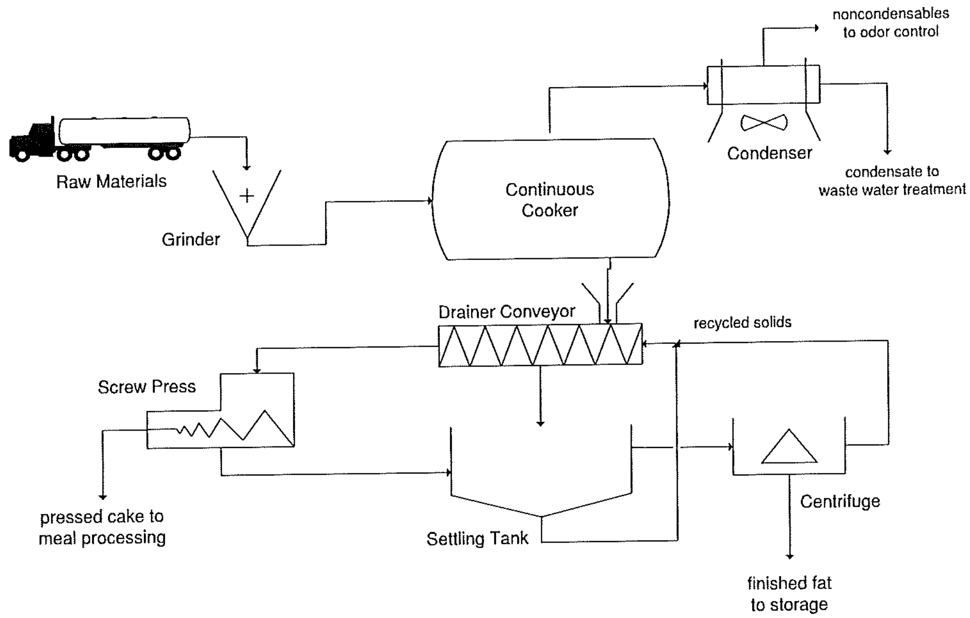

Figure 1 Continuous rendering system.

these raw materials are nearly 60% water. The other 40% of the incoming mass is converted into two broad product categories, fats and protein meals.

Anderson (2006) provides a concise description of modern rendering operations. Most industrial-scale rendering plants use the dry continuous process, which is illustrated in figure 1. Unless raw material is generated on-site in a slaughterhouse, it is normally received by truck or rail. The material is ground to a uniform size and sent to a continuous cooker where it is heated to 115°C to 145°C to kill pathogens, evaporate moisture, and melt fat. The resulting slurry is discharged to a drainer conveyor where liquid fat is separated from solid protein and bone. Fat leaving the settling tank beneath the conveyor is centrifuged to remove fine solids and then sent to finished storage and packaging.

Solids are recycled from the centrifuge back to the drainer conveyor, joining new feed from the cooker and solids recycled from the settling tank. Most solids retained by the drainer conveyor are discharged to screw presses, where the residual fat content is reduced to 10 to 12 weight percent. Larger solid particles may be sent back to the cooker. Fat pressed from the solids is recycled to the settling tank. The protein-rich cake leaving the screw presses goes to final meal processing, packaging and storage.

Water vapor leaving the cooker passes through an entrainment trap to prevent liquid and solid particles from exiting with the vapor. The vapor is condensed and sent to wastewater treatment along with other wastewater streams generated in the plant. Noncondensables are pulled from the condenser by a blower and processed through an odor control system.

Cookers require a considerable amount of steam, which is usually generated by burning purchased fuels such as oil or natural gas as well as some of the fat produced by rendering. Combustion associated with steam generation is the primary source of carbon dioxide (CO_2) emissions from rendering operations. Most rendering plants conserve fuel and reduce energy costs by employing waste heat recovery to generate hot water used in the process.

Carbon Footprint Concepts

Growing concern over environmental sustainability has caused companies, consumers, and government regulatory agencies to increase their focus on the energy consumption and environmental impact of various activities. This has led to an increasing number of comprehensive life cycle assessments as well as more limited evaluations of carbon, water, and ecological footprints. Methods, standards, and protocols for conducting these analyses are a subject of lively debate and continuing development. (See, e.g., Udo de Haes 2006; Weidema et al. 2008; Wiedmann et al. 2009).

To help member companies of the National Renderers Association quantify their role in the generation of greenhouse gas (GHG) emissions, the Fats and Protein Research Foundation decided in 2009 to provide on their Web site (www.fprf.org) a carbon footprint calculator specifically for rendering operations. The WRI (2004), the International Organization for Standardization (2006), the Climate Registry (2008), and many other entities have published methodologies for quantifying and

Table 1 Data input on raw materials entering the rendering plant

Type	*tonnes/year*	*% fat*	*% protein*	*% water*
Steer offal and bone	34,200	31	21	48
Cow offal and bone	5,000	15	30	55
Calf offal and bone	1,600	10	23	67
Hog offal and bone	19,000	28	14	58
Sheep offal and bone	300	28	22	50
Poultry offal	20,000	10	25	65
Poultry feathers	8,200	0	33	67
Whole cattle	5,200	12	26	62
Whole hogs	2,000	30	28	42
Whole sheep	100	20	25	55
Whole poultry	1,000	15	25	60
Raw grease	300	65	10	25
Blood	3,100	0	17	83
Other (placeholder)	0	25	25	50
Total	100,000	**20.5**	**22.2**	**57.3**

reporting GHG emissions and carbon footprints. The analysis reported in this article is based on the GHG Protocol, which was developed by the World Resources Institute 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 (WRI 2004). The GHG Protocol provides standards and guidance for companies and other organizations preparing a GHG emissions inventory.

The GHG Protocol requires that Scope 1 and Scope 2 emissions be reported. Scope 2 emissions are those attributable to purchased energy. Scope 1 emissions are "direct GHG emissions [that] occur from sources that are owned or controlled by the company" (WRI 2004). 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 in company-owned vehicles. Such transportation could include business travel by employees and the transport of raw materials to the site, products to customers, and wastes to off-site treatment facilities. Scope 3 emissions, not included in this tool, include other indirect emissions, "such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, and waste disposal" (WRI 2011). Thus the production of livestock is not included in this carbon footprint tool.

Data Requirements and Default Assumptions

The carbon footprint calculator described below was developed to quantify Scope 1 and 2 emissions for a typical rendering process. It uses default assumptions that may not apply to every rendering plant, so it is a template rather than a definitive case. The spreadsheet platform that is available at www.fprf.org allows the user to input plant-specific data and to override default assumptions if better data are available.

Data Input on Raw Materials and Products

Two versions of the carbon footprint calculator were developed initially using a Microsoft Excel spreadsheet platform. They differ only in the starting point for data entry on material processed by the plant. The alternatives for data input are shown in tables 1 and 2, and the common parts of the spreadsheet calculator are shown in tables 3 through 6. Table 1 illustrates input data on 13 common categories of raw materials that might enter a rendering plant. Typically offal, bone, feathers, and blood come from slaughtering operations. Whole dead animals come from farms or feedlots, and raw grease is collected from restaurants. The "other" category provides a way for the user to input data on a unique material entering the plant.

Data on the typical composition and quantity of materials rendered in North America are available from several sources (Bisplinghoff 2006; Dupps 2010; Meeker and Hamilton 2006; National Renderers Association 2009;

Table 2 Data input on products leaving the rendering plant

Type	*tonnes/yr*	*% carbon*
BFT (animal fat)	20,300	75.9
Meat and bone meal	10,400	24.3
Poultry by-product meal	5,200	28.7
Feather meal	2,700	37.5
Pork meal	3,200	25.6
Blood products	500	37.5
Other (placeholder)	0.1	50
Total	42,300	**50.7**

Table 3 Data input on transportation in company-controlled vehicles for the rendering plant

	tonnes/yr	*tonnes/load*	*Avg. km/load*	*Fuel use (l/km)*
Raw materials	100,000	20	300	0.40
Products	42,300	25	600	0.40
		No. of vehicles	*Avg. km/yr*	*Fuel use (l/km)*
Employees		5	50,000	0.10

Note: yr = year; Avg. = average; No. = number. One kilometer (km, SI) ≈ 0.621 miles (mi). One liter per kilometer (l/km) ≈ 0.426 gallons per mile (gal./mi.).

Pearl 2004; U.S. EPA 1995). The numbers shown in table 1 were determined by cross-referencing these sources to estimate the total amount of each raw material processed in North America annually and then dividing by 300, the approximate number of plants in operation. The results were rounded to define a hypothetical average plant that processes 100,000 tonnes per year (t/yr) of raw material. The percent of fat, protein, and water shown for each raw material is typical, but specific contents vary with location, time of year, and source of the feedstock.

Users of the carbon footprint calculator enter actual data for each raw material processed by a specific rendering plant into a spreadsheet analogous to table 1. The default percentages of fat, protein, and water can be replaced by the user if better composition data are available. The spreadsheet calculates the total annual input of raw material and the weighted average percentages of fat, protein, and water as shown at the bottom of table 1.

Table 2 illustrates the alternative input sheet for the carbon footprint calculator. Instead of entering raw material data, the user can enter annual production rates of animal fat (BFT) and five types of protein meal. A placeholder row is provided, and others can be added if the user prefers different product terminology. The product quantities shown in table 2 were calculated by the author. They are based on the raw material breakdown shown in table 1 and a mass balance on fat and protein, assuming 1% loss of organics to wastewater treatment. An estimate is provided for the weight percent carbon in each product category (National Renderers Association 2009). These default values can be changed if the user has more accurate data. The spreadsheet calculates the total annual production rate and the weighted average percent carbon in the products.

If accurate data on both raw materials and products are available, the two data input methods should, in principle, yield identical results for the carbon footprint of the plant. In reality, differences may occur due to inaccurate measurements or faulty assumptions about raw material and product compositions or the fraction of fat and protein lost to waste treatment. The default assumptions are that 42% of the raw material mass leaves the process as product, 1% is organic matter lost to wastewater treatment, and 57% is water. These percentages and other default assumptions can be adjusted by the user to reconcile differences between the input and output versions if sufficient data exist to evaluate the mass balances.

Data Input on Transportation in Company-Controlled Vehicles

Like other industrial operations, rendering involves the transportation of raw materials and products. Rendering plants that are integrated with a slaughterhouse receive raw materials generated on-site via conveyor belt, forklift, or by other short-range vehicular transportation. Power consumption by conveyor belts is included in table 4 . Fuel burned in vehicles used on-site can be accounted for in table 3 or deferred to table 4, depending on the nature of the vehicle. Independent rendering plants normally receive raw materials by truck. For company-controlled truck transportation, the user of the carbon footprint calculator must input the annual quantity of

Table 4 Data input on fuel burned and power purchased for the rendering plant

Estimated use of each fuel and electricity		
Type	*Annual use*	*kg CO_2eq/unit*
Natural gas (SCM)	3,100,000	2.0
No. 2 oil (l)	15,000	2.7
No. 6 oil (l)	1,700,000	3.1
Grease (kg)	220,000	2.7
Animal fat (kg)	1,200,000	2.8
Other fuel (kg)	0	
Electricity (kWh)	6,800,000	
Grid breakdown	*% generation*	*kg CO_2eq/kWh*
Coal	52	1.0
Natural gas	16	0.6
Oil	3	1.0
Renewables	1	0.0
Nuclear	20	0.0
Hydro	7	0.0
Other	1	0

Note: CO_2eq = carbon dioxide equivalent; SCM = standard cubic meter; l = liter; One kilogram (kg, SI) ≈ 2.204 pounds (lb). One kilowatt-hour (kWh) ≈ 3.6 × 10^6 joules (J, SI) ≈ 3.412 × 10^3 British Thermal Units (BTU).

raw materials received at the plant and averaged data on the size of the load, the two-way distance traveled, and fuel use. The numbers shown in table 3 are typical for an independent rendering plant that receives all raw materials by truck. The average-size load, distance traveled, and fuel use were extracted from a survey of operations at 25 independent rendering plants reported by Lopez and colleagues (2010).

Trucks are also used to transport rendered products. The survey data of Lopez and colleagues (2010) indicate that, on average, products are trucked about twice as far as raw materials. But the mass of products leaving the plant is less than half the mass of raw materials entering, so the CO_2 emissions due to product transportation are roughly comparable to those resulting from raw material transportation. The numbers provided in table 3 utilize results from the Lopez and colleagues (2010) survey on average transportation distance and fuel use. They assume that company-controlled vehicles are used to transport both raw materials and products.

In rendering operations, water and a small fraction of solids go to wastewater treatment. These are usually transported to an on-site waste treatment facility by electrically driven pumps that are accounted for in table 4. If wastes are transported in company-controlled vehicles, this must be included in the footprint by adding another row of data in table 3.

Employee transportation in company-controlled vehicles can include short-range, on-site transportation, and business trave. These are highly variable among rendering companies and were not included in the Lopez and colleagues (2010) survey. Table 3 illustrates how data can be entered into the calculator for employee transportation in company-controlled vehicles. The numbers shown correspond to use of a small fleet of company-controlled automobiles.

Data Input on Process Fuel Burned and Electric Power Purchased

Table 4 illustrates data on fuel use and power consumption for a plant rendering 100,000 t/yr of raw material. The values shown were calculated from additional survey data published by Lopez and colleagues (2010). Their article reports these data in terms of energy use per tonnes of rendered product and provides additional details on the survey participants and variability of response data.

To use the carbon footprint calculator, data on individual fuel and power consumption for an individual plant must be entered in the units specified so that subsequent calculations will be done correctly. The data input must include all electric power used and all fuel burned on-site except for fuel accounted for already in table 3. Annual quantities of grease and fat burned on-site are entered along with other fuels. If methane is produced by anaerobic wastewater treatment and burned on-site, it is not entered here, but is accounted for later in wastewater calculations. Electricity generated on-site is accounted for by entering data on the fuel consumed to generate it.

Table 4 shows CO_2 emission equivalents when each fuel is burned in a rendering plant or consumed at a utility plant to produce electricity. With the exception of animal fat and grease, these values were calculated from life cycle inventories published by the NREL (2010). Production of nitrous oxide (N_2O) and methane (CH_4) and their CO_2 equivalent (CO_2eq) factors were included in the calculations. On a mass basis, with a 100-year time horizon, CH_4 is estimated to have 23 times the global warming potential (GWP) of CO_2, and N_2O has a GWP nearly 300 times higher than CO_2 (U.S. EPA 2009). Despite these high factors, the NREL emission data indicate that contributions from N_2O and CH_4 are negligible to two significant figures for all fuels listed.

CO_2 emission factors for grease and fat were estimated from average composition data (Lopez et al. 2010) and stoichiometric calculations, assuming complete combustion. The breakdown of power generation by type of fuel corresponds to the U.S. grid average as reported by the NREL (2010). Life cycle data reported by the NREL for electricity production at hydroelectric or nuclear power plants indicate that CO_2eq emissions from these sources are negligible to three significant figures compared with emissions from other sources of purchased electricity and to fuel-burning contributions at a rendering plant. Renewable fuels and "other" means of generating electricity are also assumed to contribute negligible net CO_2 to the environment compared with the other contributions in this analysis.

Data Input on Wastewater Treatment

The flow rate and concentration of wastewater from a rendering process can vary considerably with time and from one rendering plant to another. Carbon in the organic compounds that go to wastewater treatment has three potential fates:

- aerobic conversion into CO_2,
- anaerobic conversion into methane, or
- aerobic or anaerobic conversion into solid biomass.

Aerobic wastewater treatment is used more often in rendering plants than anaerobic treatment. The most common measure of organic concentration in wastewater is biological oxygen demand (BOD), which is the amount of oxygen consumed by aerobic microbiological reactions that occur when the waste is degraded, primarily into CO_2 and water. A related quantity, carbonaceous BOD (CBOD), excludes oxidation of organic nitrogen, so CBOD is the most direct indicator of potential CO_2 emissions. A third alternative, chemical oxygen demand (COD), can be determined quickly, but like BOD, it usually includes contributions from nitrification and other oxygen-consuming reactions that do not produce CO_2. The COD:CBOD ratio depends on the specific composition of the waste, but 1.5 is a typical value (Sindt 2010).

CBOD concentrations of individual waste streams produced in a rendering plant range from about 4,000 to 10,000 mg/l (Sindt 2006). Usually the CBOD concentration must be reduced to 10 to 25 mg/l by wastewater treatment before discharge. Each kilogram (kg) of CBOD entering aerobic waste treatment ultimately results in about 1.5 kg of CO_2 being released into the atmosphere (Sindt 2010).

Table 5 Data input on wastewater treatment for the rendering plant

CBOD into WWT	500 tonnes/year
% of C released as CH_4	0.2%

Note: CBOD = carbonaceous biological oxygen demand; WWT = wastewater treatment; C = carbon; CH_4 = methane.

Studies of municipal wastewater treatment systems by Czepiel and colleagues (1993, 1995) showed that emissions of CH_4 and N_2O from properly operated activated sludge systems are small. Mass emission ratios calculated from measured data were on the order of 10^{-3} for $CH_4:CO_2$ and 10^{-4} for $N_2O:CO_2$. In a more recent study, Ahn and colleagues (2010) showed that N_2O emissions can be up to an order of magnitude higher from treatment systems designed to maximize biological nitrogen removal from wastewater. With 100-year GWP factors applied, the results of Czepiel and colleagues indicate that CO_2eq emissions from aerobic treatment are about 5% higher than CO_2 emissions alone. In the worst case, the results of Ahn and colleagues would increase the CO_2eq estimate to 30% higher than CO_2 alone.

Anaerobic wastewater treatment plants use different microorganisms in an oxygen-deficient environment to convert organic compounds into a mixture of CO_2, CH_4, and other species. Properly operated anaerobic systems capture and usually burn the gases produced so that nearly all of the carbon in the wastewater is ultimately released to the atmosphere as CO_2. Thus anaerobic and aerobic treatment facilities have the same effect on CO_2 emissions unless significant quantities of methane are released to the atmosphere rather than being burned. If methane is released during wastewater treatment, the potential impact is much larger due to the higher GWP of CH_4 emissions.

Table 5 illustrates the wastewater treatment section of the carbon footprint calculator developed in this work. The calculator is set up to estimate the release of carbon dioxide equivalents from either aerobic or anaerobic wastewater treatment. The user must enter two quantities:

- the total annual amount of CBOD going into the wastewater treatment plant, and
- the percentage of carbon entering the wastewater treatment plant that is released to the atmosphere as methane.

The total annual amount of CBOD entering the wastewater treatment plant can be estimated by multiplying the daily average CBOD of the influent by the total annual flow rate. If these data are not available, an estimate of 0.005 t of CBOD/t raw material rendered should be used to estimate total annual CBOD (Sindt 2006). For aerobic treatment, the release of carbon as CH_4 should be estimated as 0.2% unless more accurate site-specific data are available. This default value will result in a calculated CO_2 emission equivalent that is 5% higher than simply converting all carbon to CO_2 and ignoring N_2O emissions. The result is consistent with the data of Czepiel and colleagues (1993, 1995). For anaerobic treatment systems that capture and burn CH_4, the suggested data input on CH_4 loss to the atmosphere is 5%, based on Intergovernmental Panel on Climate Change (IPCC) guidelines for estimating GHG emissions (Doorn et al. 2006). Anaerobic digestion typically converts 75% of the organic carbon that enters the system into biogas with a molar composition of 25% to 50% CO_2 and 50% to 75% CH_4 (Zhang et al. 2007). This implies that as much as 50% of the carbon mass entering an anaerobic treatment facility can be released as CH_4 if the biogas is not captured.

Calculation of the Carbon Footprint

Table 6 lists CO_2 emission equivalents that would result from the sample data shown in tables 3 through 5. Emissions due to transportation of raw materials and products were determined by calculating total annual fuel consumption from the input data and applying a diesel fuel emission factor of 3.0 kg CO_2eq/l fuel consumed (NREL 2010). A lower factor, 2.7 kg CO_2eq/l fuel, was applied to employee travel, assuming that this occurs in gasoline-powered vehicles (U.S. EPA 2005). The difference is inconsequential for the example shown because employee travel contributes only 2% of the total transportation-related emissions. The carbon footprint calculator can be easily modified to accommodate a more detailed breakdown of transportation modes and emission factors.

Emissions from fuel combustion in the rendering plant are determined by multiplying the annual consumption of each fuel by the corresponding emission factor shown in table 4. As noted earlier, burning of grease and fat recovered from rendered materials is included in tables 4 and 6 because it results in CO_2 emissions just like burning any other fuel.

Table 6 Carbon dioxide (CO_2) equivalent emissions (in tonnes per year) from rendering operations

CO_2 emissions from burning purchased fuel (Scope 1)	11,500
CO_2 emissions from burning grease and fat (Scope 1)	3,950
CO_2 emission equivalents from wastewater treatment (Scope 1)	780
CO_2 emissions from company-controlled vehicles (Scope 1)	3,390
CO_2 emissions attributed to purchased electricity (Scope 2)	4,380
Total CO_2 emission equivalents (Scope 1 only)	19,600
Total CO_2 emission equivalents (Scopes 1 and 2)	24,000
Total carbon in raw material rendered (as CO_2) (based on an average of 76 weight percent carbon in fat and 27 weight percent carbon in protein)	79,000

CH_4 captured from anaerobic wastewater treatment and burned on-site is not included in the fuel use calculations, but it is accounted for as wastewater treatment emissions in table 6. The calculator first applies the cited factor of 1.5 kg CO_2 generated/kg CBOD entering wastewater treatment. If the default value of 0.005 t CBOD/t raw material has been invoked, the net result is that about 1% of the carbon that enters the plant leaves as emissions from wastewater treatment. The calculator applies the percentage release of carbon as CH_4 to calculate CH_4 emissions from wastewater treatment and multiplies this result by 23 to get CO_2eq (U.S. EPA 2009). It subtracts the CH_4 percentage from CO_2 emissions to maintain a carbon balance and assumes that the remaining CO_2 is released to the environment.

To determine CO_2 emission equivalents attributable to purchased electricity, the total kilowatt-hours (kWh) of electricity purchased is first apportioned to the different methods of power generation using the percentages provided. Each result is then multiplied by the factor that applies to the method of generation, and the emission equivalents are summed to provide the final result.

Results and Conclusions

Table 6 shows the carbon footprint of the rendering process illustrated by the composite data used in this study. Plant operations and related transportation emit 0.20 kg CO_2eq/kg rendered raw material or 0.46 kg CO_2eq/kg product. Including emissions attributed to purchased electricity adds 22% to each of these ratios. In total, Scope 1 and Scope 2 emissions are equivalent to converting 30% of the carbon that enters the plant into CO_2 and releasing it to the atmosphere.

In the hypothetical plant illustrated, fuel burning accounts for 79% of the Scope 1 emissions, transportation contributes 17%, and wastewater treatment contributes only 4%. Fuel combustion is likely to be the dominant source of GHG emissions in any rendering operation. It should be noted, however, that anaerobic wastewater treatment has the potential to increase CO_2eq emissions substantially if all of the CH_4 generated is allowed to escape.

Furthermore, it should be noted that this article does not consider the important issues of multifunctionality, allocation, and system expansion. If the rendering process is compared with other alternatives with similar or overlapping functions, these matters should be addressed.

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Note

1. One tonne (t) = 10^3 kilograms (kg, SI) $\approx$ 1.102 short tons.

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Rendering and Its Role in Capturing Carbon Emissions

June, 2012

Overview

Congress has begun deliberations on instituting a national policy to reduce greenhouse gas (GHG) emissions while promoting clean technologies and economic growth. Numerous proposals have been introduced to date with most creating a cap and trade scheme based upon emission allowances.

A major factor in all of these discussions has been cost-containment and the need to minimize impacts on families and businesses. Most legislative proposals being debated allow for some type of offset program for projects that reduce, avoid, or sequester greenhouse gas emissions. Such a program would allow for these qualified, permanent emission reductions to count as emission "credits" and would assist covered entities in reaching compliance while promoting innovation in emission reduction.

Rendering and its Role

Rendering should be recognized as an important greenhouse gas avoidance technology. It is the process of converting animal byproducts into fats and proteins. Through the rendering process, inedible wastes that are rich in carbon and nitrogen are recycled into useable materials. The rendering process also averts the release of carbon dioxide and other GHGs that would otherwise be released into the air through the normal decomposition process. Rendering is the most efficient and environmentally sound disposal alternative.

Carbon Removed in the Form of Rendered Products

	Production (metric ton)	% Carbon	Carbon, (metric ton)	CO_2 (metric ton)	CO_2 (US ton)
BFT (animal fat)	4,515,600	75.89%	3,426,889	12,566,516	13,852,070
Meat and bone meal	2,314,600	24.27%	561,661	2,059,629	2,270,329
Poultry by-product meal	1,153,500	28.68%	330,801	1,213,057	1,337,153
Feather meal	600,900	37.50%	225,350	826,364	910,901
Pork meal	720,711	25.59%	184,427	676,300	745,486
Blood products	102,512	37.50%	38,444	140,976	155,397
Total all products	9,407,823		4,767,571	17,482,842	19,271,337

If all carbon in these waste products were expressed as CO_2, using the EPA estimate of 5.46 metric ton per car, failure to remove these products from the waste stream would be **the same as adding 3,201,986 cars to the nation's roads.**

However, if 20% of the carbon in decaying organic material is expressed as methane and 10% of the nitrogen is expressed as nitrous oxide, then removing these products from the waste stream (because these greenhouse gasses have global warming potentials that are substantially greater than CO_2) would be **the same as removing 12,263,316 cars from the nation's roads.**

Nitrogen Removed in the Form of Rendered Products

	Production (metric ton)	% protein	N (metric ton)	N (US ton)
Meat and bone meal	2,314,600	55%	203,685	224,522
Poultry by-product meal	1,153,500	65%	119,964	132,236
Feather meal	600,900	85%	81,722	90,083
Pork meal	720,711	58%	66,882	73,724
Blood products	102,512	85%	13,942	15,368
Total protein meals	4,892,223		486,195	535,933

Additionality—What More Could Be Done?

Approximately 60 percent of the cattle that die each year in the U.S. are not rendered, the bulk of which are deposited in landfills or otherwise left to decompose. According to the U.S. Department of Agriculture, approximately 4.3 million cattle died in 2007 (as in most typical years). Based on GHG measurements taken from composting studies, adding one metric ton of cattle carcasses to the compost pile, results in 2 metric tons of CO_2 equivalents produced over and above any gases produced by decomposition of manure, bedding or other organic material in the pile. If GHG production is similar when carcasses decompose naturally in the environment, one adult dairy cow might be expected to add 1.2 metric tons of CO_2 equivalents to the environment. Accounting for the discrepancy in mature cattle deaths vs. calf deaths, the resulting release of CO_2 emissions from cattle not already rendered is approximately 537,000 tons per year. Using the Environmental Protection Agency's estimate for average emissions for vehicles, providing the incentives to render these additional animals would equate to taking an additional 89,000 cars off the road each year.

These estimates, however, assume that no methane or nitrous oxide gases are emitted during the decomposition process. If 20% of the carbon is released as methane rather than CO_2 and 10% of the nitrogen in a carcass is given off as nitrous oxide, the annual global warming potential for carcasses that are not rendered increases to 2.3 million tons (2.1 million metric tons) or the equivalent emissions of approximately **another 376,000 cars.**

Recommendation

As Congress continues to consider the implementation of a national cap and trade scheme, the rendering industry should be considered a viable source of emission offsets. Allowing the rendering industry to participate would create financial incentives for farmers and ranchers to properly dispose of dead animals while avoiding additional greenhouse gases, reducing concerns over the spread of disease and freeing up limited landfill space. Also, discriminating against products already recycled through rendering as "not new," but recognizing protocols for placing fallen animals in anaerobic digesters or in landfills to trap and burn off the methane produced as "new", would put rendering at a competitive disadvantage and drive these organic materials to a much less productive and environmentally advantageous end. The result would be awarding offsets for shifting carbon from recycling to disposal with no net reduction (and a probable increase) in greenhouse gas emissions.

Reference: C. H. Gooding. *Data for the Carbon Footprinting of Rendering Operations*. 2012. Journal of Industrial Ecology. Vol. 16, No. 2.

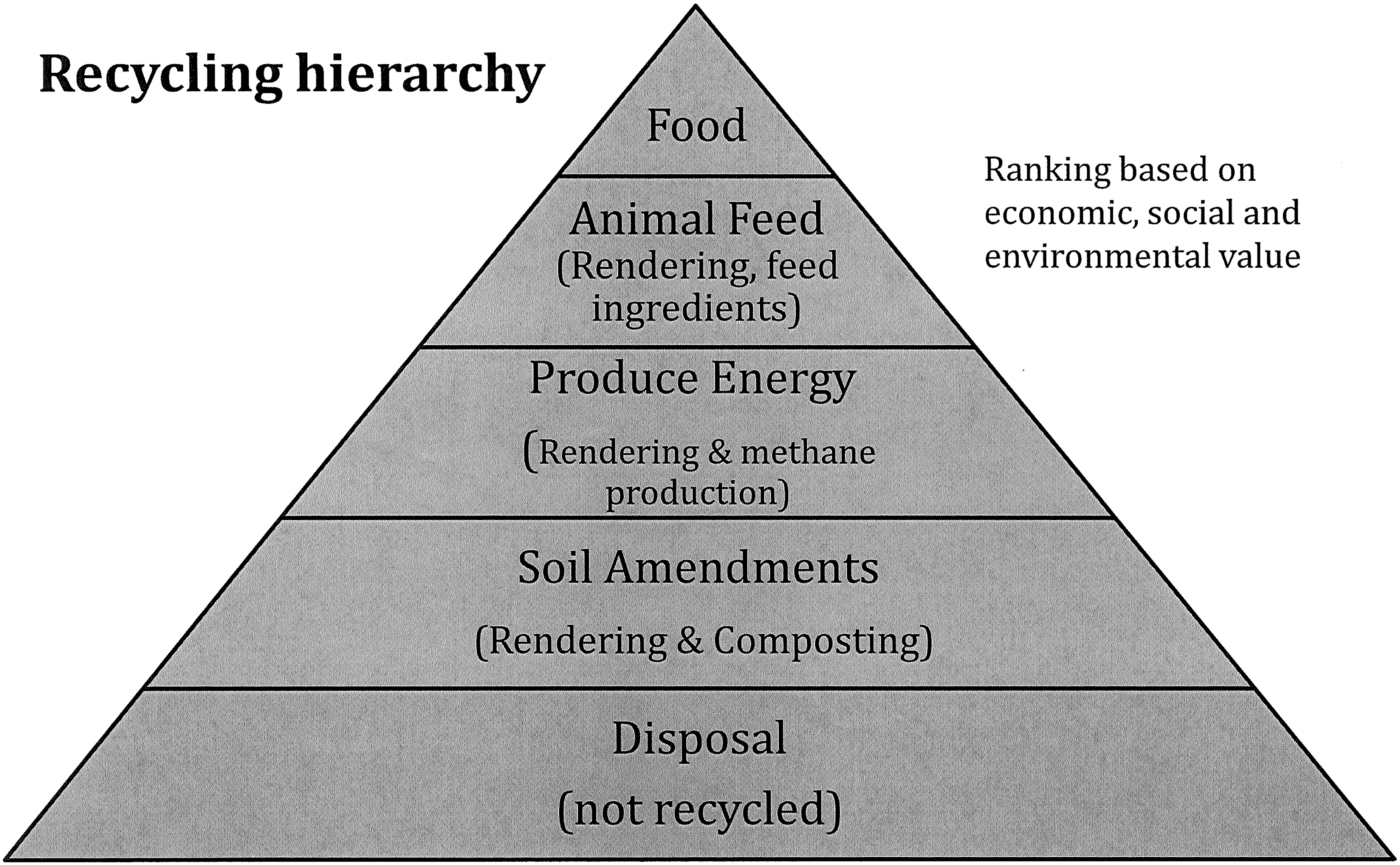
HOW RENDERING COMPARES TO ALTERNATIVES[1]

Item	Composting	Digester	Rendering
Controlled consistent process?	Little	Moderate	Full control
Timely processing of raw materials?	Weeks/months	10 + days	Same day
Take surges/changes in raw materials?	Limits	Limits	Routine
GHG emitted?	Yes	Co_2	Avoided
Wastewater controlled?	Not all	Yes	Yes
End products regulated?	Minimal	????	Yes
Safely handle **inedible** meats?	No	No	Yes
Process regulated?	Little	Little	Yes
Kills pathogens reliably?	Spotty	Not all	Yes
End products safe for animals	Hazard[2]	NA	Yes[3]
Solids suitable for land application?	Fertilizer	Toxic to plants?[4]	Fertilizer
Source of biofuel	Uses energy[1]	Yes	Yes
Sustainable	For plant material	Not if energy cheap	> 100 years old

[1] Compost and digester comparisons from Mata-Alvarez and Llabres, 2000
[2] If meat included in compost, potential violation of 21CFR 589.2000/2001 & Swine Health Protection Act
[3] Use for animals regulated. Certain products can not be fed to cattle and other ruminants
[4] Volatile fatty acids present in effluent may be toxic to plants..

FOLLOW THE VALUE PYRAMID WHEN CHOOSING WASTE REDUCTION OPTIONS

Recycling hierarchy



Ranking based on economic, social and environmental value

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ORIGINAL PAPER

Greenhouse gas emissions during co-composting of cattle mortalities with manure

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Abstract Following outbreaks of bovine spongiform encephalopathy (BSE), fewer cattle mortalities are being rendered. Composting may be a viable on-farm alternative for disposal of cattle carcasses. A study was conducted to assess feasibility and greenhouse gas (GHG) emissions during co-composting of cattle mortalities and manure. Using a tractor-mounted front-end loader, windrows were constructed containing manure + straw (control; CK) or manure + straw + cattle mortalities (cattle mortality; CM). The composting process lasted 310 d. The windrows were turned twice, at days 93 and 211, using either a tractor-mounted front-end loader or a specialized shredder bucket. Maximum windrow temperatures were >50 °C for 36 out of 92 d (before first turning) and 142 out of 208 d (after first turning) for the CM treatment and cattle mortalities were completely decomposed except for a few large bones. The cumulative CO_2 and CH_4 emissions were significantly affected by the mortality treatment, but not by the turning technology or their interactions. Significantly higher CO_2 (53.6 g d^{-1} m^{-2}) and CH_4 (2.204 g $d^{-1}m^{-2}$) emissions were observed during the co-composting of cattle mortalities than manure composted with straw (23.0 and 0.742 g $d^{-1}m^{-2}$ for CO_2 and CH_4, respectively). Similarly, N_2O emissions were higher with mortalities than without and, for the CM treatment only, higher with shredder bucket than front-end loader turning. In the final compost, CM had higher TN and NH_4^+-N contents than CK while TC and the C/N ratio were higher with compost turned with the front-end loader than with the shredder bucket. In conclusion, composting was an effective means of disposing of cattle mortalities, but did increase GHG emissions and the N content in the final compost. It is not known if GHG emissions are different than those that would be released from natural decomposition of carcasses. The higher N content in compost containing mortalities would increase its agronomic value.

Keywords Greenhouse gas emissions · Cattle mortality · Compost windrow technology · Beef feedlot manure · Compost quality

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Introduction

Following outbreaks of bovine spongiform encephalopathy (BSE), Canadian rendering companies have imposed a surcharge for the collection of cattle mortalities from farms and feedlots. This surcharge has caused many cattle producers to cease using the service and as a result the amount of beef cattle mortalities entering the rendering process in Alberta has dropped by almost 50% (West Coast Reduction, personal communication, 2006). The mortality rate in feedlots averages 1.26% (Loneragan et al. 2001), and proper disposal of carcasses is important to prevent livestock disease transmission and protect air and water quality.

Under proper management, composting appears to be a viable disposal method (Murphy et al. 2004) since the temperature attained during this process (>55 °C) is sufficient to kill many microbial pathogens (Larney et al. 2003; Van Herk et al. 2004; VanDevender and Pennington 2004). Composting of carcasses using windrows, static piles, and bins or vessels has been investigated for sheep, swine and poultry (Fulhage and Ellis 1996; Glanville 1995; Keener et al. 2000; Langston et al. 1997; Lawson and Keeling 1999; Stanford et al. 2000; Fonstad et al. 2003; Zhang and He 2006). However, despite being an attractive potential disposal method, composting of cattle mortalities has only recently been investigated (Bagley et al. 1999; Mukhtar et al. 2003; Genaille et al. 2005).

Little is known about the effect on compost nutrient composition or greenhouse gas (GHG) emissions when cattle mortalities are included with manure. We do know that GHG emissions during composting reduce the agronomic value of the compost and contribute to global warming. Every year 150,000 Mg CH_4 and 17,000 Mg N_2O are emitted from livestock manure in Canada, accounting for 2.9% of total CH_4 and 12.1% of its total N_2O emissions (Environment Canada 2004). Hao et al. (2004) reported that 40 to 54% of initial TC was lost during feedlot manure composting, mostly as CO_2, with CH_4 accounting for <14%. In Nebraska, NH_3 volatilization accounted for 19 to 42% of total N lost, and CO_2 loss was between 46% and 62% of total C during feedlot manure composting (Eghball et al. 1997).

Compost windrow turning technologies may also affect GHG emissions and nutrient loss. A tractor with a front-end loader is often used to construct and turn compost windrows (Hao et al. 2001; Fonstad et al. 2003; Mukhtar et al. 2003). A more expensive but less commonly available alternative is a windrow turner which mixes the manure more thoroughly and breaks up large manure clumps. This could shorten the time required to complete the composting process.

Stanford et al. (2005) have shown that whole cattle carcasses can be successfully composted during winter. The objectives of this study were to investigate co-composting of mature cattle (>30 months) carcasses with cattle manure under cold winter conditions using two windrow turning technologies and determine the impact on greenhouse gas emissions and final compost properties.

Materials and methods

Experimental design

The study was conducted on a commercial feedlot near High River, Alberta (50°35′N, 113°52′W, elevation 1219 m) in a semi-arid climate. The experiment was initiated on Nov 22, 2004 and completed on Sept 28, 2005 (310 d). Approximately 36 cm depth of barley straw was placed on the ground surface (about 2 m wide, 30 m long) prior to construction of the control (CK) and cattle mortality (CM) compost windrows. For the CM compost windrow, 24 partially frozen mature cattle carcasses (from animals that had died of natural causes such as pneumonia or bloat) were laid on top of the straw. The carcasses were placed side-by-side and then completely covered with fresh cattle manure (mixture of feces, urine and straw bedding) cleaned from adjacent feedlot pens. The windrow consisted of 88.3% manure, 1.5% straw and 10.2% cattle carcasses (based on a fresh weight), and were initially about 2 m high. The control windrow was constructed in an identical manner but without carcasses. Both windrows were constructed using a tractor with a front-end loader (John Deere RL 5621). (Similar equipment is available on most farms in the area.)