SCHOOL OF SUSTAINABLE ENGINEERING AND THE BUILT ENVIRONMENT

CESEM
Center for Earth Systems Engineering and Management

Finding Your Dog's Ecological 'Pawprint': A Hybrid EIO-LCA of Dog Food Manufacturing

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SSEBE-CESEM-2013-CPR-005
Course Project Report Series

May 2013

Executive Summary

Many relationships exist between humans and their animal companions. Regardless of the relationship, the costs of pet ownership are more than just veterinary bills and the purchase of pet food. The purpose of this study is to examine the environmental impacts associated with ownership of *canus lupus familiaris*, more commonly known as the domesticated dog. Since dogs are carnivorous by nature, there has already been significant interest in the ecological 'pawprint' of pet food, or the pressure that dog food production exerts on the environment.

This study utilizes Life Cycle Assessment (LCA) to determine the environmental impacts of industrial pet food production and furthermore, pet ownership through nutritional requirements. Additionally, this study aims to examine how pet food type—beef or lamb—can influence greenhouse gas (GHG) emissions. The approach taken by this study is that of a hybrid input-output LCA, combining Economic Input Output (EIO-LCA) data and process-level data to examine how supply chain decisions made by pet food manufactures can affect the ecological 'pawprint' of the domestic dog. The EIO-LCA provides an economy-wide lens, whereas, process-based LCAs provide data relevant to specific materials and processes. This approach was used to compare the environmental impacts associated with environmentally friendly supply chain decisions compared to the typical environmental impact of dog food.

1.0 Introduction

Relationships between humans and animals are complex and multifaceted. Some of the factors that influence the relationship between humans and their companions are sustenance, culture, geography, wealth, psychology, mobility and disability, health, and therapy. Due to the extensive role that animals play in human societies across the globe, it is critical to understand the potential environmental impacts and degradation associated with the maintaining a happy and healthy quality of life for pets. While much of the literature has focused on the sustenance aspect of human-animal interactions—the environmental impact of the animals we eat. However, this is not the only way that humans interact with animals. Researchers have estimated that Americans own approximately 78.2 million dogs[1], which necessitates further understanding surrounding the environmental impacts of pet ownership.

Numerous studies in the literature detail the environmental impacts of animal feed and livestock production (Jungbluth, Hartung, & Brose, 2001; Melse & van der Werf, 2005; Monteny, Bannink, & Chadwick, 2006). For example, Monteny *et al.* (2006) has shown that cattle husbandry is one of the most significant sources of methane gas emissions associated with agricultural production. Further, many researchers have studied the environmental impacts of human diet choice, specifically the differences in resource and greenhouse gas (GHG) intensity between omnivorous, vegetarian, and vegan diets. One study that performed a life cycle assessment (LCA) of the 'Finnish' lunch plate concluded that "responsible" consumers should increase their intake of vegetables and thereby decrease meat intake if they wish to reduce the GHG intensity of their diet (Virtanen et al., 2011). Further, a meta study of 52 food protein LCA's found a 2-log difference between the most GHG intense food proteins (beef) and the least GHG intense food proteins (meat substitutes and pulses) (Nijdam, Rood, & Westhoek, 2012). Since dogs are primarily carnivorous, these studies call into question the environmental impact of domesticated animals, like dogs.

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[1] The Humane Society of the United States. Accessed 3 May 2013. URL:
<http://www.humanesociety.org/issues/pet_overpopulation/facts/pet_ownership_statistics.html>

Studies similar to Nijdam *et al.* (2012) provide interesting insight into the potential environmental impact of pet ownership via industrial pet food production. To date, little research has been done on the topic except for a handful of previous studies. In 2010, a husband and wife team of sustainable architects from New Zealand, Robert and Brenda Vale, published a book, "Time to Eat the Dog?" that studied the environmental impacts of pet ownership in Western countries. The Vale's book and the subsequent press coverage in the *New Scientist* caused uproar among pet owners. The article concluded "[…] a medium size dog has roughly the ecological footprint of a Toyota Land Cruiser" (Rastogi, 2010). However, many have argued that the methodology and ecological footprint generated by the Vales is flawed due to assumptions relating to system boundaries and allocation. The goal of this study is to develop a better understanding of the environmental impacts of industrial pet food production and pet ownership. Further, this study seeks to understand pet brand or type can influence GHG emissions at the household-level.

Using the previous work done the as a starting point, this study investigates two areas of the pet food manufacturing process: how do *supply chain decisions* or *energy productions systems* generate the most reductions in relation to environmental impacts associated with industrial pet food manufacturing?

2.0 Identifying the analysis scope and methodology

2.1 Goal and Scope Definition

The purpose of this study is to examine supply chain and energy production associated with pet food manufacturing. These managerial decision and the associated environmental impacts are compared to the national average environmental impact of pet food manufacturing through the use of Economic Input Output EIO-LCA analysis. EIO-LCA was "theorized and developed" by Wassily Leontief and then later operationalized in the mid 1990's by Carnegie Mellon University's Green Design Institute (Carnegie Mellon University Green Design Institute, 2008). Therefore, the scope of this study includes the entire U.S. economy and its interaction with the supply chain of dog and pet food manufacturers. The results generated through EIOLCA.net provide insight to the direct and indirect relative impacts of the dog and

cat food manufacturing industry "[…] with respect to resource use and emissions throughout the supply chain" (Carnegie Mellon University Green Design Institute, 2008).

2.2 Methodology

A hybrid EIO-LCA is utilized in this study to understand the environmental impacts of pet food manufacturing at the national level and to model the environmental impacts of a hypothetical pet food manufacturing facility. Process-level data are used for impact analysis when managerial decisions cause the hypothetical pet food manufacturing facility to differ than a typical facility. EIO-LCA and the model building the Green Design Institute at Carnegie Mellon University rely upon US-economy wide Bureau of Labor Statistics (BLS) data and capture the economic interconnections throughout the supply chain among economic sectors and the associated environmental impacts.

However, the primary limiting factor associated with the EIO-LCA model is that model is only as current as the underlying data that describes the inputs and outputs of the US economy. In the case of the Carnegie Mellon EIO-LCA model for the US economy, the most current model is for 2002 BLS data. Especially in industries that rely upon innovation for growth, such outdated data could pose a hindrance to using the EIO-LCA model. Secondly, if the economic activity of interest belongs to a North American Industry Classification that contains many other activities, it may be difficult or impossible to disaggregate the data so that it is appropriate to the activity under analysis. For example, in the EIO-LCA model the NAICS code that contains gold mining also contains sliver and other ore mining activities, which creates an obstacle in analyzing just gold mining operations.

Fortunately, for the purposes of this study the EIO-LCA model contains a specific entry for dog and pet food manufacturing. We make several simplifying assumptions that allow the direct use of EIO-LCA output data. First, dog and cat food manufacturing make up the overwhelming majority of pet food manufactured and consumed in the United States. In data published by PetfoodIndustry.com, dog and cat

food sales comprise 94% of the global pet food market—58% and 36% respectively.[2] Though cat food typically contains a greater protein content than dog food, since dog food dominates the global pet food market, pet food sector input-output data will more closely resemble dog food inputs and outputs than that of cat food. Additionally, we assume that a pet food manufacturing facility produces only dry or wet food. For this study, we analyze dry food only. Secondly, pork is an uncommon pet food ingredient—for both dog and cat food—so the NAICS industry listing for "Animal production, except cattle and poultry and eggs" represents mostly sheep- and mutton-based animal inputs.

The hybrid EIO-LCA developed for in this report was to create an attributional LCA (ALCA) of beef- and lamb-based dog food in order to assess the environmental tradeoffs between the two protein sources and the tradeoffs between selected offal cuts and lean cuts for pet food processing.

2.3 Functional Unit Selection

This study utilizes two functional units to capture the environmental impacts of dog food manufacturing—one functional unit from the perspective of a pet food manufacturer and the other from the perspective of a dog owner and the amount of dog food consumed in one year.

In order to define our functional units, we researched a particular pet food manufacturing plant to understand its production capacity and energy consumption. A profile on the studies of the Nestle Purina Pet Care Company pet food manufacturing facility in Flagstaff, Arizona cite an annual production capacity of 220,000 tons of dog food, which for the purposes of this analysis is dry dog food (Ferguson, 2010). Manta.com, a small business directory, estimates the annual revenues the Nestle Purina Pet Care Company pet food manufacturing facility in Flagstaff, Arizona to between $100 and $500 million.[3] For this report, we used the midpoint estimate of $300 million in annual revenues. We used the $300 million midpoint estimate as input into the EIOLCA.net model and then divided the model output by tons

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[2] Jessica Taylor (2012), "Market Breakdown: A global petfood update by region." Accessed 3 May 2013. Retrieved from: <http://www.petfoodindustry.com/Market_Breakdown__A_global_petfood_update_by_region.html>
[3] Manta.com. Accessed 3 May 2012. Url: <http://www.manta.com/c/mm2yb1c/nestle-purina-pet-care-co>

produced per year and kilograms produced per year to provide functional units that are relatable to the

dog food consumer.

To create a functional unit relevant to pet food manufacturers, the kilograms of dog food each

year were normalized to kilograms of meat required to produce the dog food with a specific protein

content. By normalizing dog food mass to protein content, we were able to determine the amount meat

required—by both animal and type—to produce dog food. By understanding the amount of meat required

to produce a given amount of dog food, we can better understand the supply chain impacts of meat

selection.

2.4 System Boundary

The system boundary with respect to EIO-LCA is that of the entire U.S. economy. Based on the

EIO-LCA data we looked at the impact implications with respect to supply chain decisions and power

generation decisions. The pet food production firms' management controls each of these decisions.

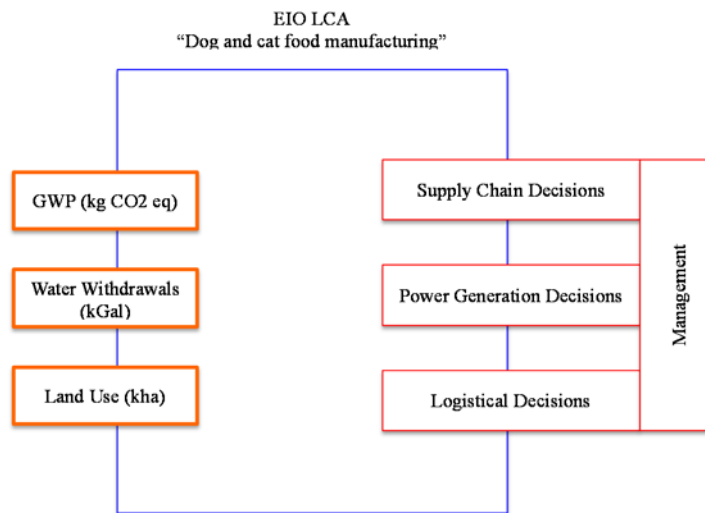Figure 1 (below) contains an illustration and description of the system boundary.

Figure 1. System Boundary Diagram with respect to EIO-LCA of "Dog and cat food manufacturing", management, and impact categories of concern. The EIO-LCA data utilizes data from the Bureau of Labor Statistics to determine purchases between sectors to provide a nationwide view in relation to the associated environmental impacts. Therefore the Blue box represents the system boundary of the entire U.S. economy. The Red boxes represent management decisions facing Industrial Pet Food manufacturers. In relation to the supply chain decisions, we have assessed them in terms of their environmental impacts, which is indicated through the Orange

boxes. Power Generation decisions were only analyzed in terms of GWP, whereas supply chain decisions have been assessed with respect to GWP, Water Withdrawals, and Land Use. EIO-LCA data was used to assess impact categories in relation to cattle, whereas Ecoinvent data was used in relation to sheep. The EIO-LCA data was last updated in 2002, whereas the Ecoinvent data was last updated in 2010 (v2.2).

2.5 Life Cycle Inventory Data Sources

EIO-LCA results were for the dog and pet food manufacturing industry from EIOLCA.net (Carnegie Mellon University Green Design Institute, 2008). Process specific data were obtained from the Ecoinvent life cycle database. These data were used to help determine the impact of beef- and lamb-based dog food on global climate change, water resources, and land use.

	Impact category	Units	Data Source	Description
Cattle	GWP	kg CO_2 eq	eiolca.net	• Based on $300 million USD of revenue from industrial pet food production
Sheep	GWP	kg CO_2 eq	ecoinvent.org	• "sheep for slaughtering, live weight, at farm" [/kg] USA • IPCC 2007 – GWP 20a (9.4465 kg CO_2)
Cattle	Water Withdrawals	kGal	eiolca.net	• Based on $300 million USD of revenue from industrial pet food production
Sheep	Water Withdrawals	kGal	ecoinvent.org	• "sheep for slaughtering, live weight, at farm" [/kg] USA • ReCiPe Midpoint (E, H, & I) (0.046301 m3 = 0.012231 kGal)
Cattle	Land Use	kha	eiolca.net	• Based on $300 million USD of revenue from industrial pet food production
Sheep	Land Use	kha	ecoinvent.org	• "sheep for slaughtering, live weight, at farm" [/kg] USA • CML 2001 w/o LT (12.066 m^2 = 0.0012066 ha)

Table 1. Life Cycle Inventory Data Sources

3.0 Results

The section contains the results of our life cycle inventory for dog food manufacturing facility with $300 million of revenue by impact category—water withdrawals, land use, and global warming potential (GWP). While the EIOLCA.net model provides results for each sector of the US economy, we only display economic sectors that constitute at least 0.5% of the total impact for a particular category.

Inventory Analysis

3.1 Land Requirements

The results below indicate the economic sectors responsible for consuming 99.5% of the land requirements throughout the life cycle of dog food manufacturing. Many of the same categories that consume the greatest volumes of water throughout the dog food manufacturing life cycle also require the most land, namely ranching, farming, and the dog food manufacturing process. Interestingly, but not surprisingly, sectors that do require large area of land but not large volumes of water are those associated with packaging or paper products—forest nurseries, forest products, and timber tracts. In addition, animal production that is not cattle, poultry or eggs is top consumer of land. We have previously identified this category with sheep farming.

Table 2. Land requirements to produce 220,000 tons of dry dog food annually

SECTOR	Land Requirements (ha/year)	Land Requirements (ha/ton dog food)	Land Requirements (m²/kg Dog Food)	Land Requirements (m²/kg Protein)
TOTAL	**23,400**	**1.06**	**11.72**	**45.09**
Cattle ranching and farming	9,430	0.43	4.72	18.17
Grain farming	9,140	0.42	4.58	17.61
Oilseed farming	3,130	0.14	1.57	6.03
Logging	535	0.02	0.27	1.03
All other crop farming	435	0.02	0.22	0.84
Forest nurseries, forest products, and timber tracts	203	0.01	0.10	0.39
Animal production, except cattle and poultry and eggs	151	0.01	0.08	0.29
Dog and cat food manufacturing	128	0.01	0.06	0.25

Data Source: Carnegie Mellon University Green Design Institute, 2008

3.2 Water Withdrawals

The results below indicate the economic sectors responsible for consuming 99.5% of the volume of water consumed throughout the life cycle of dog food manufacturing. By far, grain farming is the most water intensive process in the life cycle of dog food, which is followed by power generation. Interestingly, the single process of dog and cat food manufacturing consumes quite a large volume of water, nearly as much as power generation throughout the life cycle of the manufacturing process and twice as much as traditional water intensive economic sectors like cotton farming, sugarcane farming, and cattle ranching.

Table 3. Water Withdrawals to produce 220,000 tons of dry dog food per year			
SECTOR	Water Withdrawals (acre-feet/year)	Water Withdrawals (acre-feet/ton)	Water Withdrawals (gallons/kg Dog Food)	Water Withdrawals (gallons/kg Protein)
TOTAL	**165,179**	**7.51**	**2,697**	**10,373**
Grain farming	145,158	6.60	2,370	9,115
Power generation and supply	6,844	0.31	112	430
Dog and cat food manufacturing	4,849	0.22	79	304
Cotton farming	2,038	0.09	33	128
Sugarcane and sugar beet farming	1,795	0.08	29	113
Cattle ranching and farming	1,620	0.07	26	102

Data Source: Carnegie Mellon University Green Design Institute, 2008

3.3 Global Warming Potential

Similar to the previous results, the economic sectors that have the largest GWP are those relating to the agricultural and livestock production of meats and grains for dog food, power generation and supply, and the process of dog and cat food manufacturing. Not surprisingly, the processes related to these economic sectors are central to the dog food manufacturing process—the cultivation and procurement of ingredients, the process of combining those ingredients into a product, and the power required to transform raw ingredients into a saleable product. What is notable is that while logging and forestry are some of the top land consuming processes associated with dog food manufacturing, they are not energy intensive process that emits large amounts of GHG's. However, the most impactful sectors at the top of the list are those associated with activities that support dog manufacturing process— transporting ingredients to the manufacturing facility, shipping the goods to market, fertilizers to grow

grains, and grain farming. Grain farming is both an direct and indirect dog food ingredient in that it is also cattle feed.

Table 4. Global warming potential of the manufacture of 220,000 tons of dry dog food annually				
SECTOR	Global Warming Potential (MT CO_2e/year)	Global Warming Potential (MT CO_2e/ton dog food)	Global Warming Potential (kg CO_2e/kg Dog Food)	Global Warming Potential (kg CO_2e/kg Protein)
TOTAL	**461,772**	**20.99**	**23.14**	**88.99**
Grain farming	124,000	5.64	6.21	23.90
Power generation and supply	78,500	3.57	3.93	15.13
Cattle ranching and farming	57,200	2.60	2.87	11.02
Oilseed farming	30,000	1.36	1.50	5.78
Dog and cat food manufacturing	24,300	1.10	1.22	4.68
Fertilizer Manufacturing	17,000	0.77	0.85	3.28
Oil and gas extraction	12,800	0.58	0.64	2.47
Truck transportation	12,600	0.57	0.63	2.43
Animal production, except cattle and poultry and eggs	9,430	0.43	0.47	1.82
Wet corn milling	8,990	0.41	0.45	1.73
Iron and steel mills	7,690	0.35	0.39	1.48
Petroleum refineries	6,990	0.32	0.35	1.35
Rail transportation	6,320	0.29	0.32	1.22
All other crop farming	4,310	0.20	0.22	0.83
Other basic organic chemical manufacturing	4,210	0.19	0.21	0.81
Coal mining	3,580	0.16	0.18	0.69
Pipeline transportation	3,440	0.16	0.17	0.66
Soybean and other oilseed processing	3,240	0.15	0.16	0.62
Alumina refining and primary aluminum production	2,980	0.14	0.15	0.57
Paper mills	2,900	0.13	0.15	0.56
Waste management and remediation services	2,370	0.11	0.12	0.46

Data Source: Carnegie Mellon University Green Design Institute, 2008

3.4 The Environmental Impact of Meat Selection

Just as with a human diet, meat plays a large role in the determining the environmental impact of a pet's diet. However, unlike a human diet where a person can pick and choose the food that best suits their dietary constraints or worldviews about food, pet food options are limited to pre-determined blends of ingredients by manufacturers. So, the decision for the pet owner that wishes to reduce the environmental 'pawprint' of their pets diet becomes one in which pet food blend contains the smallest amount of embedded GHG emissions. For the pet food manufacturer, the meat purchasing decision is one of least cost and suitability for the dog food recipes. Additionally, there must be an adequate amount of meat available to satisfy specific protein content requirements for the dog food. Some dog food brands, such as Nestle Purina One Beyond, market their meat selection choices as specific reasons why someone

should buy their product—for example, only using lean cuts instead of offal or other low quality cuts of meat.

In this study, using the Flagstaff Nestle Purina Pet Care Company facility as an example, we calculated the minimum annual protein requirement to produce 220,000 tons of dog food. With this information, we examined the differing meat requirements for cattle and sheep based on the average protein content of lean and offal cuts.

For both cattle and sheep, lean cuts have higher protein content than offal. A lean cut of beef averages around 24% w/w protein content, while cattle offal averages around 11% w/w protein content (Lawrie, 1998). The contrast in cuts in sheep is not as drastic: lean cuts average around 16% w/w protein content by weight, and offal a 11% w/w protein content (Jenkins & Leymaster, 1993). Using these values, we calculated the meat requirement to satisfy a protein demand of 57,200 tons per year and then found the associated GHG intensity. The per mass GHG intensity of cattle grazing and farming is 23.13 MT CO_2e/tons meat (Phetteplace, Johnson, & Seidl, 2001), while the per mass GHG intensity of sheep grazing and farming 4.85 MT CO_2e/tons meat. The sheep emissions factor was obtained from the Ecoinvent database. From Table 5, it is evident that lean cuts are preferable to offal with respect to life cycle GHG emissions and sheep is preferable to cattle with respect to life cycle GHG emissions.

Table 5. The GHG Consequences of Meat Selection

Production	220,000	tons / year
Protein Content	26%	
Protein Requirement	57,200	tons /year

Animal	Lean Meat (tons/year)	Offal (tons/year)	Emissions Factor (MT CO_2e/tons meat)
Cattle	238,333	520,000	23.13
Sheep	361,263	488,800	4.85

Animal	Lean Meat Emissions (MT CO_2e/year)	Offal Meat Emissions (MT CO_2e/year)
Cattle	5,513,386	12,029,207
Sheep	1,753,359	2,372,348

Animal	Lean Meat Emissions (kg CO_2e/kg dog food)	Offal Meat Emissions (kg CO_2e/dog food)
Cattle	27.63	60.27
Sheep	8.79	11.89

3.5 Influence of Facility Electricity Mix on the Environmental Impact of Dog Food

As shown in Table 5, the dog food manufacturing process is the 5th most GHG intensive process throughout the dog food manufacturing life cycle. Therefore, meat selection is just one option for reducing the environmental burden of pet food manufacturing. Energy upgrades and alternative energy systems installed to offset coal-fired electricity in traditional grid-mixes have the potential to reduce the GHG-intensity pet food manufacturing. The example dog food manufacturing facility in Flagstaff, Arizona has done just that. We analyzed the per kilogram GHG reduction of a power purchase agreement (PPA) that offsets 25% of grid electricity with renewable energy. Since a dog food manufacturing facility is part of a supply chain that consumes an order of magnitude more energy, our analysis initially focused on plant level reductions. Plant level reductions in the GHG intensity of a kg of dog food are illustrated in (Table 6) below. Offsetting 25% of grid tied electricity with renewable energy was found to reduce the GWP of a kg of dog food by 270 g CO_2e/kg dog food. At the life cycle scale, this reduction results in an approximate 1% reduction of GHG intensity across dog food produced by the facility.

Table 6. Potential Life Cycle GHG Reduction From Facility Renewable Energy Installation

	Energy Mix	
	100% AZ Grid	25% solar, 75% AZ Grid
GWP: kg CO_2e/year	212,486,120	159,364,590
GWP: kg CO_2e/kg dog food	1.065	0.799
GHG reduction potential: kg CO2e/kg dog food	-	0.27

4.0 Discussion

Through our analyses, we have gained some insight into the environmental consequences of particular supply chain decisions regarding protein type and quality and power generation decisions. Despite areas of uncertainty, as discussed in our data quality assessment, the results generated provide insight into various managerial decisions with respect to their environmental impact and feasibility. Based on our results we have generated a set of recommendations as they pertain to the production of dog food through industrial processes. We have also presented easily understandable information regarding consumer choices of industrial pet foods to provide insight into the environmental cost of pet ownership.

Our findings indicate that the supply chain decision to source protein from sheep is environmentally preferable in relation to its GWP (kg CO_2 eq), however this option has limits to its scalability in terms of land use requirements. One substantial finding of our analysis is that it is environmentally preferable to utilize lean meat, rather than offal, for pet food production. This is largely because there is a higher concentration of protein in lean meat in comparison to offal and therefore less is required to satisfy protein requirement of dog food.

4.1 Uncertainty

There is quite a bit of uncertainty around the production numbers because they are based on estimated revenues from a business research organization. Additionally, the transport numbers have uncertainty associated with them because we estimated shipping volume based on population distribution. This is tied to the assumption that there is an even distribution of pet owners by city. Another assumption

is the fact that the enterprise in question only ships to major metropolitan areas. Furthermore, our EIO-LCA data is anchored in 2002 Bureau of Labor Statistic (BLS) data, whereas the management decision data is from 2012.

5.0 Conclusions

As elucidated through the use of EIO-LCA, grain farming accounts for approximately 27% of overall global warming potential (GWP) associated with industrial dog food production. This is due to the fact that grain is an ingredient within dog food itself and as feed for animal husbandry, another ingredient in industrial pet food production. Through the assessment of power generation decisions, the production of onsite renewable energy reduced overall GWP. Our assessment revealed, that a PPA of 25% renewable energy generated an overall reduction in GWP of about 0.5% per annum (270 g CO_2e/kg dog food).

In regards to the findings of this assessment, we have developed a series of recommendations that would reduce the environmental burden of dog ownership through the process of industrial pet food production.

- Utilize a greater portion of lean meat in product formulation. Lean meat has a greater concentration of protein and therefore has a lower GWP than offal. Lean meat from sheep represents a substantial GWP savings.

- Due to varying husbandry practices, cattle production requires less land area to meet the protein requirements of industrial dog food production. However, the lessened pressure on land resource is counterweighted by the order of magnitude greater GHG-intensity with respect to lamb meat.

- A renewable energy PPA at the production facility is a good start to green the energy supply of the supply chain, but overall is a drop in the bucket. Pet food manufacturers, if they want to reduce the GHG footprint of their product, should exert pressure on their upstream supply chain to rely on less GHG-intensive forms of energy.

Future research within the realm of industrial pet food manufacturing could examine and compare the contribution of pet ownership to various activities associated with society, for instance, driving a car. This would help enable pet owners to understand the environmental burden of pet ownership through the lens of industrial pet food production. Perhaps this sort of consumer information would lead pet owners to own fewer or smaller dogs.

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