Sustainability Assessment of U.S. Beef Production Systems

Submitted by

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Executive Summary

Background

With increasing public concern and awareness of agricultural sustainability issues, comprehensive methodologies such as life cycle assessment are required to benchmark the beef industry and identify areas of opportunity for continuous improvement. To that end, the Beef Checkoff completed a retrospective sustainability assessment benchmark in 2013 by using Eco-efficiency analysis to compare the years 2005 and 2011. At the time of the analysis, the methodology used was the most up-to-date and comprehensive – indeed the analysis remains one of the only complete cradle-to-grave assessments of the U.S. beef industry. In 2015, a further refined version of the Eco-efficiency analysis was completed to incorporate new primary data sources from the beef value chain for the years 2011-2013. As the young and dynamic field of sustainability science continues to evolve, there is a need to adapt and update the methodologies used in life cycle and broader sustainability assessments of the beef industry.

Consequently, this project updated and expanded the original Eco-efficiency analysis to the SimaPro™ computational platform. The move to the SimaPro™ platform will allow for direct linkages with the Integrated Farm Systems Model (USDA-ARS), which is the simulation model that has been used to generate life cycle inventories from the feed production, cow-calf, and backgrounding/feedlot segments of the beef industry. Additionally, the SimaPro™ platform will allow for even more transparent reporting of our inventories and results to the broader life cycle assessment, sustainability science, and beef communities, which is key to advancing the field and benchmarking beef's sustainability. Finally, this project further expanded the economic sustainability evaluation of U.S. beef industry to include the direct, indirect, and induced economic activity and value that is generated from beef production.

Objectives

The objective of this project was to couple farm gate environmental footprints of beef production systems in the U.S. with post-farm processing and distribution to provide an update to the full Life Cycle Assessment (LCA) of beef production and consumption in the United States. Specifically,

- Adapt the existing LCA to the SimaPro™ computational platform to enable comparison of future performance against the 2011 baseline.
- Collaborate with the USDA ARS to create links between the Integrated Farm System Model and SimaPro™.
- Expand the economic analysis to include direct, indirect and induced economic activity and value added by regional beef production.

Methods

Life Cycle Assessment is a technique to assess the potential environmental impacts associated with a product or process by compiling a cradle-to-grave inventory of relevant energy and material inputs and environmental releases, evaluating the potential environmental impacts associated with identified inputs and releases, and interpreting the results to assist in making more informed decisions. Broadly, an LCA consists of four stages (**Figure 1**): 1) Define the goal and scope – including appropriate metrics (e.g. greenhouse gas emissions, water consumption, etc.); 2) Conduct life cycle inventories (collection of data identifying system inputs, outputs and discharges to the environment); 3) Perform impact assessment; 4) Analyze and interpret the results.

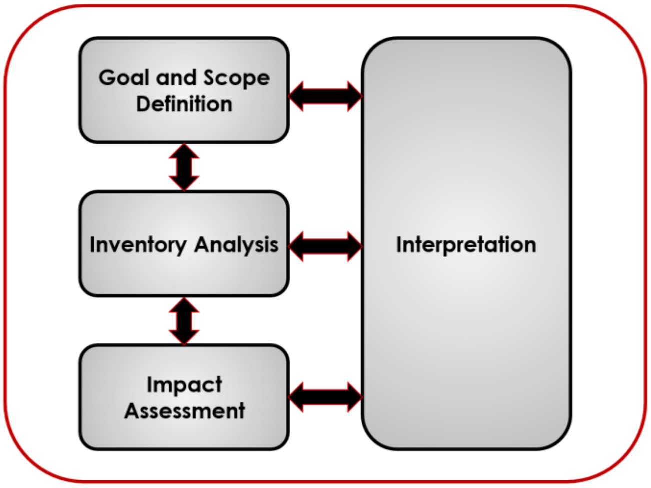

Figure 1. Stages of life cycle assessment (LCA)

We used data available in the first two Eco-efficiency analysis reports as well as other publicly available data and standard computational approaches to construct a life cycle inventory model of the beef production and consumption supply chain. We replaced proprietary background data with appropriate surrogates from publicly available and transparent lifecycle inventory databases, and we adapted the life cycle impact assessment methodology used by BASF in the original Eco-efficiency analyses as needed to the SimaPro™ modeling platform.

We used the IMPLAN multi-regional input-output model encompassing numerous aggregated sectors of the U.S. economy with state level economic transaction data to evaluate the contribution of the beef sector (production and processing) to the national economy. The model provides estimates of the direct (spending by cattle sector enterprises), indirect (non-cattle sector spending from enterprises primarily supporting cattle production), and induced (spending by wage-earning employees in the cattle sector) contributions to the economy.

Important Findings

We reproduced, using transparent and nonproprietary data sources, the major findings from the BASF report. Our results comparing the sector changes between 2005 and 2011 using both the

BASF and updated lifecycle model from this work showed significant agreement both in terms of directionality and magnitude.

The relative contribution of each segment of the beef value chain to each impact category (e.g., greenhouse gas emissions, consumptive water use) were largely in agreement with the previous Eco-efficiency analyses. For example, for both the prior analyses and the current project, 87% of carbon dioxide-equivalent emissions occurred in the pre-harvest segments of the industry, while 13% occurred post-harvest. Identifying where in the beef value chain impacts are occurring is one of the key advantages of LCA and allows the beef community to identify the areas of opportunity along the value chain. In the case of greenhouse gas emissions, the cow-calf segment is the segment with the largest contribution (**Figure 2**), with most of the segment's emissions coming from enteric methane emissions that are a part of the natural digestion process of cattle.

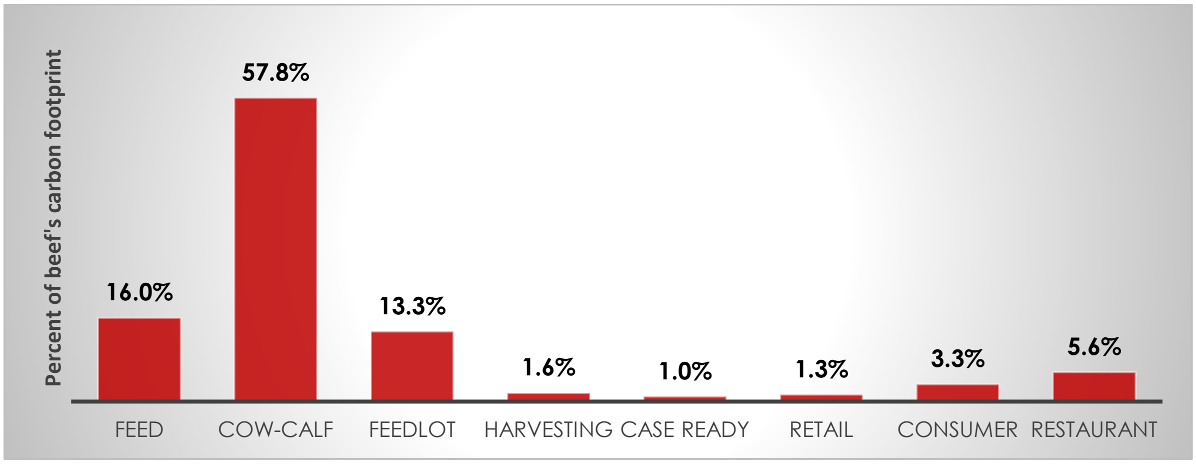

Figure 2. The global warming potential of one pound of edible, consumed beef distributed over each segment of the beef value chain for 2011-2013. Eighty-seven percent of the CO_2 equivalent emissions from beef production occur pre-harvest, with the single largest source of emissions being enteric methane emissions.

Additionally, LCA allows for an assessment of what impacts are within the control of beef producers, processing and case ready plant managers, retail and food service operators, and consumers, and what impacts lie outside of those individuals' and entities' direct control. For example, the fossil fuel combustion required to provide electricity to cow-calf and feedlot operators contributes to the acidification potential associated with beef production; however, beef producers have no control over the primary fuel sources for the electricity they purchase from a utility. Conversely, if a feedlot operator is growing a portion of the crops fed to their cattle, the operator has direct control over aspects that could reduce the impacts of feed production. Examples include changes such as adopting no-till practices, reducing synthetic fertilizer use by utilizing cattle manure as fertilizer, and improving irrigation water use efficiency.

Results of economic analysis show that, in 2014, the beef cattle production and processing industry directly contributed to the employment of nearly 883,000 workers across the U.S, resulting in more than $27 billion dollars in labor income and $58 billion in value added to the U.S. economy. **When indirect and induced impacts are added, the cattle industry's total contributions to the economy more than double to almost 2.1 million jobs, $92 billion in income and $165 billion in value added (Table 1)**. In other words, each cattle job generated almost 1.4 jobs in other industries. Each $1 of cattle industry labor income led to the creation of over $2 in labor income (often in high paying jobs) elsewhere. Finally, each $1 in value added generated by the cattle industry led to over $1.9 in value added somewhere else in the economy.

Table 1. The direct, indirect, and induced economic contributions of the cattle industry to the U.S. economy

Impact Type	*Employment*	*Labor Income*	*Total Value Added*
Direct Effect	882,862	$27,600,035,580	$58,129,513,474
Indirect Effect	506,485	$27,048,925,921	$45,677,141,364
Induced Effect	709,756	$37,263,144,089	$61,597,775,670
Total Effect	**2,099,103**	**$91,912,105,590**	**$165,404,430,508**

Implications

This work provides the framework for open and transparent assessment of sustainability metrics for the beef industry, and will enable rapid updating of data as well as scenario testing in the future. The new framework will allow data from the Beef Checkoff's regional sustainability assessments to be quickly integrated into the next national sustainability benchmark. This work also established the relative contribution of the beef production sector to the national and regional economies.

Lay Summary

Objectives:

- Adapt the existing LCA to the SimaPro® computational platform to enable comparison of future performance against the 2011 baseline.
- Collaborate with the USDA ARS to create links between the Integrated Farm System Model and SimaPro®.
- Expand the BASF economic analysis to include direct, indirect and induced economic activity and value added by regional beef production.

Outcomes:

- Our results comparing the sector changes between 2005 and 2011 using both the BASF and updated lifecycle model from this work showed significant agreement both in terms of directionality and magnitude.
- The cattle industry's total contributions to the economy, including direct, indirect and induced effects approaches 2.1 million jobs, $92 billion in income and $165 billion in value added.

Impact:

- The framework for open and transparent assessment of sustainability metrics for the beef industry has been established enabling rapid updating as well as scenario testing in the future.

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Sustainability Assessment of U.S. Beef Production Systems

1 Introduction

1.1 Project overview

This is the final report for the Sustainability Assessment of U.S. Beef Production Systems project. The objective of the study is to couple farm gate environmental footprints of beef production systems in the U.S. with post-farm processing and distribution to provide an update to the full life cycle assessment (LCA) of beef production and consumption in the United States (Battagliese et al., 2015).

1.2 Objectives

Specific tasks for this project are to:

Task 1: Adapt the existing LCA to the SimaPro® computational platform to enable comparison of future performance against the 2011 baseline.

Task 2: Collaborate with the USDA ARS to create links between the Integrated Farm System Model (IFSM) and SimaPro®.

Task 3: Expand the economic analysis to include direct and induced economic activity and value added by regional beef production.

2 Approach

Task 1: The information currently available from BASF Corporation's U.S. Beef Eco-Efficiency Analysis (EEA) study adapted from BASF's socio-eco-efficiency tool (SEEBALANCE®) platform to the SimaPro® platform. We deconstructed the BASF reports, as well as additional information provided by NSF International, BASF and the U.S. Department of Agriculture's Agricultural Research Service (USDA ARS), and constructed life cycle inventory datasets for each life cycle stage beginning with crop production and pasture through finishing, slaughtering, processing, distribution, consumption, and disposal. We utilized these information sources to construct post-processing datasets for distribution, retail, and consumption at home and at restaurants. We also reproduced, to the extent possible, the characterization models that BASF employed to perform a life cycle impact assessment (LCIA) for the impact categories covered in the eco-efficiency assessment (EEA).

Tas*k 2:* We have developed the initial framework for linking the output of the IFSM model to SimaPro® to enable more complete LCA including additional impact categories. This involved working with USDA (Al Rotz) to identify and understand algorithms within the IFSM so that the proper lifecycle inventory data are extracted.

***Task 3**:* We used the IMPLAN economic model of the US to estimate the direct, indirect and induced economic activity across seven regions and at national scale for US beef production.

2.1 Task 1 Approach

Our initial efforts to reconstruct and update the existing LCA in the SimaPro® platform identified many potential sources of disagreement between our preliminary results and those reported by BASF. To minimize the uncertainty, we constructed two separate models: a “radial” model and a “linear” model (Figure 1). The radial model was built using the Phase 2 Input Data spreadsheet, which had a complete set of life cycle inventory (LCI) data for unit processes in each supply chain stage of the Phase 2 EEA. This dataset allowed for a complete cradle-to-grave LCA model but was essentially a “black box”, meaning the underlying calculations and assumptions are not known. Despite the opaque nature of this approach, it allowed us to isolate the differences in our results from BASF’s that resulted from using a different database. It also allowed construction of the EEA impact assessment methods and testing them against the databases available in the SimaPro® environment. Once the impact of these sources of uncertainty was quantified, we could construct the linear model and test our assumptions. The linear model is a closer representation of the actual beef supply chain and utilized data from IFSM and other sources, enabling a deeper understanding of the underlying calculations that produced the results in BASF’s EEA.

Once the linear model was completed for 2005 and 2011, we used it to construct an updated version. The new model deviates from some of the modeling choices made by BASF in favor of common LCA practices and is adapted for impact assessment methods which are publicly accessible, internationally recognized, and compatible with the SimaPro® software platform. The updated version of the LCA model allows programmatic linkage between SimaPro® and

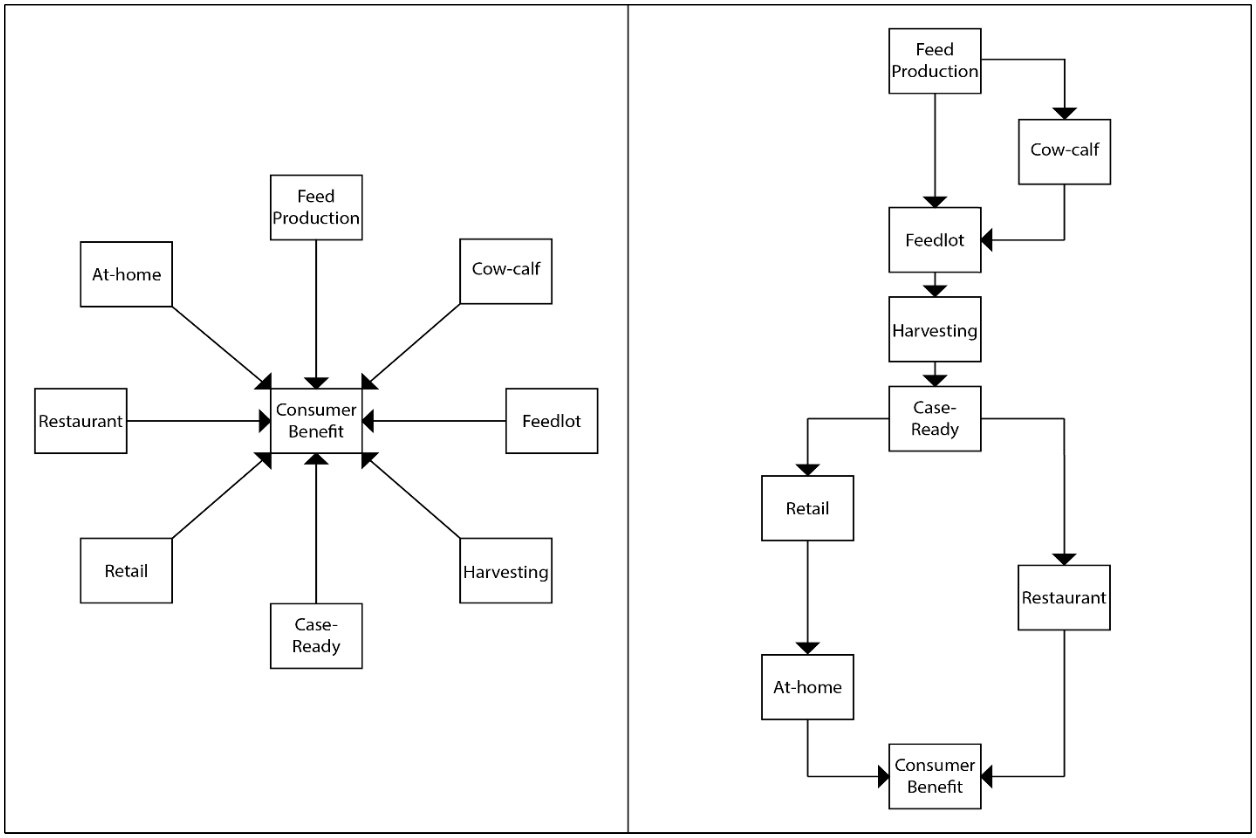

Figure 1.

Flowcharts representing the radial model structure with inventory flows directly normalized to the functional unit (left) versus the linear (supply chain) model structure, with linked reference flows to the functional unit (right).

IFSM, which will streamline scenario assessments, and assist in the comparison of future assessments.

2.1.1 Radial Approach

The raw inventory data supplied by BASF necessitated a modeling approach that was different from the flowchart presented in the EEA report. The reported inventory data are normalized to the functional unit, referred to as the “consumer benefit” by BASF. This method of reporting life cycle inventory data is not standard in existing databases where inventory flows are normalized to a reference flow which is specific to the unit process itself, and not already scaled to the functional unit. With knowledge of the carcass yields and food loss rates, it was possible to produce unit processes that can be utilized in the SimaPro® platform. Thus, this normalized LCI dataset enabled construction of a model that accurately replicated most the results presented in the Phase 2 report, but did not allow detailed evaluation of the underlying calculations and assumptions of BASF's EEA methodology presented in the Phase 2 report.

2.1.1.1 Life cycle inventory

The functional unit-normalized inventory provided by BASF were combined with Ecoinvent (2010) and US LCI (2011) unit processes (referred to as "eco-profiles" by BASF) that were identified in the EEA report. Ecoinvent and US LCI are commercially available LCI databases; however, the majority of data supporting BASF's eco-profiles comes from proprietary sources. From the information available, we identified what we believe to be comparable surrogates from Ecoinvent to bridge the data gaps in the SimaPro® model that resulted from BASF's reliance on proprietary data. Appendix A lists the background data sources used.

2.1.1.2 Characterization models

BASF's EEA methodology was validated under the NSF Protocol P352, which requires submission of a document outlining the methodological procedures. The validation document submitted to NSF (BASF 2015a) along with the Phase 2 report (BASF 2015b) provided literature citations for the models that were used to characterize the LCI for each of the 12 environmental impact categories covered in the EEA. Using these references, we could obtain the necessary information to implement 10 of the 12 impact characterization models in the SimaPro® platform. The characterization model references for each impact category are listed in Table 1.

Table 1. Characterization model references from our Model and those given for the EEA.

Impact category	**Characterization model**	
	BASF	***U of A***
Cumulative energy demand	No reference	Frischknecht et al., 2003
Consumptive water use		
Assessed	Pfister et al., 2009	Pfister et al., 2009
Absolute	Solley et al., 1998	Solley et al., 1998
Global warming	IPCC 2007 100a	IPCC 2007 100a
Photochemical ozone	Heijungs et al., 1992	Guinee et al., 2001
Ozone depletion	No reference	TRACI 2.1
Acidification	Saling et al 2002	TRACI 2.1
Water emissions	Wastewater Ordinance 2012	Wastewater Ordinance 2012
Solid waste	Klein 2011	H&W 1998
Land use	Koellner and Scholz,2008	Koellner and Scholz,2008
Human toxicity	Landsiedel and Saling, 2002	USEtox

Abiotic depletion potential	No reference	Rotz, CA 2016 pers. com.

2.1.2 Linear or supply chain modeling approach

To allow for a more detailed evaluation of the underlying calculations and assumptions of BASF’s EEA methodology presented in the Phase 1 and 2 reports, the linear model was created. This model was structured in such a way that will enable transparent comparisons of future performance against the established baseline and allow for semi-automatic linkage of IFSM with the SimaPro® platform. This will also allow other stakeholders in the beef industry to conduct further analyses.

The linear model was constructed based on the information given in the Phase 1 report and its supplementary data sources, including IFSM. We obtained a copy of IFSM version 3.6 from Dr. Al Rotz at the USDA ARS, which was the version used to produce inventory values for the feed and cattle supply chain stages. We used this version to reproduce the on-farm LCI for 2005 and 2011. Each reference year had four separate input files for IFSM: feed, spring calving, fall calving, and feedlot. Because each of these parts of the Meat Animal Research Center (MARC) farm were simulated separately, additional sources were referenced to combine this information and construct the complete on-farm portion of the linear model. The assumptions we made regarding each supply chain stage in our model are detailed in the following sections and the life cycle inventory for each is presented in Appendix A.

2.1.2.1 Feed

The output files from IFSM provided the total quantities of feeds produced, land used for each crop (including pasture), as well as the emissions associated with their production. Additional field emissions not included in IFSM output files were calculated according to methods provided in the Phase 1 report. The quantity of distillers grains (DDGS) purchased in 2011 was also determined using IFSM; however, we used an existing unit process developed for a previous project to represent DDGS and adapted it according to relevant information available in the Phase 1 report. We used the quantity of purchased corn from the same report for 2005. This stage includes production of corn grain and silage as well as pasture management. It should be noted that field emissions on pasture from excreta (e.g. ammonia) are assigned to the cattle phase, while fertilizer, lime and other pasture management activities are assigned to the feed phase.

Differentiating between types of fuels, e.g. diesel vs. gasoline, and distinguishing what fuel use is associated with which crops is not possible using only the information reported in the IFSM standard output files. These distinctions are not only important when conducting an LCA, but were necessary to produce an accurate representation of the BASF study. We supplemented the feed phase LCI from IFSM with fuel use values reported in a spreadsheet provided by Dr. Al Rotz named "BASF feed data from MARC.xlsx". This spreadsheet provided a detailed accounting of fuel types and quantities for 2005 and 2011. We also used this spreadsheet for pesticides, as IFSM only provides the cost of pesticide use as a static value per hectare of cropland. The aggregation of information in the IFSM output files is the principal reason for the second task of this project, if for which enables extraction of more granular data directly from the program.

All LCI relating to feeds produced on farm were adjusted by the allocation ratio prior to incorporation into the LCA model in accordance with methods outlined in the Phase 1 report; a fraction of the feed produced on-farm was fed to other animals, and LCA accounting requires separation of these feeds from the cattle feed. The fraction of feed production on the MARC farm attributed to beef production was 82.5% in 2011 and 85.3% in 2005.

2.1.2.2 Cattle

The LCI for drinking water consumption and air emissions for the cattle phases were adopted from the three cattle-related IFSM files – cow/calf spring; cow/calf fall; feedlot. As with the feed phase, energy consumption was supplied by a supplementary spreadsheet that had more granular accounting than the direct output produced by IFSM. This spreadsheet was also used to determine supplementary feed intake like vitamins and minerals. Transportation on farm was calculated according to methods outlined in the Phase 1 report.

The total live weight sent to harvesting was adopted from the Phase 2 data spreadsheet shared with us by Dr. Rotz. That spreadsheet reported that the total live weight sent to harvesting was 2,915,279 kg and was reported to include finishing cattle, cull cows, and cull bulls. IFSM does not directly report the total quantity of live weight produced from a simulation, only the net animal weight sold in units of kilograms per hectare. We adopted the value reported in the spreadsheet rather than the less accurate value based on area and LW/area.

2.1.2.3 Harvesting

The harvesting phase LCI was determined using data provided by the National Cattlemen's Beef Association (NCBA) for harvesting facilities in 2005 and 2011. The information provided average values for a facility that processed 1.5 million animals per year, not necessarily MARC animals. To link the harvesting stage with the cattle stage in our linear model, we converted the data to a per head processed basis and applied those LCI to the number processed from the MARC facility. We used the carcass yield and loss fractions stated in the Phase 1 report, in addition to the allocation percentages for beef byproducts to determine the quantity of beef and associated burden leaving the harvesting facility.

2.1.2.4 Case-ready

We used the packaging data supplied by the NCBA for LCI of the case-ready stage. Following the Phase 1 report, we adopted, for the case-ready LCI, values from the harvesting stage. Specifically, we adopted the BASF assumption and used 10% of the harvesting stage values for case-ready supply chain stage in our LCA model. To avoid double counting, we did not include the packaging or any other harvesting input already given in a separate dataset for the case-ready stage received directly from NCBA.

2.1.2.5 Retail and consumer

We did not receive any direct LCI for the retail or consumer stages from the BASF Phase 1 assessment. BASF reported different retail results in Phase 1 and Phase 2, but they used the same retail data for 2005 and 2011 in the Phase 1 analysis. We received data for this stage from Phase 2, and applied that information to both years. As such, our results for the retail stage are different than those reported in Phase 1 (as we had no Phase 1 data) but this difference does not influence the directionality of the results. We also used the Phase 2 data for the consumer stage, which is reported to be the same as for Phase 1. It should be noted that the LCI used in these stages are the same as those referenced in the radial model (Phase 2) and do not constitute complete representations, e.g. they report electricity consumption without an associated activity, thus it is not known if it is for cooking, dishwashing, or refrigeration. In future work, these stages of the model will need to be constructed with more detail to provide a complete understanding of the underlying calculations that will enable updated versions in future assessments.

2.2 Programmatic linkage of IFSM and SimaPro®

We received complete source code for the IFSM model from Dr. Al Rotz. A local programmer working with a SimaPro® expert identified the specific locations in the IFSM source code where relevant LCI are calculated. We identified individual flows in the LCI model for beef production that matched to the identified LCI in the IFSM model. We created additional arrays of inventory data within the IFSM code and constructed output functions to enable rapid transfer of the information into the SimaPro® platform. Most of the effort for this task is foundational for future work and is represented by source code in Fortran and C++. This code can be made available on an as needed basis. Currently its use requires a SimaPro® license.

2.3 Task 2: Approach for economic analysis

The beef industry makes a significant contribution to economic output and development within the United States. This contribution encompasses more than just the value of the beef sold through restaurants and retail stores. Dollars spent by cattle producers on the purchase of local inputs and wages to employees also serve to bolster the regional economy. Beef processing is as a subsector of beef production that also adds further value to the economy through direct, indirect, and induced channels.

In this study, direct contributions are those generated directly through activities within the beef cattle production and processing industries. Indirect contributions are generated when firms involved in beef cattle production or processing purchase materials and services from other industries in the region. Induced contributions result when employees in the beef production and processing firms, or their suppliers, spend their income within the region.

For this study, we analyzed the economic contribution of beef cattle production and processing industries within seven US regions: Northeast, Southeast, Midwest, North Plains, South Plains, Northwest, and Western. The results for each regional analysis offer a snapshot of the economic relationships existing within each region at one point in time. The overall contribution of beef cattle production and processing is measured through a combination of direct, indirect, and induced economic contributions. These contributions include jobs and value-added components such as proprietor income, employee compensation, other property type income, and taxes on production and imports.

Data and input-output (I-O) modeling software from IMPLAN Group, LLC were used in this analysis to estimate economic contributions for each region. The IMPLAN I-O model utilizes multipliers to describe the response of an economy to changes in economic activity. SAM (Social Accounting Matrix) multipliers are used to incorporate household expenditures into the models and to calculate the indirect and induced contributions. Use of the SAM framework allows for tracking of both market and non-market transactions such as those flowing from household to government (e.g. taxes), or from government to households, (e.g. transfer payments) (Alward and Lindall, 1996). Because of differences in multipliers at different levels of aggregation (e.g., region vs nation), impacts reported at the regional level will not equal those for the nation. Therefore, contributions estimated at the national level will not equal the sum of those for each region.

2.3.1 Detailed Methodology

Data and software from IMPLAN Group, LLC were used to estimate the economic contribution of beef cattle production and processing for seven US regions (IMPLAN, 2016). The first, and arguably the most difficult, step in conducting a contribution analysis is to determine the value of output for each sector of interest. In IMPLAN, output represents the value of industry production (IMPLAN 2017a). Working within IMPLAN's framework, it was necessary to estimate the annual output for four sectors related to beef cattle production and processing: 1) beef cattle ranching and farming; 2) animal, except poultry, slaughtering; 3) meat processed from carcasses; 4) rendering and by-product processing.

Using these output values, economic multipliers derived by IMPLAN are used to estimate employment, employee compensation, proprietor income, other property type income, tax on production and imports, total value added, and intermediate expenditures for the sectors of interest in each region.

Methods provided by IMPLAN explain how to adjust their model to conduct a multi-industry contribution analysis using their software (IMPLAN, 2017b). These methods were followed to obtain results for the direct, indirect, induced, and total economic contribution of beef cattle production and processing for each region. The following sections break down methods used to obtain the output estimates for each IMPLAN sector analyzed in this study.

2.3.1.1 Methods for Determining Cattle Production Output:

<u>IMPLAN Sector 11:</u> Industry data was obtained from IMPLAN for 2014 for all 50 states. IMPLAN uses preliminary values from the USDA National Agricultural Statistics Service (NASS) to generate output values for agricultural industries. They suggest updating their values with more recent data, if available. For this, we used values from NASS's Meat Animals Production, Disposition, and Income: 2015 Summary (USDA NASS, 2016a). These come from the table containing cattle and calf production and income estimates for 2014 (pg. 10 of the NASS report). After consulting with IMPLAN, they suggested using NASS's Gross Income values to update the cattle industry (Appendix A). Gross income is defined by NASS as the sum of cash receipts and value of home consumption. Cash receipts are receipts from marketings and any sale of farm-slaughtered meats. Marketings include animals for the slaughter market and younger animals shipped to other states for feeding and breeding purposes. Marketings exclude inter-farm sales within the same state and farm slaughter. This value does include dairy cattle and calves sold for slaughter or sent out of state for feeding/breeding purposes. It should be noted that dairy heifer replacement and veal calf production (many of which come from the dairy sector) are included under NAICS code 112111 – beef cattle ranching and farming. While it would be ideal to separate all dairy ties from beef cattle marketings, the lack of available data and large scope of this project made it unfeasible to account for this within the time allotted for this study.

2.3.1.2 Methods for Determining Beef Processing Output:

Unlike cattle production, which is covered by only one IMPLAN sector, the chain of beef processing is distributed between several sectors in IMPLAN. Although additional sectors could be disputed, the sectors selected for analysis in this study were: 1) animal, except poultry, slaughtering (IMPLAN sector 89; NAICS code 311611); 2) meat processed from carcasses (IMPLAN sector 90; NAICS code 311612); and 3) rendering and meat byproduct processing (IMPLAN sector 91; NAICS code 311613).

Although IMPLAN provides data for these sectors, the vales provided cover more than just beef. The value of all animal processing, outside of poultry, are included within these sectors. Since output for pork, mutton, lamb, etc. are included, it was necessary to develop methods for estimating the beef component comprising each of the three animal processing sectors. Methods for each sector are described in the following sections.

Animal, except poultry, slaughtering: IMPLAN Sector 89: Values were obtained for commercial cattle live weight (lbs) going to slaughter from NASS's Livestock Slaughter Annual Summary (USDA NASS, 2016b). This value excludes calf and on-farm slaughter but does include the slaughter of any cattle brought in from other countries for slaughter in each respective state. Since live weight differs from the dressed weight, or hot carcass weight (HCW) coming out of slaughter, average dressed weight percentages for 2014 were calculated from AMS's 5 Area Weekly Direct Slaughter Cattle Report – Formulated, Forward Contract, and Negotiated Grid Sales: LM_CT145 (USDA AMS, 2014a). These data come from federally inspected facilities processing 125,000 head or more per year. This document reports a weekly weighted average of the dressed weight percentage for various types of cattle. For the purposes of this study, a representative from AMS suggested that values for "mixed steer/heifer/cow" be used. Using these data, the average percentage of dressed cattle weight coming from slaughtered cattle was determined to be 62.7% for 2014. So, for every 1,000 lbs of cattle coming into the slaughterhouse, it's expected that 627 lbs of hot carcass weight will remain after the animals are bled and have their hide, head, hooves, viscera, lungs, and heart removed.

To obtain an output dollar value for beef slaughter (sector 89), the dressed weight for each state was multiplied by the 2014 national average price for mixed steer/heifer/cow at the formula net price. This price average was also calculated from AMS's 5 Area Weekly Direct Slaughter Cattle Report – Formulated, Forward Contract, and Negotiated Grid Sales: LM_CT145 (USDA AMS, 2014a). The price per cwt taken from the report is an average of all grades which was then divided by 100 lbs to yield a price per pound. Using these data, the 2014 average price per lb for a dressed carcass was estimated to be $2.36. This price was multiplied by the total dressed carcass weight for each state to obtain an estimate for the value of dressed carcasses sold.

In addition to carcasses, slaughterhouses bring in additional revenue through the sale of beef by-products. AMS's USDA By-Product Drop Value (CATTLE) FOB Central U.S. report – NW_LS441 provides the by-product drop value per live cwt for an average steer (USDA AMS, 2014b). This value was multiplied by NASS's state-level live weight slaughter totals to estimate the value of by-product output for each state (USDA NASS, 2016b).

Output estimates for carcass and beef by-product sales were summed for each state to obtain a total output value for slaughter. State output totals were summed by region to obtain the regional total output used in the IMPLAN model (Appendix B).

Meat processed from carcasses: IMPLAN Sector 90: Unfortunately, there are no regionally reported values for these fields. Therefore, output for this sector was estimated from the state-level hot carcass weight (HCW) totals derived in the calculations for sector 89. These total HCW estimates were multiplied by the primal to carcass yields listed in AMS's Boxed Beef Cutout & Cuts – Negotiated Sales Overview (USDA AMS, 2015). These percentages were applied to our dressed carcass weight estimates to determine the total weight of the various beef cuts coming from each state. The total weight for each cut was multiplied by the 2014 average national value for primal rib, chuck, round, loin, brisket, short plate, and flank cuts obtained from AMS's National Weekly Boxed Beef Cutout and Boxed Beef Cuts – Negotiated Sales report LM_XB459 (USDA AMS, 2014c). The cut values were then summed to provide a value of beef carcass processing for each state. Regional values were obtained by summing the values for each state included in the region (Appendix C).

Rendering and byproduct processing: IMPLAN Sector 91: After speaking to several researchers in the field of beef production and economics, it became clear that the majority of beef by-products end up being sold wholesale to processors overseas. There were, however, four by-product items believed to be primarily processed within the US: 1) tallow, edible; 2) bleachable tallow; 3) meat and bone meal; and 4) blood meal. AMS's USDA By-Product Drop Value (CATTLE) reports – NW_LS441 were used to obtain an average value per live cwt for each of these products (USDA AMS, 2014b). These values were then multiplied by NASS's state-level live weight slaughter totals to estimate the total lbs of each by-product produced in each state (USDA NASS, 2016b). Average wholesale prices for each by-product were estimated using Feedstuffs weekly ingredient market price reports for 2014 (Feedstuffs, 2014). These prices were converted to a per pound value then multiplied by the state-level by-product weight estimates to determine a total value of output for the rendering and byproduct processing sector in each state. Regional values were obtained by summing the values for each state included in the region.

2.3.1.3 Methods (Contribution Analysis):

IMPLAN's suggested methodology for conducting a multi-industry contribution analysis was used to determine, the direct, indirect, and induced effects of cattle production and processing in each region (IMPLAN, 2017b).

This method begins by updating output values for each sector being analyzed in the study. As previously stated, four sectors were selected for inclusion in the analysis: 1) beef cattle ranching and farming; 2) animal, except poultry, slaughtering; 3) meat processed from carcasses; 4) rendering and by-product processing. Using IMPLAN's "Customize Study Area Data" feature, output values for each sector were adjusted to match the estimate output values for beef production and processing. When adjusting output value using the "Customize Study Area Data" feature, the program automatically adjusts corresponding employment and value-added components, based on IMPLAN's default multiplier values for the chosen study area. Lacking available data for these fields, values for these areas were not adjusted, leaving the estimated IMPLAN values.

To prevent double-counting, commodity production coefficients for the four sectors were set to one (1), with by-product coefficients being zero (0), and the local use ratios for each sector were also set to zero (0). Industry change activities were setup for both production and processing with events being created for each sector. Within the events, the estimated output values were entered for each sector.

3 Results and Discussion

3.1 Task 1: Radial Model Results

A summary of the environmental impact results from our radial model adaptation of the U.S. Beef EEA is presented in Table 2 alongside the original values reported by BASF. Sections 3.1.1 through 3.1.11 present more detailed discussion of our findings. This table was created as a direct reproduction in SimaPro® of the BASF model in radial form, normalizing each unit process to the Consumer Benefit. Thus the differences are driven almost entirely by changes in background processes that were used in our model to replace proprietary data from BASF.

Table 2.

Results from the EEA alongside those from this study's radial model for each impact category, broken down by life cycle stage. Light red highlighted pairs signify impact totals with greater than 5% difference between our results those of BASF.

Impact	**Units**	**Study**	**Life cycle stage**								**Impact total**
			Feed	Cow-calf	Feedlot	Harvesting	Case ready	Retail	Consumer	Restaurant	
Cumulative energy demand	MJ	U of A	448.0	7.16	4.66	6.56	3.08	3.38	15.2	24.0	512.0
		BASF	448.2	5.20	2.70	5.20	3.80	3.00	13.3	21.9	503.3
Assessed water use	liter-eq.	U of A	1137.3	5.81	5.35	1.47	0.70	0.58	2.38	5.25	1158.8
		BASF	1137.0	5.40	5.10	1.70	0.90	0.80	3.10	6.40	1160.4
Absolute water use	liter-abs.	U of A	2279.1	11.6	10.7	2.94	1.40	1.17	4.77	10.5	2322.3
		BASF	2278.0	10.8	10.2	3.40	1.70	1.50	6.20	12.7	2324.5
Global warming potential	kg CO_2-eq.	U of A	3.59	13.01	3.00	0.37	0.22	0.30	0.74	1.26	22.5
		BASF	3.37	12.93	2.90	0.25	0.12	0.21	0.91	1.28	22.0
Photochemical ozone creation	g $C2H_4$-eq.	U of A	62.8	2.77	0.78	0.27	0.15	0.11	0.49	0.75	68.1
		BASF	62.1	3.11	0.80	0.11	0.07	0.06	0.07	0.16	66.5
Ozone depletion potential	ug CFC-11-eq.	U of A	341.6	40.9	29.9	28.1	106.3	37.3	27.9	193.2	805.3
		BASF	55.1	0.03	0.62	16.8	152.7	82.0	0.39	457.1	764.6
Acidification potential	g SO_2-eq.	U of A	61.8	164.5	96.3	2.31	1.35	1.66	6.63	9.77	344.3
		BASF	57.8	163.0	95.6	1.20	0.80	1.00	3.50	6.30	329.2
Water emissions	liter diluted water-eq.	U of A	2761.4	85.2	21.4	40.6	23.1	2.39	37.4	21.6	2993.0
		BASF	2779.0	8.10	1.10	57.2	137.7	1.00	90.2	20.8	3095.1
Solid waste	g municipal waste-eq.	U of A	74.6	9.10	7.68	15.6	17.0	5.73	49.4	42.5	***221.7***
		BASF	41.4	46.0	9.77	20.5	3.17	4.57	11.5	30.5	***167.5***
Land use	m^{2}a-eq.	U of A	20.8	0.01	0.26	0.08	0.14	0.00	0.01	0.06	21.4
		BASF	20.8	0.13	0.32	0.06	0.09	0.01	0.03	0.08	21.5
Toxicity potential	N/A	U of A	0.91	0.03	0.02	0.00	0.00	0.00	0.01	0.04	1.00
		BASF	0.93	0.03	0.03	0.00	0.00	0.00	0.00	0.00	1.00
Abiotic depletion	mg Ag-eq.	U of A	0.80	1.85	1.26	0.15	0.07	0.08	0.34	0.55	***5.12***
		BASF	0.69	1.79	1.22	0.11	0.07	0.06	0.27	0.46	***4.67***

3.1.1 Cumulative energy demand

The BASF report calculates the total cumulative energy demand (CED) to include not only the fossil energy requirements, but also the biological energy requirements of the animals, fulfilled through the caloric content of feed. This is occasionally included in LCA, but is relatively uncommon, and inclusion of caloric feed energy does not support farm level decisions around energy efficiency. We have included gross feed energy for our comparison analysis and our CED result differs by slightly more than 1% and the magnitude of contributions from each of the value chain stages are very similar. As shown in Figure 2, the feed energy content dominates based on inclusion of the gross calorific energy content for feeds reported by BASF, which ranged from 17.8 – 18.6 MJ/kg of dry matter. Table 3 presents a contribution analysis for the CED category.

None of the datasets or reports associated with the U.S. beef EEA contained or identified a citation for the characterization factors used by BASF to estimate the potential environmental impacts arising from fossil or renewable energy consumption. In order to calculate the contributions from other energy sources like electricity, natural gas, and diesel, we utilized an impact assessment method for CED provided in the SimaPro® platform (Frischknecht et al. 2003) – which does not track the caloric content of feeds. Future work will exclude caloric feed energy (using the method of Frischknecht et al. (2003)) from this category and rely on feed conversion ratio to quantify the efficacy of feed utilization that is, the effect will be captured for systems that are more efficient through a reduced feed requirement that will translate into smaller impacts across a broad range of categories.

Table 3.

Contributions to CED by energy source as reported by BASF in comparison to the results of this study.

	U of A		**BASF**	
Feed Energy (MJ/ lb. beef consumed)	409	(80%)	404	(80.3%)
Renewable Energy (MJ/ lb. beef consumed)	2	(0.4%)	3	(0.6%)
Fossil Energy (MJ/ lb. beef consumed)	100	(19.6%)	104	(19.1%)

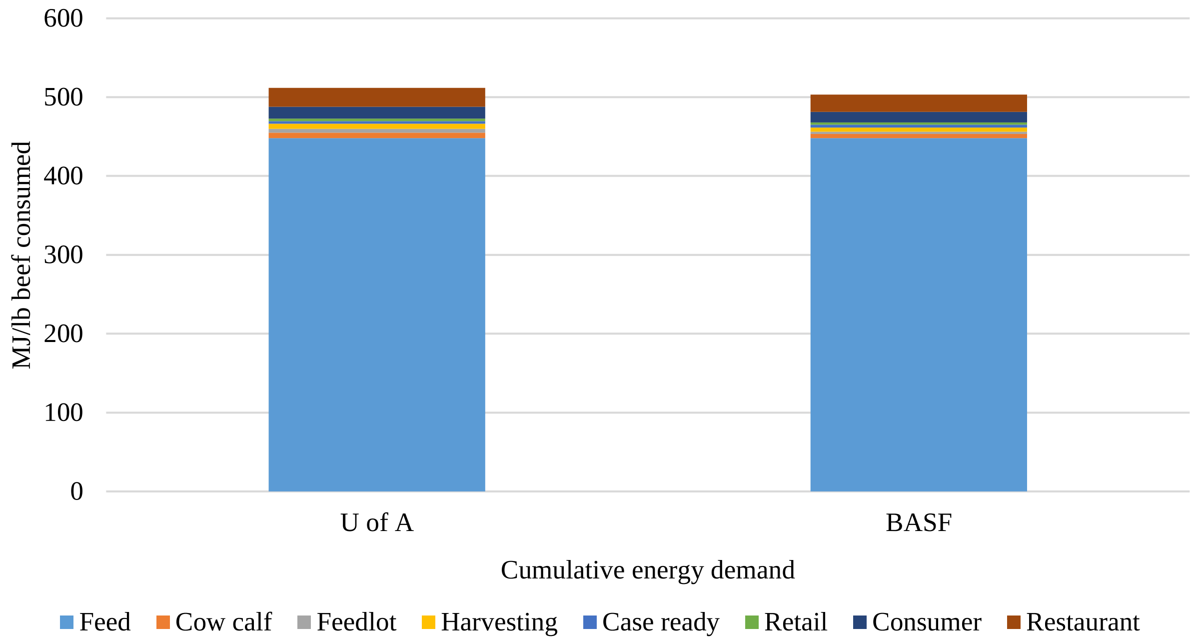

Figure 2.

Cumulative energy demand (CED) as reported by BASF in comparison to the results of this study.

3.1.2 Consumptive water use

Consumptive water use (CWU) is reported in two subcategories: absolute and assessed. Absolute CWU refers to the amount of water used that is not eventually returned to the system. BASF published the CWU characterization factors in the Phase 2 report, and we were able to implement those directly in SimaPro®. Assessed CWU is the absolute CWU multiplied by 0.499, which is a water scarcity indicator based on the ratio of withdrawn water to available water. The scarcity indicator is country-specific and is derived from the work of Pfister et al. (2009). Results from our model are similar to those reported by BASF (Figure 3 through Figure 6), with crop irrigation water contributing the vast majority to the impact category. Minor variations between our results and those from the EEA are attributable to differing background unit processes, but the accumulated variations result in less than one percent difference between the final values for CWU.

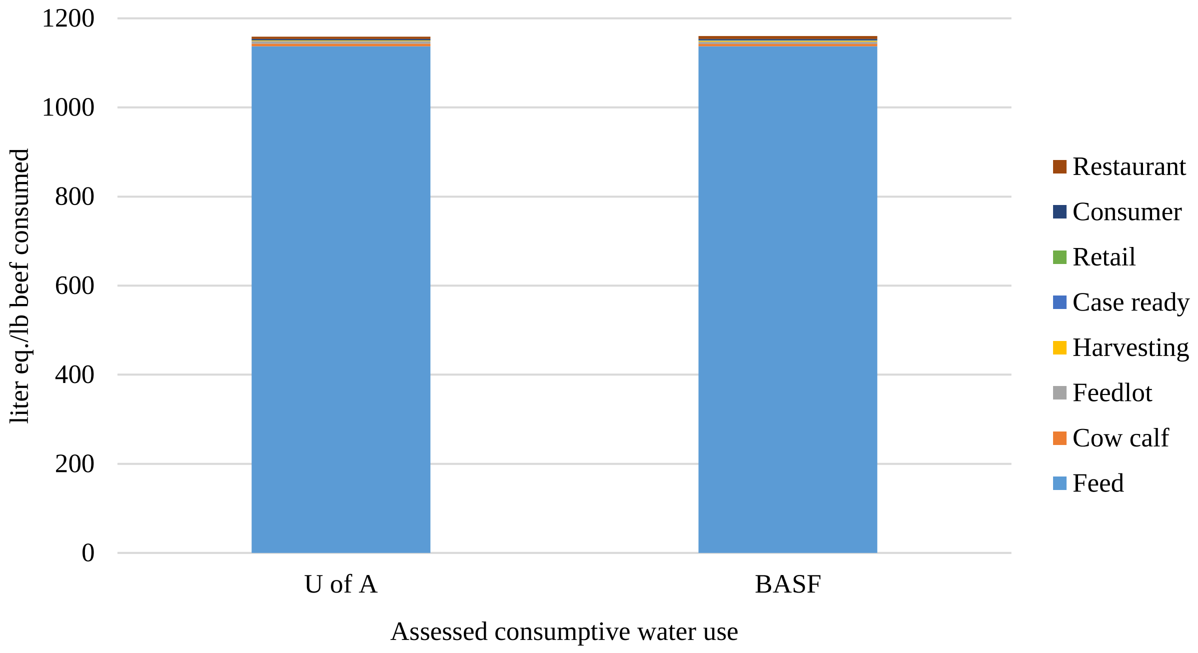

Figure 3.

Assessed consumptive water use as reported by BASF in comparison to this study.

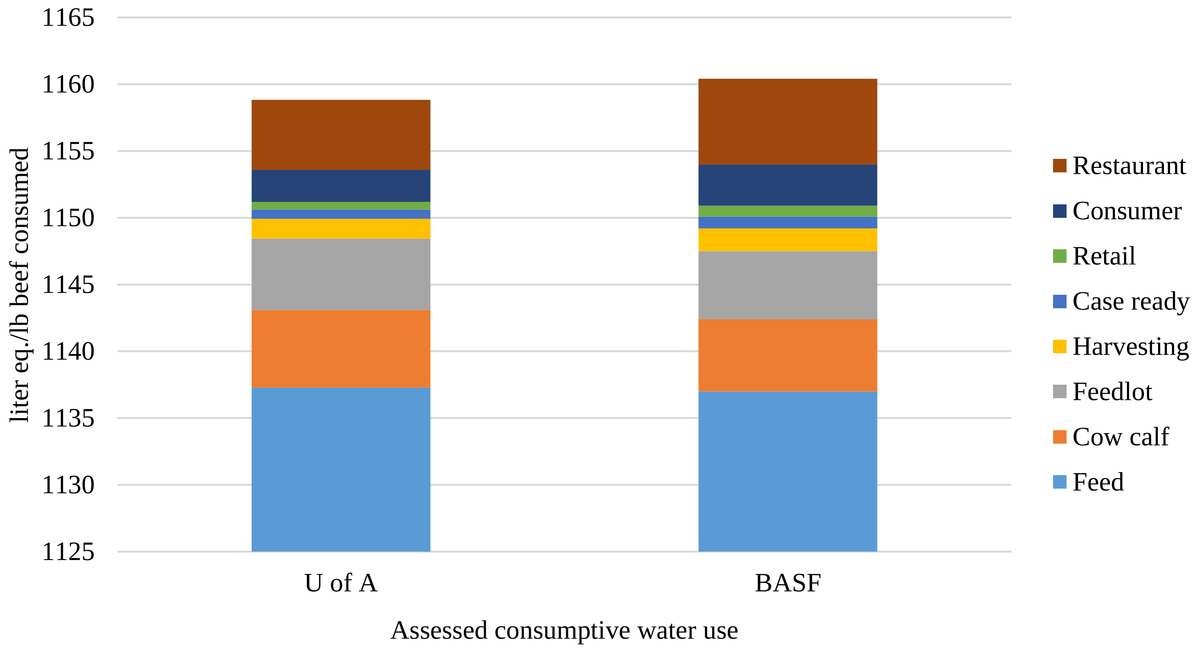

Figure 4.

Assessed consumptive water use with the y-axis beginning at 1125 liter-eq., highlighting the contributions from non-feed stages.

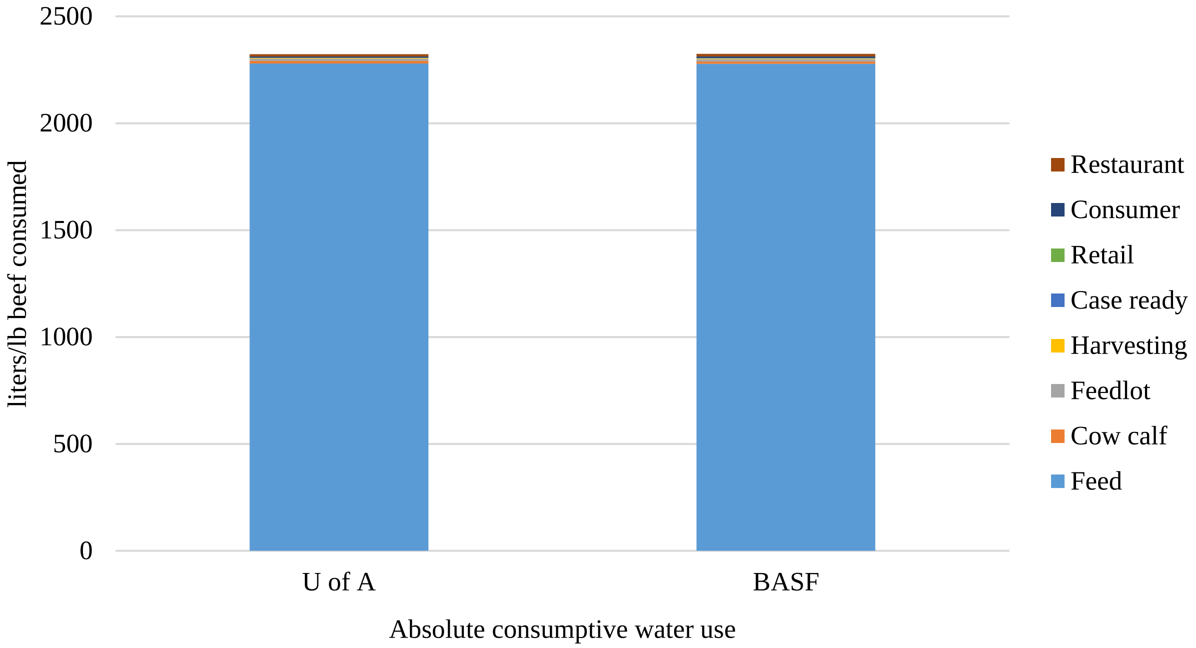

Figure 5.

Absolute consumptive water use as reported by BASF in comparison to this study.

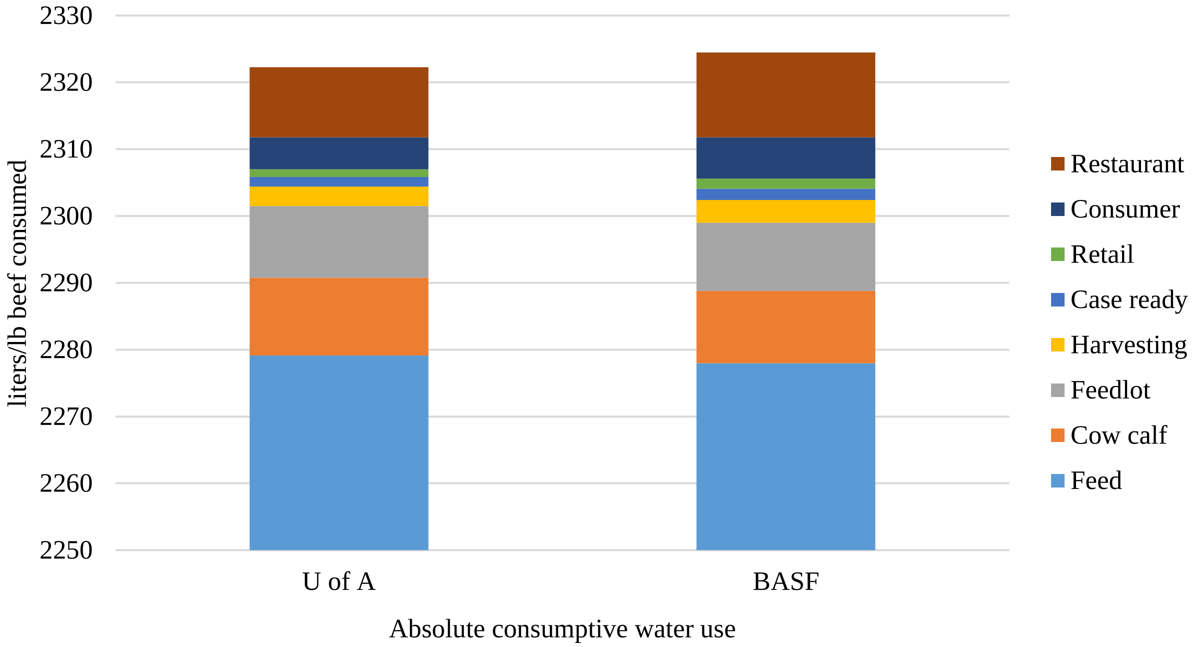

Figure 6.

Absolute consumptive water use with the y-axis beginning at 2250 liters, highlighting the contributions from non-feed stages.

3.1.3 Global warming potential

The global warming potential (GWP) characterization model used by BASF in the EEA was the IPCC 2007 100a model (IPCC 2007), the industry standard (prior to the 2013 update). As such, implementation of the characterization factors in the SimaPro® platform presented few challenges. The GWP results are very similar across all life cycle stages (Figure 7). Emissions from the Cow/calf operation account for 58.0% of the impact category, versus 58.9% in the EEA. The feed and feedlot stages are also major contributors, followed by refrigerant leakage in the retail stage. While BASF does provide the eco-profile names for the types of refrigerants, none of the data available gives an indication of the amount of refrigerant emission. The only information provided gave the equivalent amount of CO_2 released as a result of refrigerant leakage. Using this information, we estimated refrigerant leakage and could reproduce the results. However, this was not the case for ozone depletion potential, which will be addressed in Section 3.5.

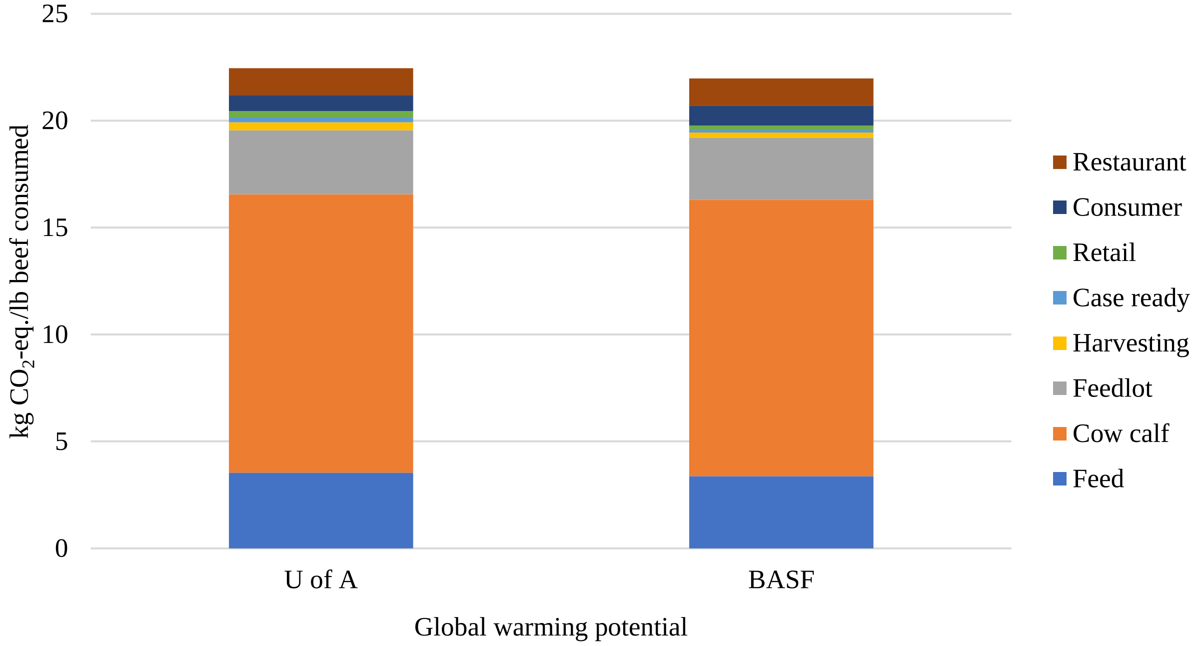

Figure 7.

Global warming potential (GWP) as reported by BASF in comparison to the results of this study.

3.1.4 Photochemical ozone creation potential

Significant non-methane volatile organic compounds (NMVOC) emissions occur during the silage production. The inventory provided in the Phase 1 report explicitly stated that the NMVOC emissions were already characterized as C_2H_4 equivalents. Although Phase 2 report did not explicitly state this, we made this assumption. The EEA methodology validation report cites a paper by Van Zelm et al. (2008) for the photochemical ozone creation potential (POCP) characterization model. However, additional information provided by the USDA ARS cites Heijungs et al. (1992) for POCP characterization factors (Rotz, C.A., 2016, personal communication). Neither of those two characterization models, when implemented in SimaPro®, reproduces the Phase 2 results. We were able to recreate the Phase 2 results more closely with the CML-IA baseline method coupled with the assumption that all (NMVOC) in the inventory are reported as C_2H_4-equivalents. NMVOC emissions during silage production make up more than 90% of the impacts in this category in our model as well as in the EEA (Figure 8). The bulk of the 2.4% difference between our total and BASF's is attributed to the background unit processes in the post-farm gate supply chain, some of which were the best available surrogates from the Ecoinvent database.

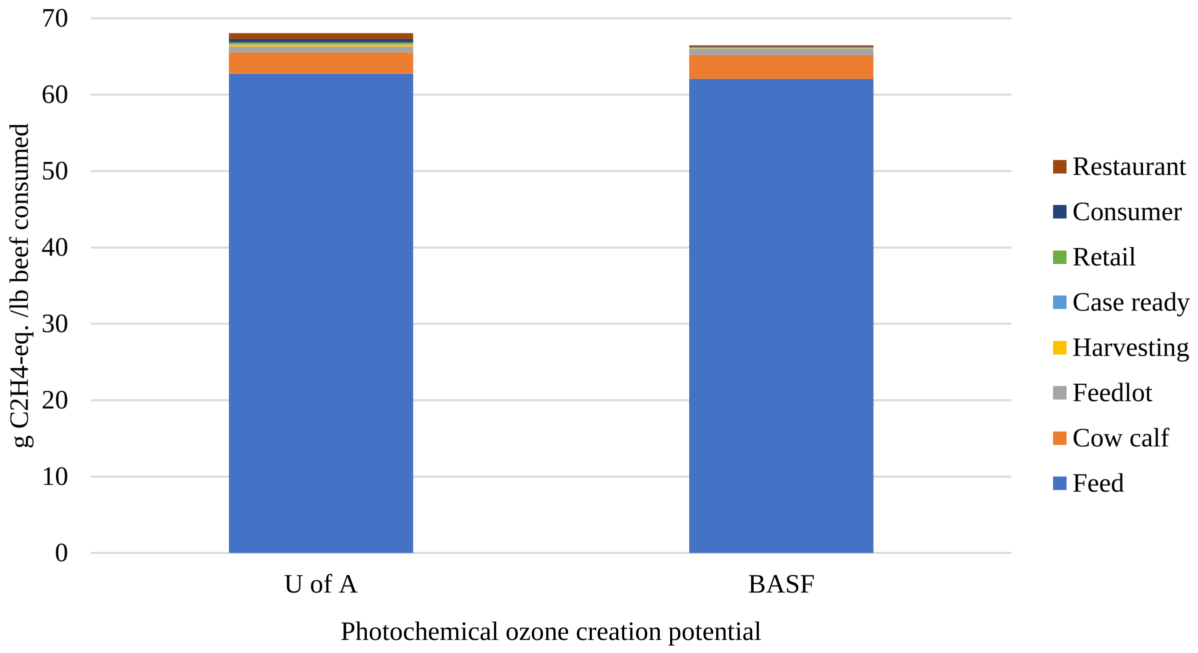

Figure 8.

Photochemical ozone creation potential (POCP) as reported by BASF in comparison to the results of this study.

3.1.5 Ozone depletion potential

The BASF methodology validation submission cites a report from the World Meteorological Organization (WMO 1999) as the characterization model for ozone depletion potential (ODP). This report is not available in electronic format and has since been updated several times. In the supplementary material, the only factor given for ODP is in regard to the emission of "halogenated hydrocarbons" with an equivalence factor of 1.0 kg CFC-11 but no reference or further explanation is given for this value. In our model, we apllied the TRACI model, which was developed by the US EPA and relies on the most recent data from the WMO. The relative potency of emissions that cause ozone depletion is internationally agreed upon and therefore the difference in methods alone should not indicate an error in either model. In addition, ODP is not much of an issue to the beef value chain, or for many industries at all since the Montreal Protocol, and the ozone layer is expected to recover in approximately 50 years (US EPA 2008). Our model shows 3.5 times greater ODP in the feed phase than BASF (Figure 9), driven by halogenated methanes like Halon 1211, which are commonly used in natural gas and crude oil production, and ultimately are associated with unit processes for diesel and natural gas consumed on farm for irrigation. Diesel and natural gas are also used in the Cow calf and feedlot phases. The Phase 2 report by BASF shows ODP results in these life cycle stages that are two orders of magnitude lower, and their report makes no mention of emissions from halons. However, all relevant unit processes in the Ecoinvent database for diesel and natural gas have halon emissions associated with their production. Further investigation into other publicly-available databases and unit processes representing oil and gas production in various places around the world revealed that the quantity of halon emissions is highly variable. The proprietary nature of the dataset(s) responsible for the oil and gas production portion of the LCI utilized by BASF prevented determination of the factors that influenced the omission – or insignificant contribution – of these types of emissions from the EEA.

Our results are also somewhat different from those of the EEA when considering the post-farm gate portion of the model. BASF reports much larger values than those from our model, particularly in the restaurant phase. BASF reports refrigerants driving this category, and while the Ecoinvent unit process for production of R134a does have some associated ODP, R134a released into the atmosphere itself does not deplete the ozone layer. The same can be said of R143, which is also cited in BASF’s report. There are very few refrigerants that were used in the U.S. during the timeframe of the EEA study that have ODP. However, we were not able to replicate the post-farm gate results without incorporating some ODP associated with refrigerant leakage. We chose not include these emissions for two reasons: the first being that the BASF Phase 2 report does not cite any sources for refrigerant types or emission rates, only the refrigerant eco-profile used in the analysis and the second being that we were unable to identify an external source that could support the inclusion of refrigerant leakage in the beef value chain that would be a significant source of ODP. In addition, the total amount of ozone depleting emissions found by our analysis and that of BASF are both less than one microgram of CFC-11 equivalent, which, as a practical matter, is insignificant and results from background processes that are far removed from the operations of beef producers.

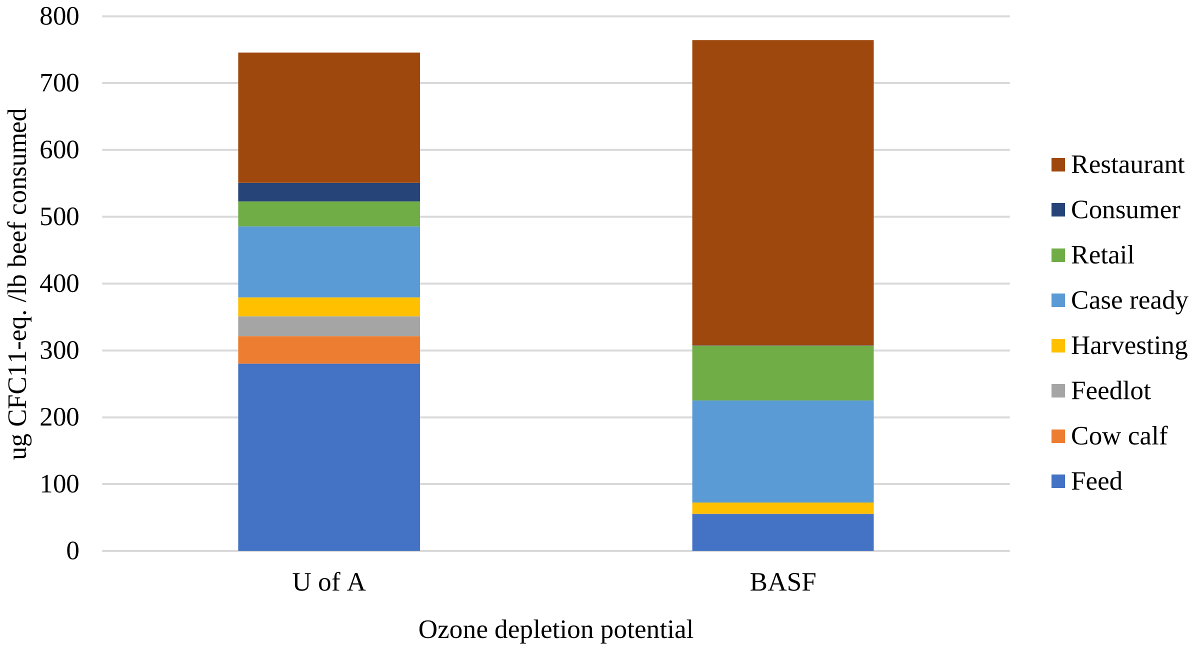

Figure 9.

Ozone depletion potential (ODP) as reported by BASF in comparison to the results of this study.

3.1.6 Acidification potential

The characterization model for acidification potential (AP) cited in the EEA methodology submission is from Seppala et al. (2006), which only provides characterization factors for European countries; however, that report also states that other methods like TRACI 2.1 may be used. The supplementary material cited Saling et al. (2002) for AP characterization factors, which are similar to those in TRACI 2.1. The TRACI method is available in the SimaPro® platform, and so we implemented its AP characterization model in our study. Our analysis shows the same major contributors as the EEA (Figure 10), with cow-calf, finishing, and feed production phases accounting for more than 90% of the AP impacts. Our analysis found natural gas use throughout the value chain to be a minor contributor as well, which was only mentioned in the harvesting phase of the EEA results. We also found emissions from fossil fuel combustion for electricity production to contribute to AP, but with a slightly larger contribution than reported by BASF, which accounts for some of the difference between results.

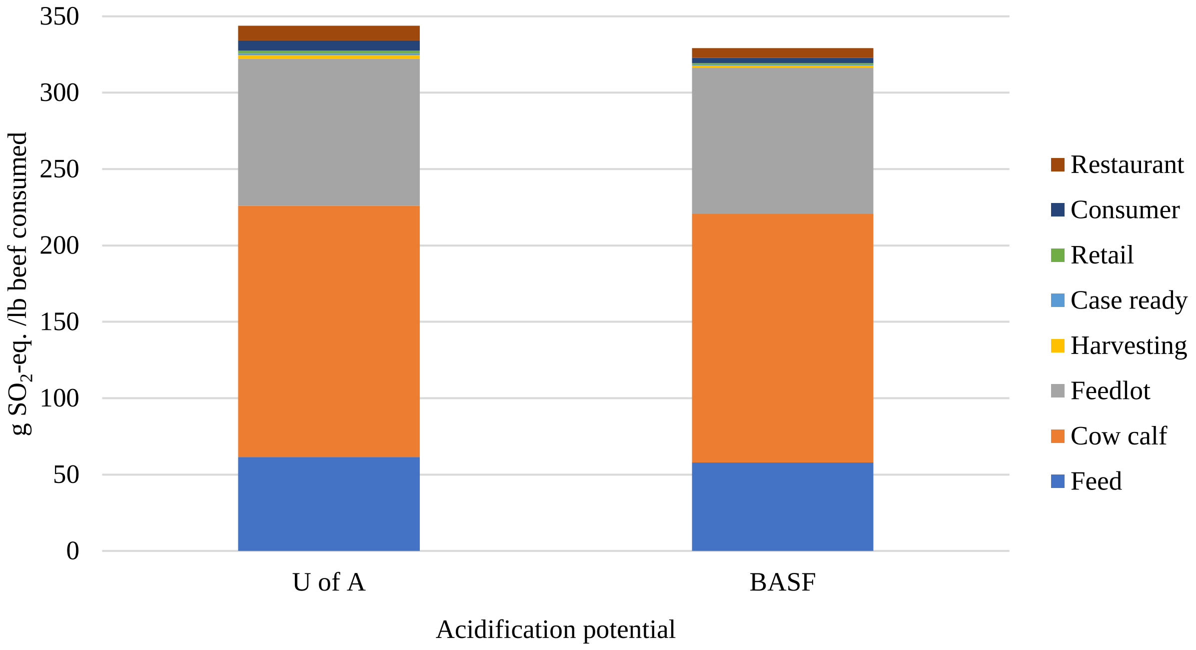

Figure 10.

Acidification potential (AP) as reported by BASF in comparison to the results of this study.

3.1.7 Water emissions (water quality)

The method for assessing emissions to water was developed by BASF and we recreated this method using characterization factors provided in the supplementary material. According to the supplementary material, the water emission factors are based on regional regulatory limits, but we were unable to confirm those values because the Wastewater Ordinance (2012) referenced is entirely in German, which may affect the interpretation of the results in a US context. When we used the life cycle inventory dataset provided by BASF, our results showed water emissions associated with nitrogen in the feed phase to be well below the 31% stated in the Phase 2 report. Based on emissions data (Rotz, C.A., 2016, personal communication), we assumed an additional emission of 30% of the nitrogen from fertilizer lost to leaching. With this added emission, our results were more closely aligned (Figure 11). While our analysis and the EEA did find approximately 90% of water emissions to be associated with the feed production phase, other phases did not align as closely with the Phase 2 results, but those discrepancies combined had a minimal contribution to the total impact category results. We plan, for future assessment, to replace this category with a combination of water quality indicators, including eutrophication, acidification and aquatic ecotoxicity; the “distance-to-target” approach used in the BASF report is similar to the grey water footprint from the Water Footprint Network (Hoekstra et al., 2011), which has generally not been adopted by the broader LCA community.

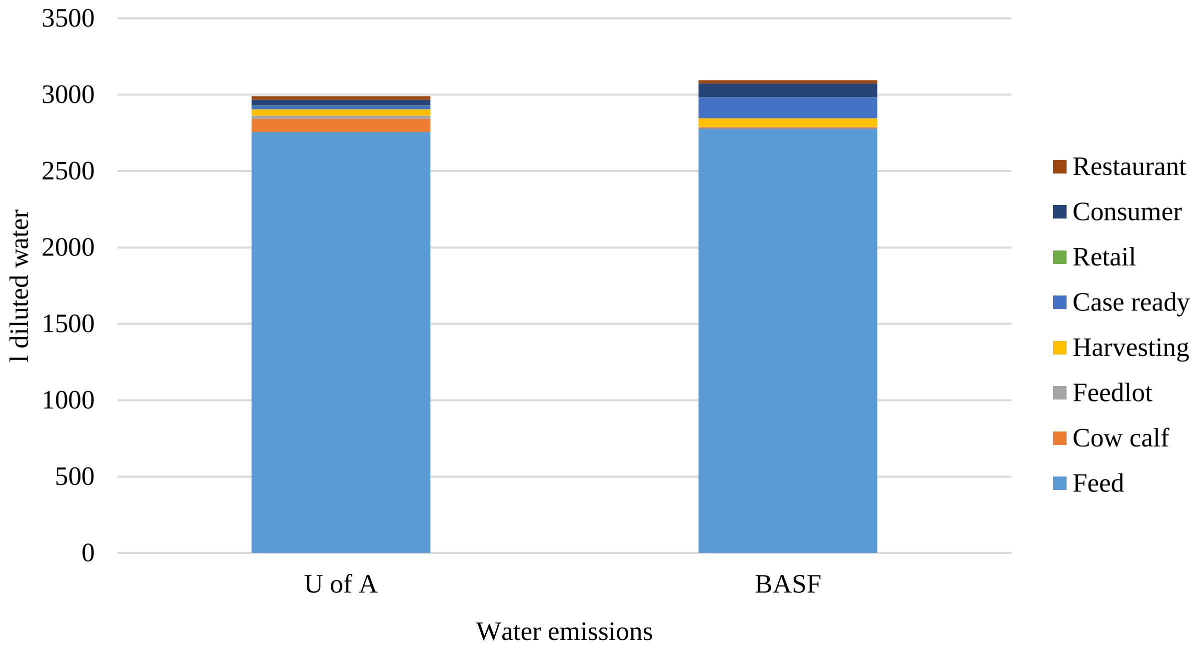

Figure 11.

Water emissions as reported by BASF in comparison to the results of this study.

3.1.8 Solid waste

We were unable to accurately reproduce the solid waste impacts reported by BASF for several reasons. The first being that the reference given by BASF in the supplementary material for determining the characterization factors is an unpublished document, internal to BASF. BASF did however provide characterization factors, but the SimaPro® platform is not designed to calculate solid waste inventory in a way that is useful in recreating the EEA results. The solid waste results arise from background unit processes, of which the majority are proprietary to BASF, and the surrogates available in the Ecoinvent database do not produce the same results. Finally, 'solid waste' is not an impact category, but an inventory category. The impacts of solid waste are typically accounted for through models of the waste treatment processes, such as incineration or landfilling with the associated emissions that are then characterized through the normal impact pathway modeling (e.g., TRACI).

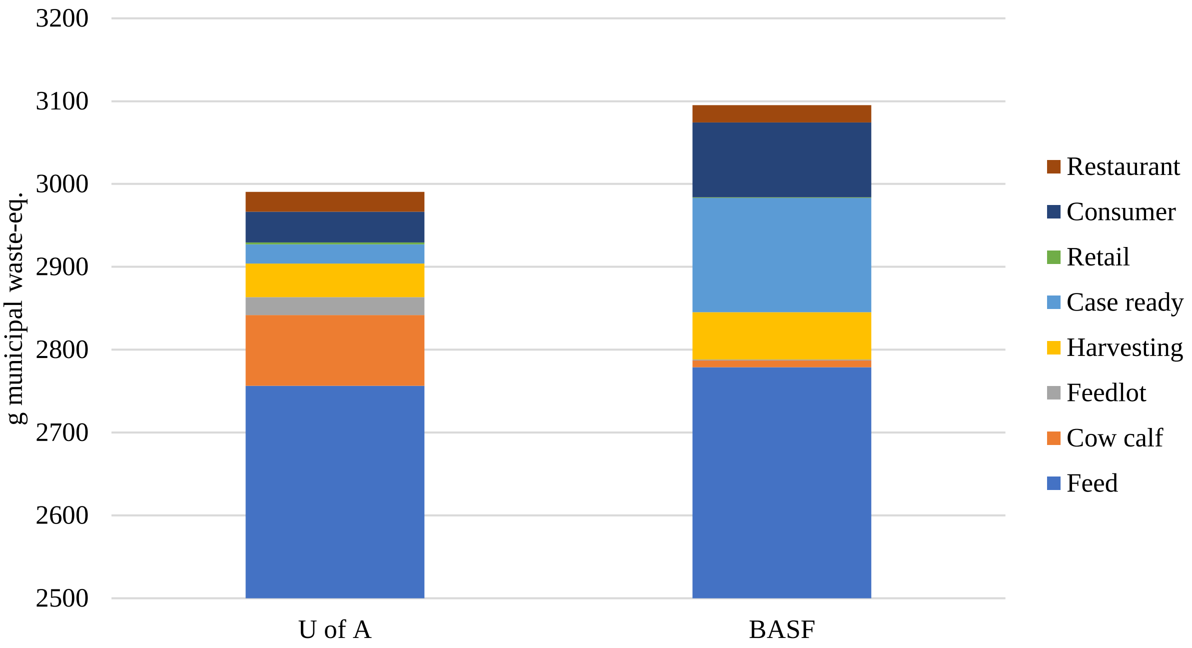

Figure 12.

Solid waste as reported by BASF in comparison to the results of this study.

3.1.9 Land use

The land use results were relatively straightforward with 97% of the impact coming from the feed production phase, which is consistent with BASF's findings (Figure 21). The remainder of the land use impacts are attributed to background processes, particularly those associated with cardboard production. BASF used the Ecosystem Damage Potential model developed by Koellner and Scholz (2008) to characterize land use impacts. This impact assessment method depends on the area and duration of occupation for specified land-cover types in order to calculate the total ecosystem damage. Each land-cover type has a characterization factor between negative one (indicating a positive contribution to the ecosystem) and one, which is multiplied by the amount of occupied land of a specific type and the length of time of the occupation. The result is a land use impact that is smaller than the total land area occupied, so it is important to note that these values are not simply the land use inventory, and do not include land transformation impacts.

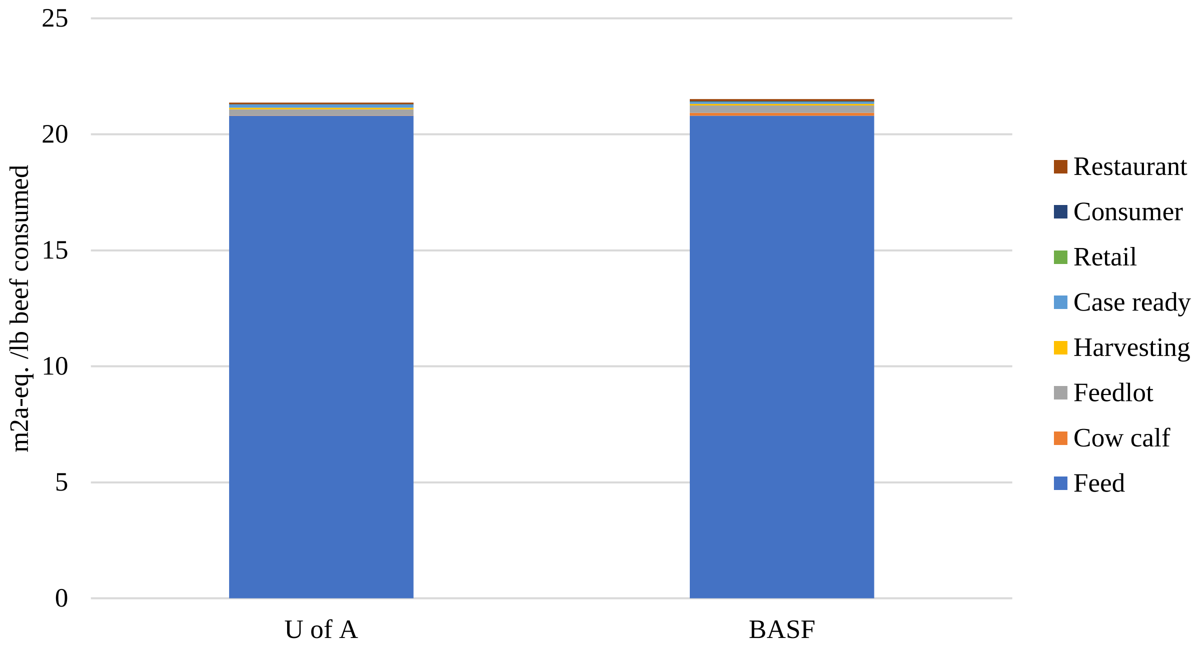

Figure 13.

Land use as reported by BASF in comparison to the results of this study.

3.1.10 Toxicity potential

The BASF EEA employs a characterization model for toxicity potential that was developed in-house and is used solely by BASF, which makes it difficult to replicate and implement in the SimaPro® platform. We requested BASF's spreadsheet model cited in the EEA methodology submission to NSF so that we could more accurately recreate the results for toxicity potential shown in the Phase 2 report but BASF denied our request, stating that the information is proprietary. We decided to implement the USEtox consensus model, which was developed by an international team of researchers from the United Nations Environment Program (UNEP) and the Society for Environmental Toxicology and Chemistry (SETAC) as part of the Life Cycle Initiative. USEtox was developed to provide midpoint characterization factors for human health impacts of chemicals in life cycle impact assessment and is considered the international scientific consensus (Rosenbaum et al. 2008; Hauschild et al. 2011). Our findings point to the feed phase as a major source of potential human toxicity in the beef value chain, as did the EEA (Figure 14). This is mostly due to the production and application of fertilizers and pesticides. Where our results differ from BASF’s is most notable in the restaurant phase, which has the second greatest contribution to this category as a result of a background unit process for the production of polyvinyl chloride that is found in vinyl gloves. BASF’s methodology for determining human toxicity potential (Landsiedel and Saling 2002) assigns weightings to chemical emissions based on the probability of exposure. However, due to the proprietary nature of this LCIA method and the lack of the necessary information to replicate Landsiedel and Saling (2002), we chose not to implement BASF’s weighting factors. Furthermore, the Phase 2 report did not include the unweighted and non-normalized results, which prevented a true impact assessment comparison for this category. Despite the methodological differences between our human toxicity impact assessment and that in the EEA, our results also indicate that the primary concern for beef producers should be on the feed phase impacts. The large difference in the restaurant phase arises because of a background process where PVC is produced for gloves. The weighting used by BASF, apparently, reduces the exposure likelihood as the gloves are used in the restaurant; hence the potential exposure in the background (well outside the beef sector’s control) is not as important. This approach is not, to our knowledge, supported by the ISO standard as a mid-point indicator.

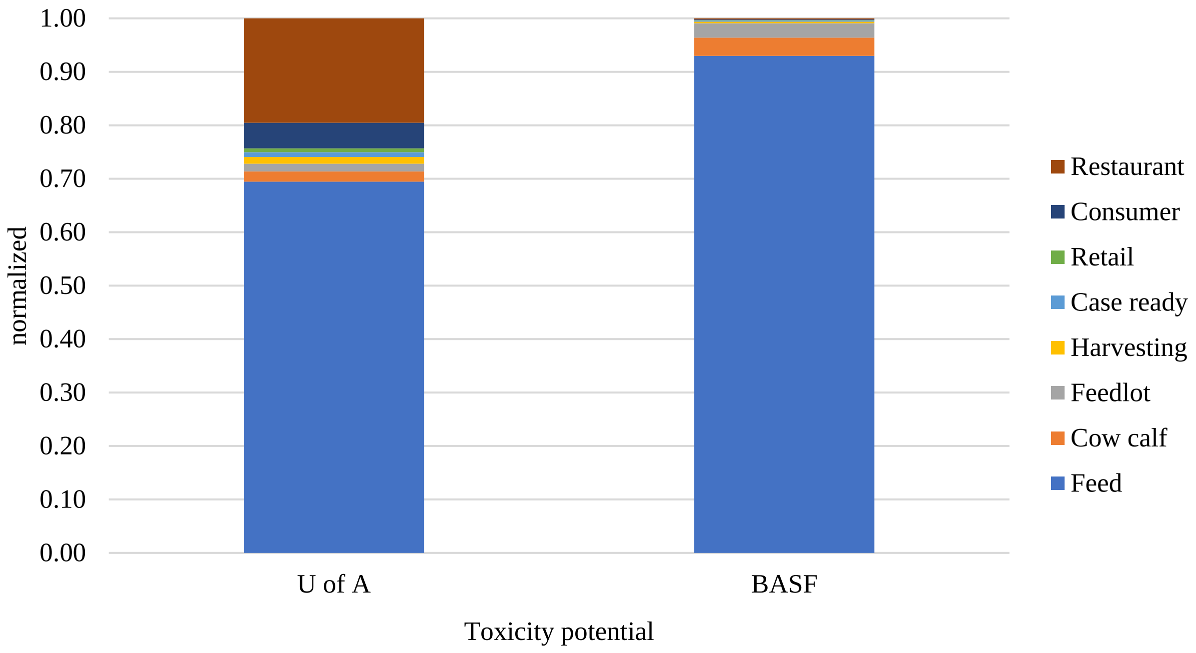

Figure 14.

Toxicity potential as reported by BASF in comparison to the results of this study.

3.1.11 Abiotic depletion potential

The characterization of impacts associated with abiotic depletion potential was performed according to BASF's own methods in which the demand and available reserves of raw materials are considered to create characterization factors for materials that are scarce and/or in high demand. The assigned characterization factors used in the EEA were provided in the supplementary material. We were able to implement these factors into our SimaPro® model in order to obtain results similar to those from the Phase 2 report (Figure 15). Results from our analysis show the highest impact phase is cow-calf, followed by the feedlot, and then feed production. Results were comparable to the EEA in the post-farm gate phases as well. When we compare ADP results in terms of raw material contribution we see the same primary drivers as those reported by BASF. Zinc tops the list, followed by natural gas, oil, uranium, coal, and then copper. We employed the same characterization factors for this category, so the differences in material energy source consumption are a result of differences in background unit processes that we used as surrogates for proprietary background processes that BASF used in the EEA.

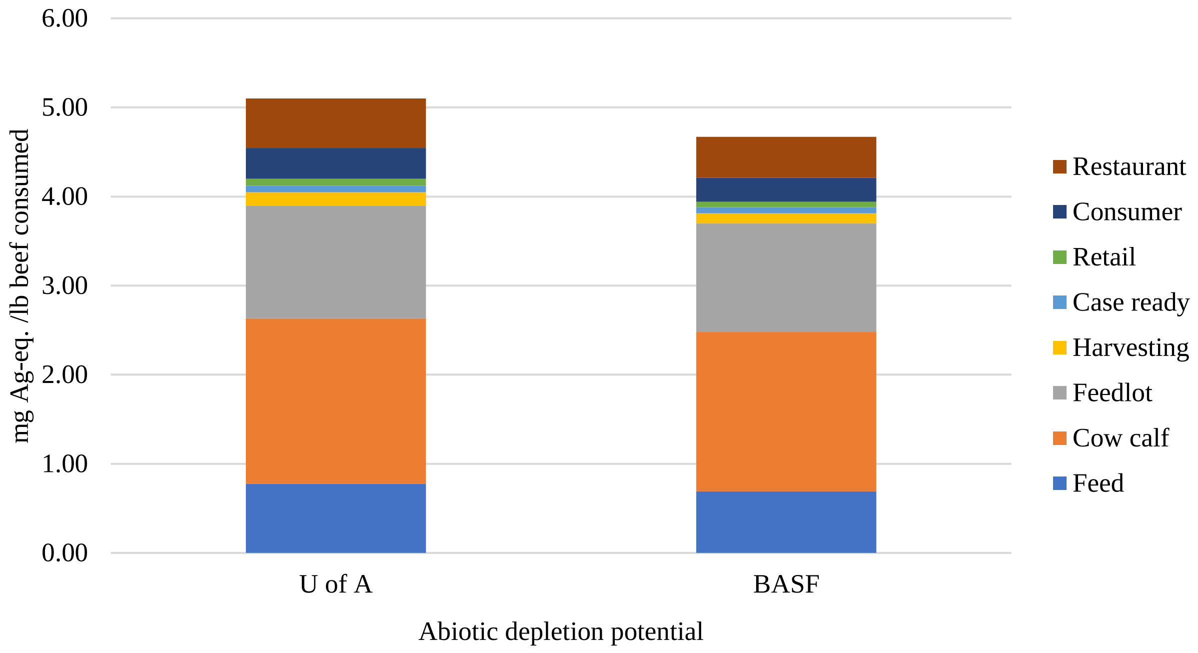

Figure 15.

Abiotic depletion potential (ADP) as reported by BASF in comparison to the results of this study.

3.2 Linear (Supply Chain) Model Results

The following sections compare the results from the linear model adaptation of the 2005 and 2011 U.S. beef supply chains with those from Phase 1 of the EEA. We compare results for six of the twelve impact categories assessed by BASF. The radial model approach indicated that the remaining six categories were either not reliably compatible with the SimaPro® software platform or relied on elements that were proprietary or not part of the Ecoinvent database. We only included categories that were well documented and could be reliably implemented using SimaPro® to enhance the accuracy of comparative assertions between our results and the EEA.

Overall consumer benefit (CB) results are similar to those reported by BASF for the 2005 (Table 4) and 2011 (

) U.S. beef supply chains. The largest disagreements between this assessment and the EEA are in the post-farm gate supply chain, particularly in the retail stage. Phase 1 inventory data were not available for this stage, so Phase 2 data was used in our modeling. BASF reported that the life cycle inventory for Phase 2 was updated to reflect new data, so our retail results are not directly comparable to Phase 1, similar to the discussion of the radial modeling. We included this stage in our results so that our model would have the same system boundaries as the EEA and allow for comparisons on the CB basis. Four of the six impact categories were within 5% of the EEA on-farm results in both 2005 and 2011. In 2005, acidification potential and POCP in the feed phase were the primary drivers of this discrepancy; whereas in 2011, feed-related POCP was the sole source of disagreement greater than 5%.

Table 5.
Results from the 2011 linear model adaption compared to the results from Phase 1 of the EEA.

Table 4.
Results from the 2005 linear model adaption compared to the results from Phase 1 of the EEA.

Phase 1 - 2005										
Impact category	**Units**	**Study**	**Beef Supply Chain Stage**						**Farm Gate**	**CB**
			Feed	*Cattle*	*Harvest*	*Case-ready*	*Retail*	*Home*		
GWP	kg CO_2e	BASF	3.21	15.39	0.37	0.32	2.50	1.96	18.61	23.74
		U of A	3.22	15.42	0.49	0.24	0.47	1.72	18.64	21.36
Energy use	MJ	BASF	439.0	8.05	6.90	13.13	25.56	28.47	447.0	521.1
		U of A	429.9	11.97	8.56	7.35	7.80	33.78	441.9	495.8
Water use	liter	BASF	2359	21.20	3.72	6.18	14.18	13.39	2380	2418
		U of A	2337	20.15	2.56	0.11	0.14	0.00	2357	2359
POCP	g C_2H_4e	BASF	21.39	3.89	0.33	0.28	0.27	0.16	25.28	26.32
		U of A	18.37	3.26	0.34	0.23	0.10	1.05	21.62	23.21
AP	g SO_2e	BASF	88.16	226.9	2.21	2.54	8.28	7.60	315.1	335.7
		U of A	55.93	227.8	4.63	1.32	3.62	15.03	283.7	306.4
Land use	m^2a	BASF	20.27	0.47	0.11	0.40	0.12	0.06	20.74	21.43
		U of A	20.60	0.26	0.10	0.37	0.01	0.03	20.86	21.32

Table 5.
Results from the 2011 linear model adaption compared to the results from Phase 1 of the EEA.

Phase 1 - 2011

Impact category	Units	Study	Beef Supply Chain Stage						Farm Gate	CB
			Feed	*Cattle*	*Harvest*	*Case-ready*	*Retail*	*Home*		
GWP	kg CO_2e	BASF	3.29	15.38	0.24	0.26	2.45	1.94	18.67	23.56
		U of A	3.27	15.49	0.36	0.23	0.47	1.72	18.76	21.39
Energy use	MJ	BASF	436.08	7.88	5.04	8.47	25.38	28.26	444.0	511.1
		U of A	421.37	11.62	6.53	7.27	7.80	33.78	433.0	485.7
Water use	liter	BASF	2282	20.54	3.29	3.39	14.06	13.25	2302	2336
		U of A	2260	19.55	2.17	0.10	0.14	0.00	2280	2281
POCP	g C_2H_4-e	BASF	21.42	3.82	0.10	0.18	0.26	0.16	25.24	25.94
		U of A	17.84	3.22	0.22	0.23	0.10	1.05	21.06	22.57
AP	g SO_2-e	BASF	56.22	252.20	1.16	1.74	8.22	7.53	308.4	327.1
		U of A	52.99	252.18	2.92	1.26	3.62	15.03	305.2	326.8
Land use	m^2a	BASF	19.58	0.47	0.06	0.18	0.12	0.06	20.05	20.47
		U of A	19.29	0.26	0.11	0.37	0.01	0.03	19.55	20.01

The linear model showed similar changes to the Phase 1 2005 to 2011 comparison in impact in five of the six categories (

). The only contradictory results were seen for AP, in which BASF reported improvements per CB; whereas our results indicated the opposite.

Table 6.
Comparison of the change in results from 2005 to 2011 in the EEA and this study. Red shading represents an increase in impact from 2005, whereas green shading represents no change or a decrease in impact.

We identified several possible explanations for the differences between the results from our linear model and the results from the EEA, although the magnitude and direction of influence from individual sources is difficult to isolate and quantify. The following sections briefly address known sources of uncertainty regarding comparisons between our results and those from Phase 1 of the EEA.

Table 6.
Comparison of the change in results from 2005 to 2011 in the EEA and this study. Red shading represents an increase in impact from 2005, whereas green shading represents no change or a decrease in impact.

Phase 1 – Change from 2005 to 2011

Impact category	**Units**	**Study**	**Beef Supply Chain Stage**						**Farm Gate**	**CB**
			Feed	*Cattle*	*Harvest*	*Case-ready*	*Retail*	*Home*		
GWP	kg CO_2e	BASF	2.6%	-0.1%	-35.2%	-19.0%	-1.7%	-0.7%	0.4%	-0.8%
		U of A	1.6%	0.4%	-26.7%	-2.1%	0.0%	0.0%	0.6%	-0.1%
Energy use	MJ	BASF	-0.7%	-2.2%	-26.9%	-35.4%	-0.7%	-0.8%	-0.7%	-1.9%
		U of A	-2.0%	-3.0%	-23.8%	-1.0%	0.0%	0.0%	-2.0%	-2.0%
Water use	liter	BASF	-3.3%	-3.1%	-11.6%	-45.2%	-0.8%	-1.0%	-3.3%	-3.4%
		U of A	-3.3%	-3.0%	-15.1%	-13.1%	0.0%	0.0%	-3.3%	-3.3%
POCP	g C_2H_4-e	BASF	0.1%	-1.8%	-68.7%	-35.0%	-0.4%	-0.8%	-0.2%	-1.4%
		U of A	-2.8%	-1.2%	-35.4%	-2.1%	0.0%	0.0%	-2.6%	-2.8%
AP	g SO_2-e	BASF	-36.2%	11.1%	-47.4%	-31.7%	-0.7%	-1.0%	-2.1%	-2.6%
		U of A	-5.3%	10.7%	-37.1%	-5.2%	0.0%	0.0%	7.6%	6.6%
Land use	m^2a	BASF	-3.4%	-0.4%	-46.1%	-54.4%	-0.4%	-1.0%	-3.4%	-4.5%
		U of A	-6.3%	-0.1%	1.8%	0.0%	0.0%	0.0%	-6.3%	-6.1%

The first cause was identified in the radial model portion of this assessment. The unit processes that make up most of the background data utilized in the SimaPro® software platform are different from those used by BASF. As discussed in other sections of this report, these differences can influence results in either direction from those obtained by BASF. Post-farm gate supply chain stages are disproportionately influenced by database uncertainty because those results are driven primarily by their constituent background unit processes, as opposed to on-farm impacts, which were derived from well documented LCI and were largely attributable to just a few emitted substances with well documented characterization factors.

Another potential source applies specifically to the harvesting stage, but is likely affecting outcomes in each of the impact categories. The harvesting LCI data provided values for the inventory flows on the basis of 1.5 million processed animals, but gave no indication of the average weight of each animal. Without this information, we assumed that the average weight of an animal going through the harvesting facility was equal to that of the MARC farm. This meant that the average weight of an animal sent to harvesting may not be the same as in the EEA. Additionally, the average incoming slaughter weight in 2011 was different than that of 2005, which also may not align with the calculations in the EEA.

We also identified the total animal weight sent to harvest as a potential source of disagreement with our results. The Phase 1 report states the approximate number of animals maintained on the MARC farm but does explicitly report the total LW sent to slaughter. We did receive one spreadsheet reporting a value for LW produced, but were unable to reproduce this value according to the methods described in the Phase 1 report, or any other variation on those methods that have been described in published documents or sources of data we have received. While our calculations produce a value that is very similar to the one found in the spreadsheet, a slight difference in the total LW could be magnified by the potential difference indicated in the aforementioned harvesting calculations. Our findings are discussed in further detail for each impact category in Sections 3.2.1 through 3.2.6.

3.2.1 Global warming potential

Results for GWP using the linear model are within 1% of BASF's in the feed and cattle stages for both 2005 and 2011; however, our post-farm gate values are consistently lower in most supply chain stages. While this is true for both 2005 and 2011, the difference is more pronounced in 2005. One possible explanation is that the average animal weight at harvest in our model is different than that in the EEA, which would affect comparisons for both harvesting and case-ready supply chain stages.

When comparing the change in GWP from 2005 to 2011 in the EEA versus in this study, we see that the assessments show directionally similar outcomes at the farm gate and for the CB. The one discrepancy between studies arises from differences in the results for the cattle stage. Our model suggests a slight increase in GWP from 2005 but the EEA shows a slight decrease. We compared LCIs and found that the methane emissions in the 2011 cattle phase of the EEA did not include manure storage; however, manure storage emissions were included in 2005. We simulated 2011 without the manure storage emissions and found that the cattle stage GWP also decreased from 2005 as a result. We suspect that this omission in the EEA was made in error.

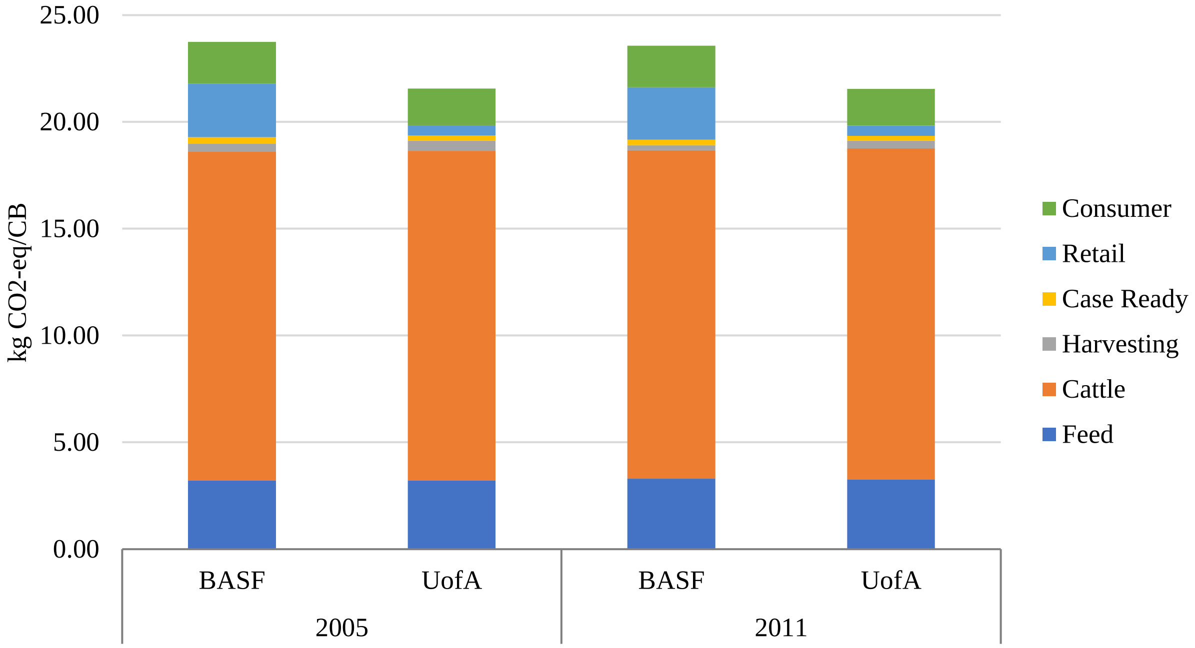

Figure 16.

GWP results for the 2005 and 2011 linear model (UofA) as compared to the results from the EEA (BASF).

3.2.2 Energy use

Energy use at the farm gate for 2005 and 2011 is comparable to the EEA findings. Both years show less than 3% difference from BASF’s results; however, our values for the cattle stage are higher. One contributing factor is the impact assessment method that our model uses. We found that this method follows different accounting procedures than the EEA. Energy use in the EEA is the sum of energy consumed at the point of consumption – apparently excluding energy consumed in the upstream supply chain. The method employed by our model includes the upstream energy consumption. Because energy is lost during transportation and distribution, non-bio based energy sources contribute more to this category in our results. This slight difference in accounting did not influence the direction of change from 2005 to 2011, as our results and BASF's show a 2% improvement in energy use associated with the CB.

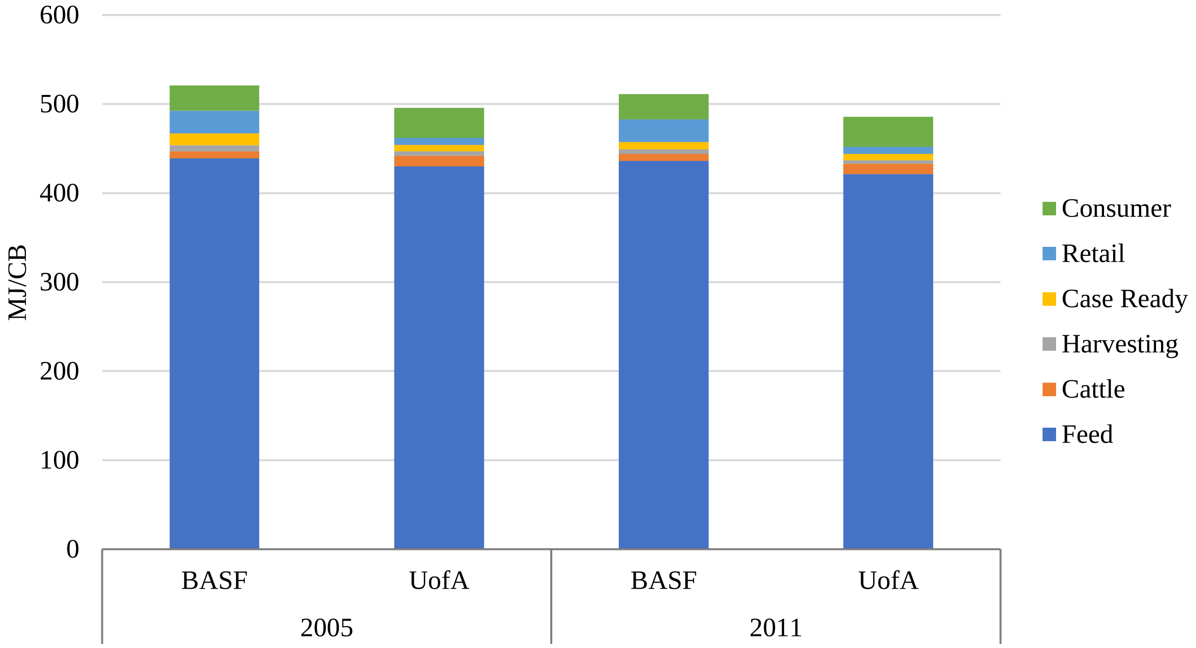

Figure 17.

Energy Use results for the 2005 and 2011 linear model (UofA) as compared to the results from the EEA (BASF).

3.2.3 Water use

This impact category is the only one of the six compared that is not a published impact assessment model. We chose to include it in this comparative assessment because water use is an important consideration to the U.S. beef industry. The majority of consumption is tied to feed production. Irrigation water use does not rely on proprietary unit processes for accounting, and as such, the on-farm water use results from our model are reliably comparable to the EEA.

The larger discrepancies between post-farm gate results are likely due to data gaps related to pre-chain impact differences between our unit process database and BASF's. In particular, the consumer stage results in the EEA has a relatively high water use reported, but the data we received for this stage showed near-zero direct water use (0.06 kg water per CB). We obtained a spreadsheet containing the breakdown of EEA results from the NCBA indicating that water use in the consumer stage is almost entirely attributed to direct use, but inexplicably the impact result is more than 100 times larger than the inventory value.

Another likely contribution the differences between models relates to our assumptions regarding water use categories. BASF applied "consumptive water values" from USGS coefficients, which presented challenges when applying these coefficients in our model. It was often unclear whether post-farm gate water consumption – particularly from pre-chain sources – should be categorized as "industrial use" or "utilities". Despite this uncertainty in BASF's methodology, there are not significant differences in the result.

Results for water use at the farm gate are within 1% of BASF's for both 2005 and 2011 and show nearly identical decreases from 2005 at both the farm gate and CB. There are relatively large percentage differences in the post-farm gate supply chain, but those stages are such minor contributors to the total water consumption that the conclusions remain unaffected.

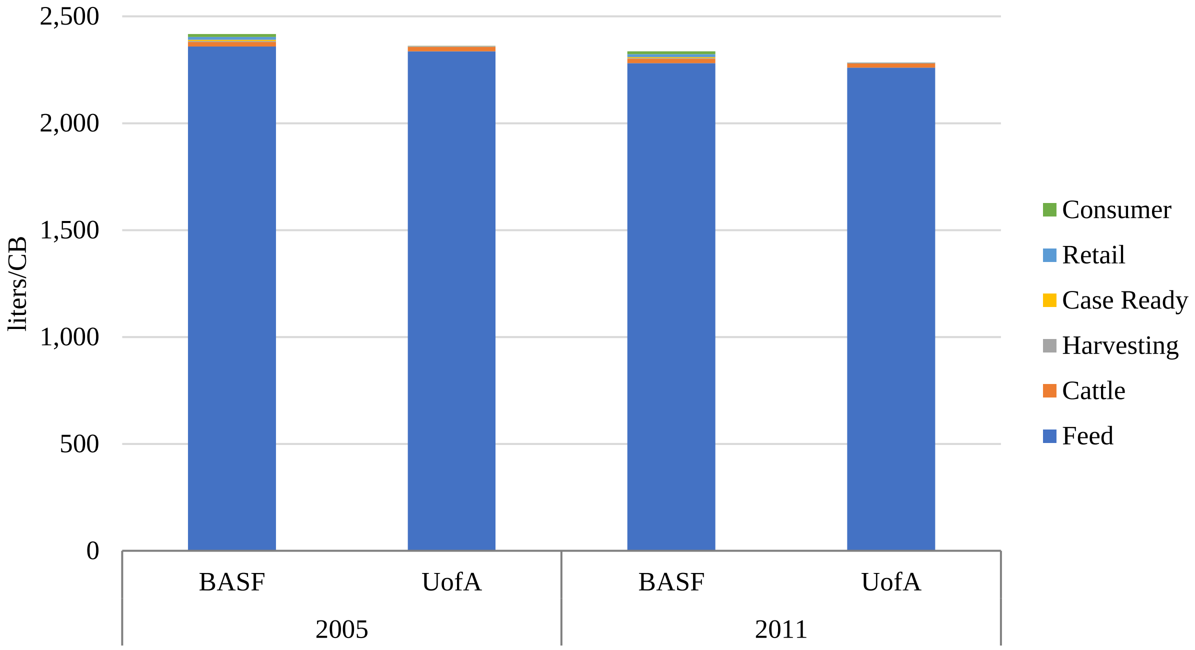

Figure 18.

Water use results for the 2005 and 2011 linear model (UofA) as compared to the results from the EEA (BASF).

3.2.4 Photochemical ozone creation potential

Results for photochemical ozone creation potential were the least well aligned of the six impact categories. The non-methane volatile organic carbons (NMVOCs) that drive the impact in this category were not one of the emissions calculated in the older version of IFSM. Therefore the only sources of NMVOC emission data were the cattle and feed spreadsheets obtained from the USDA. Results from our assessment show somewhat lower POCP at the farm gate and per CB in both 2005 and 2011. However, the change in impact from 2005 to 2011 is similar to the EEA as both show improvement at the farm gate and CB.

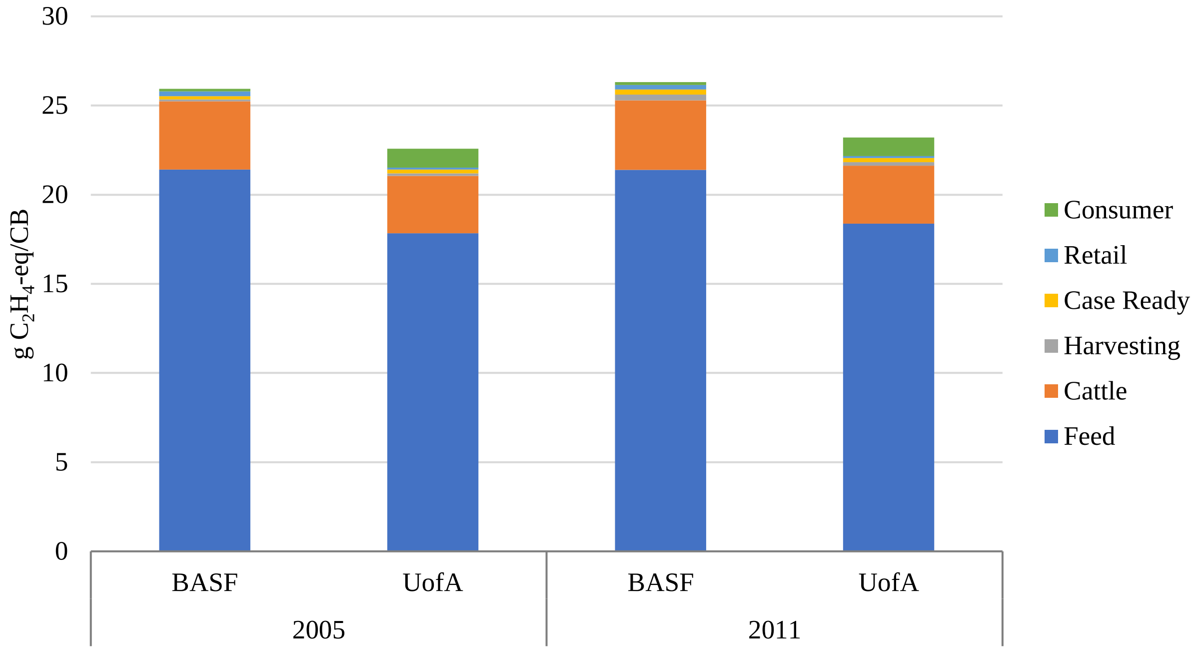

Figure 19.

POCP results for the 2005 and 2011 linear model (UofA) as compared to the results from the EEA (BASF).

3.2.5 Acidification potential

Our acidification results are very similar to the EEA for 2011, particularly at the farm gate. The 2005 results for this category are not quite as well aligned, at least for the feed stage. The difference in 2005 feed stage AP results come from the emissions from purchased corn. BASF shows 34 g SO_2-eq/CB for purchased corn, which is 63% of the entire feed stage. We found this result surprising considering that purchased corn accounts for less than 10% of the feed consumed. We followed the procedures outlined in the Phase 1 report to calculate the LCI for purchased corn, which resulted in a contribution to AP approximately ten times lower than that reported by BASF. This discrepancy in purchased corn impact is responsible for a majority of the difference between our 2005 result and that from the EEA.

Interestingly, when it comes to the change in AP from 2005 to 2011, our results are directionally equivalent to BASF’s at each individual supply chain stage, showing a decrease in each one except the cattle stage in which both show an increase. Yet results at the farm gate and the CB do not agree, with our model showing higher AP in 2011 and the EEA showing lower. If our AP associated with purchased corn was in line with BASF's (or vice versa) our overall results would be in directional agreement.

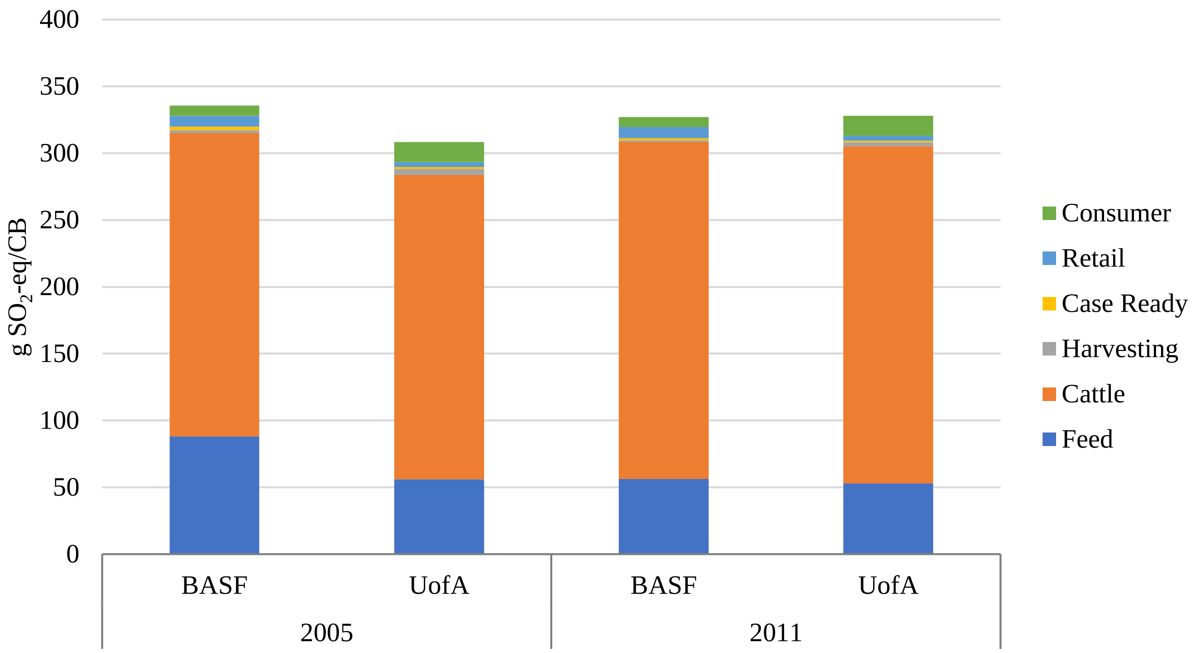

Figure 20.

AP results for the 2005 and 2011 linear model (UofA) as compared to the results from the EEA (BASF).

3.2.6 Land use

Land use results between our assessment and BASF's are very similar, with less than 2% difference in the feed stage for 2005 and 2011. The feed phase (crop production and pasture) accounts for approximately 95% of the land use in 2005 and 2011 in our assessment and the EEA. Our results are noticeably lower in the cattle stage, despite the only major land use belonging to the feedlot. We used the exact same input value for the size of the feedlot and were unable to account for the fact that BASF reports nearly double the land use in the cattle stage as our results. Despite this reported difference, the overall contribution to land use is relatively minor, and differences in the results per CB in 2005 are less than 1%, and less than 3% in 2011. Our results are directionally similar with the EEA, showing a decrease in land use from 2005 to 2011 at both the farm gate and the CB.

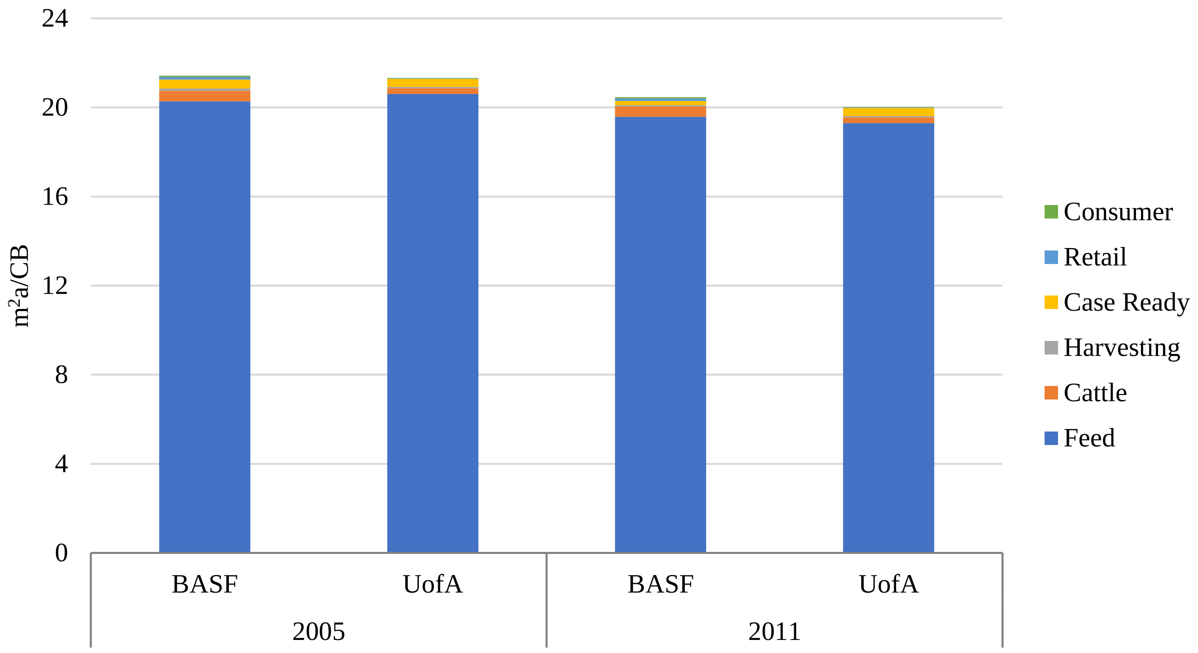

Figure 21.

Land use results for the 2005 and 2011 linear model (UofA) as compared to the results from the EEA (BASF).

3.2.7 Monte Carlo Simulations

We conducted an additional analysis with our linear model in order to determine the extent that our conclusions were affected by uncertainty. We compared our 2005 results to 2011 using Monte Carlo simulations. We ran comparative MCS for 2005 CB versus 2011 CB for 1000 simulations. We assigned uncertainty to input parameters for each life cycle stage using the pedigree matrix approach. Data quality scores were based on information describing the data sources in each supply chain stage given by BASF in the Phase 1 report. Results from this analysis are shown in Figure 22.

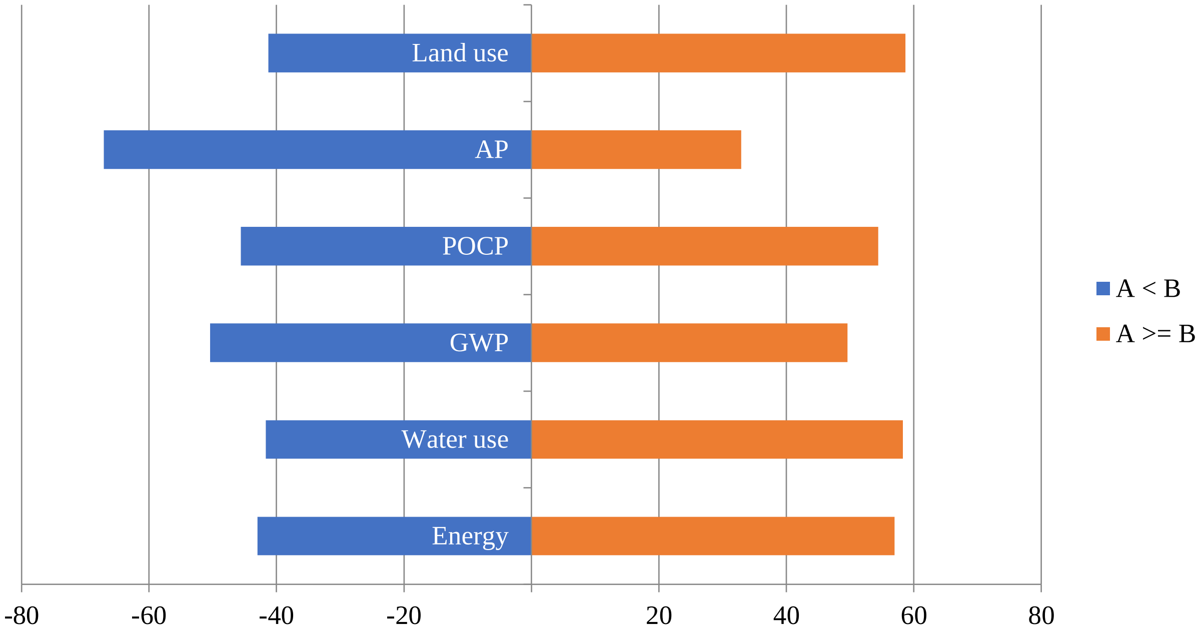

Figure 22.

Results from the Monte Carlo simulation of 1 lb beef consumed at home in 2005 'CB 2005' (A) minus 1 lb beef consumed at home in 2011 'CB 2011' (B).

Interpretation of Figure 22 is based on the understanding that the length of the bars represent the fraction of the 1000 simulations, chosen randomly, for which 2005 was larger than 2011 for each impact category. For each of the categories, aside from acidification potential, there is a slight bias showing that impact in 2005 are larger than in 2011; approximately a 55 to 45% chance that 2011 represents decreased impacts of. For acidification potential, based on the discussion above, we see that there is an increase in 2011 primarily associated with purchased corn. For global warming potential, there is no statistical difference between the two years, as half of the simulations show 2011 has lower GWP and half show 2005 has lower GWP.

3.3 Economic Results

Results of this study show that, in 2014, the beef cattle production and processing industry directly contributed to the employment of nearly 883,000 workers across the U.S, resulting in more than $27 billion dollars in labor income and $58 billion in value added to the U.S. economy. When indirect and induced impacts are added, the cattle industry’s total contributions to the economy more than double to almost 2.1 million jobs, $92 billion in income and $165 billion in value added. Sectors that benefited most were: Wholesale Trade, Real Estate, Truck Transportation, Agricultural Support Activities, Hospitals and Natural Gas and Crude Petroleum Extraction.

An examination of the individual regions shows that South Plains region (Kansas, Oklahoma, Texas) held the greatest economic contribution with beef cattle production and processing employing approximately 311,000 workers directly, and supporting almost 210,000 additional jobs through indirect and induced contributions. In terms of value added, this region contributed more than $18 billion directly, and an additional $17 billion through indirect and induced contributions. This outcome was expected as Texas, Kansas, and Oklahoma each fell into the top five states in terms of cattle inventory, production, value of production, and gross income during 2014 (USDA NASS, 2016a).

The North Plains (Nebraska, North Dakota, South Dakota) and Midwest (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Wisconsin) regions showed the second greatest contributions to beef production and processing in the U.S. Although the Midwest employed more workers through direct and indirect channels, the North Plains region showed higher induced employment and value added within the region. Nebraska and South Dakota appear to carry the North Plains region with Nebraska ranking first in the nation in gross income from cattle and calves and second in cattle inventory, production, and value of production. South Dakota ranked within the top ten for each of these areas. In the Midwest, Iowa ranks high in terms of inventory, production, and value, followed closely by Missouri and Wisconsin (USDA NASS, 2016a).

In terms of total jobs, beef cattle production and processing contributed almost 197,000 jobs in the Western region, 149,000 in the Southeast, 96,500 in the Northwest, and 77,500 in the Northeast. These were coupled with value added contributions of $17 billion in the Western region, $7 billion in the Northwest, $6 billion in the Southeast, and $4 billion in the Northeast.

Outside industries shown to be most heavily affected by beef cattle production and processing in terms of employment include Wholesale Trade, Truck Transportation, Employment and Payroll of Local Government/Education, Real Estate, and Full-Service Restaurants. In terms of value added, industries most heavily affected by beef cattle production and processing include Wholesale Trade, Real Estate, Owner-Occupied Dwellings, Truck Transportation, Employment and Payroll of Local Government/Education, Real Estate, and Full-Service Restaurants.

3.3.1 National Contribution Assessment

As mentioned, direct impacts are those attributed to the beef industry itself. Direct employment is influenced by the type of beef activity that is prevalent in the region, not just cattle inventory numbers. For example, regions with large numbers of small production operations generally have higher employment per head than larger, more efficient feedlots. Regional indirect and induced impacts are not only shaped by the composition of the beef industry there (e.g., production and/or processing) but also by the presence and absence of other industries that support the beef industry as well as general regional population levels. Regions with sectors that support the beef industry (providing inputs to production and processing activities such as packaging, truck transportation, hay farming) will generally have higher indirect and induced impacts than those regions with less of these support sectors.

The cattle production and processing industries' direct contributions to the national economy in 2014 approximated 883,000 jobs, \$27.6 B in labor income and \$58 B in value added (Table 7).

Table 7.
The US Direct, Indirect, and Induced Contributions

Nation **Impact Type**	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	882,861.9	27,600,035,580.1	58,129,513,474.3
Indirect Effect	506,485.3	27,048,925,921.2	45,677,141,364.1
Induced Effect	709,756.2	37,263,144,088.9	61,597,775,670.1
Total Effect	**2,099,103.5**	**91,912,105,590.2**	**165,404,430,508.4**

The activities of the cattle industry contributed to the creation of additional jobs, income, and value added in all other sectors of the economy, leading to a total contribution of approximately 2.1 million jobs, \$92 B in labor income and \$165 B in value added. In other words, each cattle job generated almost 1.4 jobs in other industries. Each \$1 of cattle industry labor income led to the creation of over \$2 in labor income (often in higher paying jobs) elsewhere. Finally, each \$1 in value added generated by the cattle industry led to over \$1.9 in value added somewhere else in the economy. Sectors that benefited most were: Wholesale Trade, Real Estate, Truck Transportation, Agricultural Support Activities, Hospitals and Natural Gas and Crude Petroleum Extraction.

3.3.2 Regional Contribution Assessment

In the Northwest region, consisting of Alaska, Idaho, Montana, Oregon, Washington, and Wyoming, beef cattle production and processing had a direct contribution of 57,456 jobs, $1.6 billion in labor income and $4.1 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 96,510 jobs, $3.5 billion in labor income, and $7.3 billion in value added to the regional economy (Table 8).

Table 8.

Northwest Region's Direct, Indirect, and Induced Contributions

Northwest			
Impact Type	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	57,456.1	1,581,914,133.5	4,087,177,012.6
Indirect Effect	16,796.9	816,314,243.3	1,397,203,412.5
Induced Effect	22,256.6	1,070,175,218.4	1,768,663,388.7
Total Effect	**96,509.6**	**3,468,403,595.2**	**7,253,043,813.7**

In the Western region, consisting of Arizona, California, Colorado, Hawaii, Nevada, New Mexico, and Utah, beef cattle production and processing had a direct contribution of 100,603 jobs, $3.5 billion in labor income and $8.3 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 196,999 jobs, $8.7 billion in labor income, and $17.0 billion in value added to the regional economy (Table 9).

Table 9.

Western Region's Direct, Indirect, and Induced Contributions

Western			
Impact Type	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	100,603.0	3,459,563,061.8	8,312,056,811.0
Indirect Effect	39,313.9	2,123,974,691.1	3,671,807,453.5
Induced Effect	57,082.4	3,114,245,600.4	5,040,756,546.1
Total Effect	**196,999.2**	**8,697,783,353.3**	**17,024,620,810.6**

In the North Plains region, consisting of Nebraska, North Dakota, and South Dakota, beef cattle production and processing had a direct contribution of 114,860 jobs, $7.4 billion in labor income and $12.5 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 233,996 jobs, $13.6 billion in labor income, and $22.3 billion in value added to the regional economy (Table 10).

Table 10.

North Plains Region's Direct, Indirect, and Induced Contributions

North Plains **Impact Type**	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	114,860.1	7,473,079,696.8	12,461,184,376.2
Indirect Effect	40,663.1	2,798,190,094.9	4,342,291,103.4
Induced Effect	78,472.9	3,336,428,083.4	5,536,488,005.5
Total Effect	**233,996.0**	**13,607,697,875.0**	**22,339,963,485.1**

In the South Plains region, consisting of Kansas, Oklahoma, and Texas, beef cattle production and processing had a direct contribution of 311,092 jobs, $8.1 billion in labor income and $18.2 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 520,646 jobs, $18.3 billion in labor income, and $35.4 billion in value added to the regional economy (Table 11).

Table 11.

South Plains Region's Direct, Indirect, and Induced Contributions

South Plains **Impact Type**	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	311,092.8	8,078,292,524.6	18,208,433,151.8
Indirect Effect	94,159.2	4,585,875,361.0	8,014,334,761.5
Induced Effect	115,394.2	5,599,603,843.6	9,146,740,123.1
Total Effect	**520,646.2**	**18,263,771,729.2**	**35,369,508,036.4**

In the Midwest region, consisting of Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, and Wisconsin, beef cattle production and processing had a direct contribution of 134,575 jobs, $4.4 billion in labor income and $8.7 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 258,967 jobs, $10.9 billion in labor income, and $19.3 billion in value added to the regional economy (Table 12).

Table 12.

Midwest Region's Direct, Indirect, and Induced Contributions

Midwest **Impact Type**	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	134,575.8	4,426,684,038.2	8,729,251,621.2
Indirect Effect	48,812.3	2,916,498,411.6	4,644,582,090.2
Induced Effect	75,579.1	3,603,983,059.8	5,887,610,438.0
Total Effect	**258,967.3**	**10,947,165,509.6**	**19,261,444,149.4**

In the Southeast region, consisting of Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Virginia, beef cattle production and processing had a direct contribution of 115,447 jobs, $1.6 billion in labor income and $3.6 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 149,056 jobs, $3.0 billion in labor income, and $6.0 billion in value added to the regional economy (Table 13).

Table 13.

Southeast Region's Direct, Indirect, and Induced Contributions

Southeast **Impact Type**	**Employment**	**Labor Income**	**Total Value Added**
Direct Effect	115,447.3	1,597,680,689.7	3,553,581,049.1
Indirect Effect	17,078.3	691,265,503.3	1,205,072,381.7
Induced Effect	16,531.1	707,389,000.9	1,267,402,053.8
Total Effect	**149,056.7**	**2,996,335,193.9**	**6,026,055,484.5**

In the Northeast region, consisting of Delaware, Maryland, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, Ohio, Pennsylvania, West Virginia, beef cattle production and processing had a direct contribution of 50,990 jobs, $739 million in labor income and $2.0 billion in total value added. When adding in indirect and induced effects, the total contribution of beef production and processing was valued at 77,545 jobs, $2.0 billion in labor income, and $4.0 billion in value added to the regional economy (Table 14).

Table 14.

Northeast Region's Direct, Indirect, and Induced Contributions

Northeast Impact Type	Employment	Labor Income	Total Value Added
Direct Effect	50,990.2	738,538,886.3	1,950,001,524.7
Indirect Effect	13,643.9	516,023,362.5	914,352,040.3
Induced Effect	12,911.8	742,131,149.8	1,179,800,643.8
Total Effect	**77,545.9**	**1,996,693,398.6**	**4,044,154,208.8**

3.3.3 Summary of economic contribution

The results suggest that the cattle industry provided large contributions both the national and regional economies in terms of jobs, income and value added. Importantly, the cattle industry served as an important driver of the economy in 2014 as each individual cattle industry job and $1 in cattle industry income and value added led to the creation of 1.4 jobs, and almost $2 in value added and over $2 in labor income elsewhere in the economy.

While government sources represent the most reliable and consistently reported data for the cattle industry, these data are often highly aggregated and/or available for only some states, and not others. Therefore, these results represent initial estimates and could be improved with better data.

4 Ongoing work

4.1 Updated Model

Several aspects of the modeling approach are being updated to reflect new information or to adjust for methodological choices in the EEA that are inconsistent with common LCA practices. The following sections detail the changes being made to the updated LCA model.

4.1.1 IFSM software updates

The inventory data for the EEA conducted by BASF was supplemented by IFSM version 3.6. Since that time, IFSM has undergone several updates, and is currently at version 4.4. Because livestock modeling and environmental impact assessments are an ongoing science, many of the emissions produced by IFSM have changed since version 3.6.

In addition, version 4.4 of IFSM does not have the same file structure representing the MARC farm as was made available for version 3.6. The latest version of IFSM combines the four individual files used in the EEA and in our linear model to one file for the entire farm. These differences will likely contribute to slightly different numerical results, but we expect overall conclusions will be robust.

In addition to the updated algorithms within IFSM, we are continuing the adaptation of the software to export simulation results in a spreadsheet. The spreadsheet exports ease the burden of manipulating data from IFSM output files, which were text files and necessitated data be manually extracted. This process will allow us to extract more granular data. The LCI data from IFSM used in the EEA was supplemented with primary data obtained from the MARC farm, which was needed to assess which energy uses were attributable to which stages of beef production. Similarly, individual files were created for each aspect of the production on the MARC farm (cow-calf, feedlot, crops) to classify emissions and determine associated burdens. With the IFSM updates, we can extract activities and emissions per crop or per herd group without mixing data sources or having to create multiple IFSM files to represent one farm.

4.1.2 LCA model updates

The linear model constructed to reproduce the findings from Phase 1 of the EEA is continually updated to adhere to common LCA practices and adapted for impact assessment methods which are publicly accessible, internationally recognized, and compatible with the SimaPro® software platform. We are adapting the model so that individual crops and life stages of the cattle are distinct unit processes. This will enable us to differentially account for the quantities of feed consumed by individual herd groups and avoid the blanket attribution approach used in the EEA, by which beef was assigned a certain percentage of the burden associated with total crop production regardless of how much of each individual crop was fed to cattle or sold.

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5.1 Additional sources of data

- U.S. Beef LCA Manuscript. (2016). Submitted to Int. J. LCA.
- U.S. Beef LCA Manuscript – Supplementary Info. (2016).
- Case-Ready Packaging Data
- Spreadsheet Data
  - BASF Feed Data from MARC
  - BASF Cattle Data from MARC
  - NCBA Phase 1 Data
  - Phase 2 Input Data from MARC
  - Beef Cooking Trends
  - Harvesting Data
  - BASF Phase 1 Diagrams for NSF Submission
  - BASF Phase 2 Diagrams for NSF Submission
  - Food Waste Scenarios
- IFSM Input Files
  - IFSM v3.6
    - MARC Farm: 2005 and 2011
      - Cow-Calf: Fall
      - Cow-Calf: Spring
      - Feedlot
      - Farm
  - IFSM v4.3
    - MARC Farm 2011
      - Combined File: Cow-Calf, Feedlot, Farm (“MARCfullsystem”)

6 Supplemental Information

Dissemination Plan/Progress Report

- i. We are in the process of drafting a manuscript which will define this work as the foundation for future benchmarking and identification of improvement opportunities for the sector.
- ii. This project did not rely on MS or PhD students, one research associate was fully supported and a second was partially supported.
- iii. No additional funding was secured as a result of beef industry support of this project.

a. Financial Report
  - i. Was the project completed on budget? Yes.
  - ii. If the project was completed under budget, why was the cost less than the original estimate?

7 Appendix A: Lifecycle Inventory Sources

Table A1: Life cycle inventory data sources for the feed phase from this study. A “No” in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

	Life Cycle Phase: Feed		
Category	Substance/Resource from BASF report	Substance/Resource SimaPro® input	Exact match?
Corn silage	Urea fertilizer (CH_4N_2O)	Urea, as N, at regional storehouse/RER	No
	Glyphosate	Glyphosate, at regional storehouse/RER	No
	Dimethylamine salt of dicamba	Dicamba, at regional storehouse/RER	No
	Dimethenamide pesticide	Dimethenamide, at regional storage/RER	Yes
	Atrazine	Atrazine, at regional storehouse/RER	Yes
	S-metolachlor	Metolachor, at regional storehouse/RER	No
	Acetochlor	Acetamide-anillide-compunds, at regional stroehouse/RER	No
	Pyraclostrobin	Fungicides,, at regional storrehouse/RER	No
	Electricity, irrigation	Electricity, low voltage, at grid/US	No
	Natural Gas, irrigation wells	Natural gas, combusted in industrial equipment	No
	Diesel, irrigation surface water, off road and road	Diesel, burned in building machine/GLO	No
	Gasoline, all uses	Gasoline, combusted in equipment NREL/US	No
	Lubricant, all uses (road and ag)	Heavy fuel oil, burned in refinery furnace/MJ/RER	No
Corn Grain (MARC)	Urea fertilizer (CH_4N_2O)	Urea, as N, at regional storehouse/RER	No
	Glyphosate	Glyphosate, at regional storehouse/RER	No
	Dimethylamine salt of dicamba	Dicamba, at regional storehouse/RER	No
	Dimethenamid	Dimethenamide, at regional storage/RER	Yes
	Atrazine	Atrazine, at regional storehouse/RER	Yes
	S-metalochlor	Metolachor, at regional storehouse/RER	No
	Acetochlor	Acetamide-anillide-compunds, at regional stroehouse/RER	No
	Pyraclostrobin	Fungicides,, at regional storrehouse/RER	No
	Electricity, irrigation	Electricity, low voltage, at grid/US	No
	Natural Gas, irrigation wells	Natural gas, combusted in industrial equipment	No
	Diesel, irrigation surface water, off road and road	Diesel, burned in building machine/GLO	No
	Gasoline, all	Gasoline, combusted in equipment NREL/US	No
	Lubricant, all uses (road and ag)	Heavy fuel oil, burned in refinery furnace/MJ/RER	No
Distillers Grain	WDG	DDGS,wet, at farm/US U-economic value allocation	No
	Transport WDG	Transport, single unit truck, diesel powered NREL/US	Yes
Alfalfa	SSP (20% P_2O_5)	Single supperphosphate, as P2O5 at regional storehouse/RER	No
	Ammonium salt of imazethaphyr	Herbicides, at regional storehouse/RER	No
	Diesel, irrigation surface water, off road and road	Diesel, burned in building machine/GLO	No
	Gasoline, all	Gasoline, combusted in equipment NREL/US	No

Category	Life Cycle Phase: Feed Substance/Resource from BASF report	Substance/Resource SimaPro® input	Exact match?
Pasture (grass)	Lubricant, all uses (road and ag)	Heavy fuel oil, burned in refinery furnace/MJ/RER	No
	Urea fertilizer (CH_4N_2O)	Urea, as N, at regional storehouse/RER	No
	Glyphosate	Glyphosate, at regional storehouse/RER	No
	Paraquat Dichloride	Pesticide unspecified, at regional storehouse/RER	Yes
	Clopyralid	Pesticide unspecified, at regional storehouse/RER	Yes
	2,4-D	2,4-D, at regional storehouse/RER	Yes
	Dimethylamine salt of 2,4-D-Dichlorophenoxyacetic acid	2,4-D, at regional storehouse/RER	Yes
	Picloram	Pesticide unspecified, at regional storehouse/RER	Yes
	Carbaryl	Insecticides, at regional storehouse/RER	No
	Electricity, irrigation	Electricity, low voltage, at grid/US	No
	Natural Gas, irrigation wells	Natural gas, combusted in industrial equipment	No
	Diesel, irrigation surface water, off road and road	Diesel, burned in building machine/GLO	No
	Gasoline, all	Gasoline, combusted in equipment NREL/US	No
	Lubricant, all uses (road and agriculture)	Heavy fuel oil, burned in refinery furnace/MJ/RER	No

Table A2: Life cycle inventory data sources for the cow-calf phase from this study. A “No” in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

Life Cycle Phase: Cow-Calf			Exact match?
Category	Substance/Resource from BASF	Substance/Resource SimaPro® input	
Supplementary Feed	Corn	Corn grain, region 3, at field/US U	No
	Dicalcium phosphate	Dicalcium phosphate	No
	Iodine	Iodine, proxy	No
	Limestone (Calcium Carbonate)	Limestone, milled, packed, at plant/CH	No
	Magnesium oxide	Magnesium oxide, at plant/RER	No
	Molasses	Molasses, from sugar beet, at sugar refinery/CH	No
	Potassium fertilizer	Single superphosphate, as P2O5, at regional storehouse/RER	No
	Sodium chloride	Sodium chloride, at plant NREL	No
	Zinc Sulfate	Zinc monosulphate, ZnSO4, H2O, at plant/RER	No
Utilities	Electricity, pole sheds	Electricity, low voltage, at grid/US	No
	Diesel, road	Diesel, burned in diesel-electric generating set/GLO	No
	Gasoline, all	Gasoline, combuted in equipment NREL	No
	Lubricant	Heat, heavy fuel oil, at industrial furnace 1MW/RER	No
Transport	Cows / Calves	Transport, single unit truck long-haul, diesel powered /tkm/RNA	Yes

Table A3: Life cycle inventory data sources for the feedlot phase from this study. A “No” in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

Life Cycle Phase: Feedlot			Exact match?
Category	Substance/Resource from BASF	Substance/Resource SimaPro® input	
Supplementary Feed	Copper Chloride	Copper oxide, at plant/RER	No
	Limestone (Calcium Carbonate)	Limestone, milled, packed, at plant/CH	No
	Magnesium oxide	Magnesium oxide,, at plant/CH	No
	Molasses	Molasses, from sugar beet, at sugar refinery/CH	No
	Sodium chloride	Sodium chloride, at plant NREL	No
	Sodium Selenite	Sodium sulphate, powder, production mix, at plant/RER	No
	Thiamine Mononitrate	Potassium nitrate, as K2O, at regional storehouse/RER	No
	Urea	Urea, as N, at regional storehouse/RER	No
	Zinc Sulfate	Zinc monosulphate, ZnSO4, H2O, at plant/RER	No
Utilities	Electricity, pole sheds	Electricity, low voltage, at grid/US	No
	Diesel, road	Diesel, burned in building machine/GLO	No
	Gasoline, all	Gasoline, combuted in equipment NREL	No
	Lubricant	Heat, heavy fuel oil, at industrial furnace 1MW/RER	No
Transport	Cows / Calves	Transport, single unit truck long-haul, diesel powered /tkm/RNA	Yes

Table A4: Life cycle inventory data sources for the harvesting phase from this study. A "No" in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

Life Cycle Phase: Harvesting Categories	Substance/Resource from BASF	Substance/Resource SimaPro® input	Exact match?
Chemicals	Acetic Acid	Acetic acid, at plant/kg NREL	No
	Acid Phosphoric	Phosphoric acid, industrial grade, 85% in H2O, at plant/RER	No
	Anhydrous Ammonia	Ammonia aqua, at regional storehouse/US U	No
	Antifoam	Antifoam, proxy	No
	Carbon Dioxide	Carbon dioxide liquid, at plant/RER	No
	Chlorine	Chlorine, production mix, at plant/kg NREL/RNA	No
	Citric Acid	Acetic acid, at plant/kg NREL	No
	Detergent	Detergent, proxy	No
	Hydrogen Peroxide	Hydrogen Peroxide, 50% in H2O, at plant/RER	No
	Hypochlorite Calcium	Calcium chloride, from hypochlorination of allyl chloride, at plant/RER	No
	Lactic Acid	Acetic acid, at plant/kg NREL	No
	Nitric Acid	Nitric acid, 50% in H2O, at plant/RER	No
	Sodium Chloride	Sodium Chloride,at plant NREL/RNA	No
	Silica	Silica sand , at plant/DE	No
	Sodium Bicarbonate	Sodium percarbonate, powder, at plant/RER	No
	Sodium Chlorite	Sodium Chloride,at plant NREL/RNA	No
	Sodium Hydroxide	Sodium hydroxide, production mix, at plant/kg NREL	No
	Sodium Hypochlorite	Sodium hypochlorite, 15% in H2O, at plant/RER	No
	Sulfamic Acid	Sulphuric acid, liquid, at plant/RER	No
	Triazine pesticide	Triazine compunds, at regional storehouse/RER	Yes
Packaging	Aluminum Alloy	Aluminum ingot, production mix, at plant NREL	No
	Cardboard, recycled	Corrugated board, recycling fibre, double wall, at plant/RER	Yes
	Cardboard, virgin	Corrugated board, fresh fibre, single wall, at plant/RER	Yes
	HDPE	Polyethylene, HDPE, granulated, at plant/RER	No
	Label, paper	Paper, woodfree, uncoated, at non-integrated mill/RER	Yes
	LDPE	Packaging film, LDPE, at plant/GLO	No
	Polypropylene	Polypropylene, granulated, at plant/RER	No
	Wood pallets	Wood container and pallet manufacturing	Yes
Consumables	Cotton	Textile, woven cotton, at plant/GLO	No
	HDPE	Polyethylene, HDPE, granulated, at plant/RER	No
	Iron	Iron and Steel, production mix NREL	No
	Nylon	Nylon 66, at plant/RER	No
	PVC	Polyvinylchloride, bulk polymerised, at plant/RER	No
	Steel	Cold rolled sheet, stell, at plant NREL/RNA	No
	Uniform Laundering	Uniform Laundering, proxy	No
	Biogas (on site generation & use)	Electricity, at cogen with biogas engine, agricultural covered, alloc. Exergy/CH	Yes

Life Cycle Phase: Harvesting Categories	Substance/Resource from BASF	Substance/Resource SimaPro® input	Exact match?
Utilities	Diesel	Diesel, burned in building machine/GLO	No
	Electricity (Purchased)	Electricity, low voltage, at grid/US	No
	Gasoline	Gasoline, combusted in equipment NREL/US	No
	LPG Butane Propane (liquid)	LPG production and combustion, at industrial boiler/US U	No
	Lubricant Oil	Heat, heavy fuel oil, at industrial furnace 1MW/RER	No
	Natural Gas	Heat, natural gas, at industrial furnace > 100kW/RER	No
Transport	Cardboard	Transport, single unit truck, long-haul, diesel powered, Central/tkm/RNA	Yes
	Cattle	Transport, single unit truck, long-haul, diesel powered, Central/tkm/RNA	Yes
	CO_2	Transport, single unit truck, long-haul, diesel powered, Central/tkm/RNA	Yes
	Plastic	Transport, single unit truck, long-haul, diesel powered, Central/tkm/RNA	Yes
	Waste	Transport, single unit truck, long-haul, diesel powered, Central/tkm/RNA	Yes
	Average for all other material inputs	Transport, single unit truck, long-haul, diesel powered, Central/tkm/RNA	Yes
Waste	Landfill	Disposal, inert waste, 5% water, to inert material landfill/CH	Yes
	Wastewater municipal treatment	Treatment, sewage, to wastewater treatment, class 3/CH	Yes

Table A5: Life cycle inventory data sources for the case ready phase from this study. A “No” in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

Life Cycle Phase: Case Ready			Exact match?
Categories	Substance/Resource from BASF	Substance/Resource SimaPro® input	
Chemicals	Alcohols C12-16 Ethoxylated	Ethoxylated alcohols (AE7), petrochemical, at plant/RER	No
	Antifoam	Antifoam, proxy	No
	Dimethyl-dodecylamine-n-oxide	Dummy_Surfactant, unspcified/kg/RNA	No
	Nitric Acid	Nitric acid, 50% in H2O, at plant	No
	Paraffin	Paraffin, at plant/RER	Yes
	Phosphoric Acid	Phosphoric acid, industrial grade. 85% in h20, at plant/RER	No
	Potassium Metasilicate	Sodium metasilicate pentahydrate, 58%, powder, at plant/RER	No
	Propylene Glycol n-butyl ether	Propylene glycol, liquid, at plant/RER	No
	Quaternary ammonium	Esterquat, coconut oil and palm kernel oil, at plant/RER	No
	Silica	Silica sand, at plant/DE	No
	Sodium Hydroxide	Sodium hydroxide, production mix, at plant/kg NREL	No
	Sodium Hypochlorite	Sodium hypocholrite, 15% in H2O, at plant/RER	No
	Sodium Xylene Sulfonate	Sodium sulphate, podwer, production mix, at plant/RER	No
Packaging	Cardboard, recycled	Corrugated board, recycling fibre, double wall, at plant/RER	Yes
	Cardboard, virgin	Corrugated board, fresh fibre, single wall, at plant/RER	Yes
	Label, paper	Paper, woodfree, uncoated, at non-integrated mill/RER	Yes
	Latex	Latex, at plant, RER	Yes
	LDPE	Packaging film, LDPE, at plant/RER	No
	Polypropylene	Polypropylene resin, at plant NREL/RNA	No
	Wood pallets	Wood container and pallet manufacturing	Yes
Consumables	Cotton	Textile, woven cotton, at plant/GLO	No
	Nylon	Nylon 66, at plant/RER	No
	Steel	Cold rolled sheet, steel, at plant NREL/RNA	No
	Uniform Laundering	Uniform Laundering, proxy	No
Utilities	Diesel	Diesel, burned in building machine/GLO	No
	Electricity (Purchased)	Electricity, low voltage, at grid/US	No
	Gasoline	Gasoline, combusted in equipment NREL	No
	LPG Butane Propane (liquid)	Propane/butane, at refinery/RER	No
	Lubricant Oil	Heat, heavy fuel oil, at industrial furnace 1MW/RER	No
	Natural Gas	Natural gas, at consumer/RNA	No
	Refrigerant Gas	Refrigerant R134a, at plant/RER	Yes
Transport	Harvesting to case-ready	Transport, single unit truck, long-haul, diesel powered /tkm/RNA	Yes
	Average for all other material inputs	Transport, single unit truck, long-haul, diesel powered /tkm/RNA	Yes
Waste	Landfill	municipal solid waste, 22.9% water, to sanitary landfill/CH U	Yes
	Wastewater municipal treatment	Treatment, sewage, to wastewater treatment, class3/CH	Yes

Table A6: Life cycle inventory data sources for the retail phase from this study. A "No" in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

Life Cycle Phase: Retail Categories	Substance/Resource from BASF	Substance/Resource SimaPro® input	Exact match?
Packaging	Cardboard, corrugated	Corrugated board, mixed fibre, single wall, at plant/RER	Yes
	Label, paper	Paper, woodfree, unocated, at non-integrated mill/RER	Yes
	LDPE	Packaging film, LDPE at plant/RER	No
	Polypropylene	Polypropylene resin, at plant NREL/RNA	No
	Polystyrene	Polystyrene, general purpose, at plant, CTR/kg/RNA	No
Consumables	LDPE	Packaging film, LDPE, at plant/RER	No
	Nylon	Nylon 66, at plant/RER	No
Waste	Landfill	municipal solid waste, 22.9% water, to sanitary landfill/CH U	Yes
Utilities	1,1,1-trifluoroethane	1,1-diflouroethane, HFC-152a, at plant/RER	No
	134 A	Refrigerant R134a, at plant	Yes
	Electricity (refrigeration)	Electricity, low voltage, at grid/US	No
	Natural Gas	Natural gas, at consumer/RNA	No
	Propane (liquid)	Heat, natural gas, at boiler atm. Low NOx condening non-modulating ,100kW RER	No
Transport	Case Ready to Retail	Trasport, single unit trucck, long haul, diesel powered/tkm/RNA	Yes
Air Emissions[†]	Gas Refrigerant Leakage	Ethane, 1, 1, 1-triflouro, HFC-143a	No
		Ethane, 1, 1, 1,2-tetraflouro, HFC-134a	No

[†] BASF only reports CO2-eq. from refrigerant leakage

Table A7: Life cycle inventory data sources for the consumer phase from this study. A "No" in the match column means that we substituted a commercially available dataset for the proprietary one used by BASF.

Life Cycle Phase: Consumer Categories	Substance/Resource from BASF	Substance/Resource SimaPro® input	Exact match?
Packaging	LDPE	Packaging film, LDPE, at plant/RER	No
Waste	Landfill	municipal solid waste, 22.9% water, to sanitary landfill/CH U	Yes
Utilities	Electricity (refrigeration)	Electricity, low voltage, at grid/US	No
	Electricity (cooking)	Electricity, low voltage, at grid/US	No
	Natural Gas	Natural gas, at consumer/RNA	No
Transport	Supermarket to consumer	Transport, single unit truck, long haul, diesel powered/tkm/RNA	Yes

8 Appendix B: Regional Output Totals

These values were used as the regional output values for sectors 11, 89, 90, and 91 in the IMPLAN model.

Northwest	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Alaska	2,467,000	1,057,438	956,996	21,565
Idaho	2,058,947,000	55,455,679	50,188,133	1,130,920
Washington	1,999,106,000	2,318,218,228	2,098,018,571	47,275,941
Montana	986,736,000	39,359,663	35,621,022	802,670
Oregon	959,183,000	130,883,010	118,450,879	2,669,126
Wyoming	1,198,782,000	11,376,070	10,295,496	231,995
REGIONAL TOTAL	*7,205,221,000*	*2,556,350,089*	*2,313,531,097*	*52,132,217*

Western	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Arizona	1,020,426,000	1,150,820,928	1,041,508,366	23,468,947
California	3,746,059,000	2,902,955,463	2,627,213,606	59,200,617
Colorado	3,901,925,000	5,481,421,590	4,960,760,015	111,783,851
Hawaii	62,241,000	19,061,763	17,251,151	388,731
Nevada	427,638,000	2,393,582	2,166,223	48,813
New Mexico	1,090,170,000	6,467,589	5,853,254	131,895
Utah	806,683,000	1,243,400,074	1,125,293,734	25,356,935
REGIONAL TOTAL	*11,055,142,000*	*10,806,520,988*	*9,780,046,349*	*220,379,789*

North Plains	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Nebraska	12,785,559,000	15,246,642,764	13,798,416,075	310,928,182
North Dakota	1,373,256,000	19,661,798	17,794,190	400,967
South Dakota	3,159,122,000	1,397,191,821	1,264,477,326	28,493,244
REGIONAL TOTAL	*17,317,937,000*	*16,663,496,382*	*15,080,687,591*	*339,822,393*

South Plains	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Kansas	9,057,968,000	12,876,390,367	11,653,305,883	262,591,097
Oklahoma	4,054,404,000	37,671,040	34,092,796	768,234
Texas	10,972,826,000	11,100,406,906	10,046,017,045	226,373,070
REGIONAL TOTAL	*24,085,198,000*	*24,014,468,313*	*21,733,415,725*	*489,732,401*

Midwest	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Illinois	846,754,000	298,650,941	270,283,104	6,090,455
Indiana	445,225,000	65,202,147	59,008,817	1,329,682
Iowa	4,735,405,000	2,033,965,084	1,840,765,665	41,479,103
Michigan	699,905,000	1,166,993,998	1,056,145,211	23,798,769
Minnesota	2,432,338,000	1,565,202,368	1,416,529,124	31,919,520
Missouri	2,010,059,000	103,555,194	93,718,839	2,111,824
Wisconsin	1,892,399,000	2,990,950,737	2,706,850,509	60,995,125
REGIONAL TOTAL	*13,062,085,000*	*8,224,520,468*	*7,443,301,269*	*167,724,478*

Southeast	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Alabama	674,959,000	9,766,141	8,838,488	199,163
Arkansas	780,317,000	8,866,089	8,023,929	180,808
Florida	872,378,000	224,463,764	203,142,715	4,577,540
Georgia	556,976,000	201,636,941	182,484,134	4,112,027
Kentucky	1,045,744,000	24,121,073	21,829,894	491,906
Louisiana	346,470,000	7,979,152	7,221,239	162,721
Mississippi	306,060,000	1,713,214	1,550,482	34,938
North Carolina	429,759,000	139,454,000	126,207,739	2,843,916
South Carolina	200,881,000	322,008,863	291,422,338	6,566,798
Tennessee	827,279,000	77,452,039	70,095,133	1,579,497
Virginia	714,626,000	20,737,270	18,767,507	422,900
REGIONAL TOTAL	*6,755,449,000*	*1,038,198,545*	*939,583,600*	*21,172,214*

Northeast	Sector 11 Output	Sector 89 Output	Sector 90 Output	Sector 91 Ouput
States:	($)	($)	($)	($)
Deleware	22,996,000	70,228,668	63,557,886	1,432,189
Maryland	6,658,000			
Connecticut	31,173,000	36,903,782	33,398,418	752,587
Maine	104,162,000			
Massachusetts	16,126,000			
New Hampshire	16,661,000			
Rhode Island	10,668,000			
Vermont	423,842,000			
New Jersey	697,090,000	60,705,165	54,938,988	1,237,974
New York	932,366,000	63,206,949	57,203,136	1,288,993
Ohio	2,447,000	198,572,187	179,710,491	4,049,527
Pennsylvania	85,836,000	1,901,067,774	1,720,491,818	38,768,899
West Virginia	258,120,000	14,174,594	12,828,197	289,066
REGIONAL TOTAL	*2,608,145,000*	*2,344,859,119*	*2,122,128,934*	*47,819,234*

9 Appendix C: Sector 89 Output Calculations

Northwest	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Dressed Carcass Value**	**Dressed Carcass Output**	**By-Product Value**	**By-Product Output**	**Total Slaughter Output**
States:	**(lbs)**	**%**	**(lbs)**	**$/lb**		**$/lb**		
Alaska	645,000	0.627	404,668	2.36	$ 955,016.34	0.16	$ 102,422.11	$ 1,057,438.46
Idaho	33,826,000	0.627	21,222,167	2.36	$ 50,084,314.35	0.16	$ 5,371,365.03	$ 55,455,679.38
Washington	1,414,031,000	0.627	887,151,959	2.36	$ 2,093,678,623.15	0.16	$ 224,539,604.54	$ 2,318,218,227.69
Montana	24,008,000	0.627	15,062,431	2.36	$ 35,547,336.93	0.16	$ 3,812,325.77	$ 39,359,662.70
Oregon	79,834,000	0.627	50,087,225	2.36	$ 118,205,852.06	0.16	$ 12,677,158.27	$ 130,883,010.34
Wyoming	6,939,000	0.627	4,353,474	2.36	$ 10,274,199.06	0.16	$ 1,101,871.40	$ 11,376,070.46
REGIONAL TOTAL	***1,559,283,000***	***0.627***	***978,281,925***	***2.36***	***$ 2,308,745,341.89***	***0.16***	***$ 247,604,747.13***	***$ 2,556,350,089.02***

Western	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Dressed Carcass Value**	**Dressed Carcass Output**	**By-Product Value**	**By-Product Output**	**Total Slaughter Output**
States:	**(lbs)**	**%**	**(lbs)**	**$/lb**		**$/lb**		
Arizona	701,960,000	0.627	440,404,198	2.36	$ 1,039,353,908.30	0.16	$ 111,467,019.33	$ 1,150,820,927.62
California	1,770,700,000	0.627	1,110,923,292	2.36	$ 2,621,778,969.49	0.16	$ 281,176,493.13	$ 2,902,955,462.62
Colorado	3,343,473,000	0.627	2,097,668,737	2.36	$ 4,950,498,219.04	0.16	$ 530,923,371.00	$ 5,481,421,590.04
Hawaii	11,627,000	0.627	7,294,689	2.36	$ 17,215,465.11	0.16	$ 1,846,297.56	$ 19,061,762.67
Nevada	1,460,000	0.627	915,993	2.36	$ 2,161,742.42	0.16	$ 231,839.20	$ 2,393,581.62
New Mexico	3,945,000	0.627	2,475,062	2.36	$ 5,841,146.46	0.16	$ 626,442.23	$ 6,467,588.69
Utah	758,430,000	0.627	475,833,034	2.36	$ 1,122,965,959.13	0.16	$ 120,434,115.14	$ 1,243,400,074.27
REGIONAL TOTAL	***6,591,595,000***	***0.627***	***4,135,515,004***	***2.36***	***$ 9,759,815,409.95***	***0.16***	***$ 1,046,705,577.60***	***$ 10,806,520,987.55***

North Plains	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Dressed Carcass Value**	**Dressed Carcass Output**	**By-Product Value**	**By-Product Output**	**Total Slaughter Output**
States:	**(lbs)**	**%**	**(lbs)**	**$/lb**		**$/lb**		
Nebraska	9,299,912,000	0.627	5,834,691,848	2.36	$ 13,769,872,762.02	0.16	$ 1,476,770,002.03	$ 15,246,642,764.05
North Dakota	11,993,000	0.627	7,524,314	2.36	$ 17,757,381.36	0.16	$ 1,904,416.15	$ 19,661,797.52
South Dakota	852,237,518	0.627	534,687,134	2.36	$ 1,261,861,636.96	0.16	$ 135,330,183.83	$ 1,397,191,820.79
REGIONAL TOTAL	***10,164,142,518***	***0.627***	***6,376,903,297***	***2.36***	***$ 15,049,491,780.34***	***0.16***	***$ 1,614,004,602.02***	***$ 16,663,496,382.36***

South Plains	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Dressed Carcass Value**	**Dressed Carcass Output**	**By-Product Value**	**By-Product Output**	**Total Slaughter Output**
States:	**(lbs)**	**%**	**(lbs)**	**$/lb**		**$/lb**		
Kansas	7,854,142,000	0.627	4,927,627,090	2.36	$ 11,629,199,931.66	0.16	$ 1,247,190,435.49	$ 12,876,390,367.15
Oklahoma	22,978,000	0.627	14,416,217	2.36	$ 34,022,272.07	0.16	$ 3,648,767.98	$ 37,671,040.05
Texas	6,770,855,000	0.627	4,247,981,322	2.36	$ 10,025,235,920.52	0.16	$ 1,075,170,985.72	$ 11,100,406,906.24
REGIONAL TOTAL	***14,647,975,000***	***0.627***	***9,190,024,629***	***2.36***	***$ 21,688,458,124.25***	***0.16***	***$ 2,326,010,189.19***	***$ 24,014,468,313.44***

Midwest	Cattle Live Weight	Dressed Wt. Percentage	Est. Dressed Wt.	Dressed Carcass Value	Dressed Carcass Output	By-Product Value	By-Product Output	Total Slaughter Output
States:	(lbs)	%	(lbs)	$/lb		$/lb		
Illinois	182,166,495	0.627	114,289,830	2.36	$ 269,723,998.64	0.16	$ 28,926,941.95	$ 298,650,940.59
Indiana	39,771,000	0.627	24,952,013	2.36	$ 58,886,751.79	0.16	$ 6,315,395.22	$ 65,202,147.01
Iowa	1,240,646,652	0.627	778,371,979	2.36	$ 1,836,957,869.73	0.16	$ 197,007,214.51	$ 2,033,965,084.24
Michigan	711,825,000	0.627	446,593,422	2.36	$ 1,053,960,476.06	0.16	$ 113,033,521.90	$ 1,166,993,997.96
Minnesota	954,718,000	0.627	598,982,585	2.36	$ 1,413,598,901.11	0.16	$ 151,603,467.09	$ 1,565,202,368.20
Missouri	63,165,000	0.627	39,629,226	2.36	$ 93,524,972.39	0.16	$ 10,030,221.49	$ 103,555,193.88
Wisconsin	1,824,374,000	0.627	1,144,597,939	2.36	$ 2,701,251,135.53	0.16	$ 289,699,601.00	$ 2,990,950,736.53
REGIONAL TOTAL	***5,016,666,146***	***0.627***	***3,147,416,994***	***2.36***	***$ 7,427,904,105.25***	***0.16***	***$ 796,616,363.14***	***$ 8,224,520,468.39***

Southeast	Cattle Live Weight	Dressed Wt. Percentage	Est. Dressed Wt.	Dressed Carcass Value	Dressed Carcass Output	By-Product Value	By-Product Output	Total Slaughter Output
States:	(lbs)	%	(lbs)	$/lb		$/lb		
Alabama	5,957,000	0.627	3,737,375	2.36	$ 8,820,205.19	0.16	$ 945,935.71	$ 9,766,140.90
Arkansas	5,408,000	0.627	3,392,937	2.36	$ 8,007,330.81	0.16	$ 858,757.82	$ 8,866,088.63
Florida	136,914,945	0.627	85,899,363	2.36	$ 202,722,495.79	0.16	$ 21,741,268.47	$ 224,463,764.27
Georgia	122,991,391	0.627	77,163,834	2.36	$ 182,106,648.76	0.16	$ 19,530,292.02	$ 201,636,940.78
Kentucky	14,713,000	0.627	9,230,821	2.36	$ 21,784,737.10	0.16	$ 2,336,335.77	$ 24,121,072.86
Louisiana	4,867,000	0.627	3,053,518	2.36	$ 7,206,301.60	0.16	$ 772,850.28	$ 7,979,151.88
Mississippi	1,045,000	0.627	655,625	2.36	$ 1,547,274.54	0.16	$ 165,939.70	$ 1,713,214.24
North Carolina	85,062,000	0.627	53,367,232	2.36	$ 125,946,666.69	0.16	$ 13,507,333.18	$ 139,453,999.87
South Carolina	196,414,000	0.627	123,228,603	2.36	$ 290,819,503.31	0.16	$ 31,189,359.98	$ 322,008,863.29
Tennessee	47,243,000	0.627	29,639,888	2.36	$ 69,950,134.89	0.16	$ 7,501,903.80	$ 77,452,038.70
Virginia	12,649,000	0.627	7,935,883	2.36	$ 18,728,684.81	0.16	$ 2,008,585.00	$ 20,737,269.81
REGIONAL TOTAL	***633,264,336***	***0.627***	***397,305,078***	***2.36***	***$ 937,639,983.49***	***0.16***	***$ 100,558,561.74***	***$ 1,038,198,545.23***

Northeast	Cattle Live Weight	Dressed Wt. Percentage	Est. Dressed Wt.	Dressed Carcass Value	Dressed Carcass Output	By-Product Value	By-Product Output	Total Slaughter Output
States:	(lbs)	%	(lbs)	$/lb		$/lb		
Deleware	42,837,000	0.627	26,875,598	2.36	$ 63,426,410.86	0.16	$ 6,802,257.55	$ 70,228,668.41
Maryland								
Connecticut	22,510,000	0.627	14,122,597	2.36	$ 33,329,329.98	0.16	$ 3,574,452.40	$ 36,903,782.38
Maine								
Massachusetts								
New Hampshire								
Rhode Island								
Vermont								
New Jersey	37,028,000	0.627	23,231,077	2.36	$ 54,825,341.21	0.16	$ 5,879,823.34	$ 60,705,164.55
New York	38,554,000	0.627	24,188,477	2.36	$ 57,084,806.23	0.16	$ 6,122,142.95	$ 63,206,949.18
Ohio	121,122,000	0.627	75,990,993	2.36	$ 179,338,743.06	0.16	$ 19,233,443.95	$ 198,572,187.01
Pennsylvania	1,159,584,000	0.627	727,513,907	2.36	$ 1,716,932,820.10	0.16	$ 184,134,953.75	$ 1,901,067,773.86
West Virginia	8,646,000	0.627	5,424,433	2.36	$ 12,801,660.91	0.16	$ 1,372,932.72	$ 14,174,593.62
REGIONAL TOTAL	***1,430,281,000***	***0.627***	***897,347,082***	***2.36***	***$ 2,117,739,112.36***	***0.16***	***$ 227,120,006.65***	***$ 2,344,859,119.01***

10 Appendix D: Sector 90 Output Calculations

Northwest	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Alaska	645,000	0.627	404,668	$ 956,995.98
Idaho	33,826,000	0.627	21,222,167	$ 50,188,133.19
Washington	1,414,031,000	0.627	887,151,959	$ 2,098,018,570.53
Montana	24,008,000	0.627	15,062,431	$ 35,621,022.34
Oregon	79,834,000	0.627	50,087,225	$ 118,450,878.77
Wyoming	6,939,000	0.627	4,353,474	$ 10,295,496.25
REGIONAL TOTAL	***1,559,283,000***	***0.627***	***978,281,925***	***$ 2,313,531,097.06***

Western	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Arizona	701,960,000	0.627	440,404,198	1,041,508,365.64
California	1,770,700,000	0.627	1,110,923,292	2,627,213,606.24
Colorado	3,343,473,000	0.627	2,097,668,737	4,960,760,014.50
Hawaii	11,627,000	0.627	7,294,689	17,251,150.73
Nevada	1,460,000	0.627	915,993	2,166,223.45
New Mexico	3,945,000	0.627	2,475,062	5,853,254.46
Utah	758,430,000	0.627	475,833,034	1,125,293,734.33
REGIONAL TOTAL	***6,591,595,000***	***0.627***	***4,135,515,004***	***9,780,046,349.35***

North Plains	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Nebraska	9,299,912,000	0.627	5,834,691,848	13,798,416,074.54
North Dakota	11,993,000	0.627	7,524,314	17,794,190.31
South Dakota	852,237,518	0.627	534,687,134	1,264,477,326.42
REGIONAL TOTAL	***10,164,142,518***	***0.627***	***6,376,903,297***	***15,080,687,591.27***

South Plains	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Kansas	7,854,142,000	0.627	4,927,627,090	11,653,305,883.38
Oklahoma	22,978,000	0.627	14,416,217	34,092,796.21
Texas	6,770,855,000	0.627	4,247,981,322	10,046,017,045.15
REGIONAL TOTAL	***14,647,975,000***	***0.627***	***9,190,024,629***	***21,733,415,724.74***

Midwest	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Illinois	182,166,495	0.627	114,289,830	270,283,104.49
Indiana	39,771,000	0.627	24,952,013	59,008,817.04
Iowa	1,240,646,652	0.627	778,371,979	1,840,765,665.45
Michigan	711,825,000	0.627	446,593,422	1,056,145,211.08
Minnesota	954,718,000	0.627	598,982,585	1,416,529,123.92
Missouri	63,165,000	0.627	39,629,226	93,718,838.56
Wisconsin	1,824,374,000	0.627	1,144,597,939	2,706,850,508.65
REGIONAL TOTAL	***5,016,666,146***	***0.627***	***3,147,416,994***	***7,443,301,269.18***

Southeast	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Alabama	5,957,000	0.627	3,737,375	8,838,488.42
Arkansas	5,408,000	0.627	3,392,937	8,023,929.06
Florida	136,914,945	0.627	85,899,363	203,142,715.48
Georgia	122,991,391	0.627	77,163,834	182,484,134.24
Kentucky	14,713,000	0.627	9,230,821	21,829,894.27
Louisiana	4,867,000	0.627	3,053,518	7,221,239.41
Mississippi	1,045,000	0.627	655,625	1,550,481.85
North Carolina	85,062,000	0.627	53,367,232	126,207,739.18
South Carolina	196,414,000	0.627	123,228,603	291,422,337.64
Tennessee	47,243,000	0.627	29,639,888	70,095,133.22
Virginia	12,649,000	0.627	7,935,883	18,767,507.15
REGIONAL TOTAL	***633,264,336***	***0.627***	***397,305,078***	***939,583,599.93***

Northeast	**Cattle Live Weight**	**Dressed Wt. Percentage**	**Est. Dressed Wt.**	**Boxed Beef Cutout Value**
States:	**(lbs)**	**%**	**(lbs)**	
Deleware	42,837,000	0.627	26,875,598	63,557,886.29
Maryland				
Connecticut	22,510,000	0.627	14,122,597	33,398,417.73
Maine				
Massachusetts				
New Hampshire				
Rhode Island				
Vermont				
New Jersey	37,028,000	0.627	23,231,077	54,938,987.64
New York	38,554,000	0.627	24,188,477	57,203,136.26
Ohio	121,122,000	0.627	75,990,993	179,710,491.00
Pennsylvania	1,159,584,000	0.627	727,513,907	1,720,491,818.14
West Virginia	8,646,000	0.627	5,424,433	12,828,197.23
REGIONAL TOTAL	***1,430,281,000***	***0.627***	***897,347,082***	***2,122,128,934.29***

Appendix D: Sector 91 Output Calculations

Northwest	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Alaska	$ 2,295.61	$ 10,682.76	$ 5,650.12	$ 2,936.09	$ 21,564.58
Idaho	$ 120,389.87	$ 560,240.19	$ 296,311.51	$ 153,978.45	$ 1,130,920.02
Washington	$ 5,032,667.42	$ 23,419,765.79	$ 12,386,733.91	$ 6,436,773.51	$ 47,275,940.63
Montana	$ 85,446.70	$ 397,630.42	$ 210,307.06	$ 109,286.19	$ 802,670.37
Oregon	$ 284,136.61	$ 1,322,243.70	$ 699,335.81	$ 363,410.26	$ 2,669,126.38
Wyoming	$ 24,696.54	$ 114,926.59	$ 60,784.77	$ 31,586.84	$ 231,994.74
REGIONAL TOTAL	***$ 5,549,632.75***	***$ 25,825,489.44***	***$ 13,659,123.19***	***$ 7,097,971.34***	***$ 52,132,216.72***

Western	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Arizona	$ 2,498,340.72	$ 11,626,151.62	$ 6,149,081.41	$ 3,195,373.75	$ 23,468,947.49
California	$ 6,302,085.45	$ 29,327,065.17	$ 15,511,109.55	$ 8,060,357.13	$ 59,200,617.30
Colorado	$ 11,899,730.37	$ 55,375,981.57	$ 29,288,403.44	$ 15,219,735.94	$ 111,783,851.32
Hawaii	$ 41,381.57	$ 192,571.18	$ 101,851.06	$ 52,926.96	$ 388,730.77
Nevada	$ 5,196.28	$ 24,181.12	$ 12,789.42	$ 6,646.03	$ 48,812.84
New Mexico	$ 14,040.62	$ 65,338.72	$ 34,557.70	$ 17,957.93	$ 131,894.98
Utah	$ 2,699,322.68	$ 12,561,431.09	$ 6,643,751.52	$ 3,452,429.35	$ 25,356,934.65
REGIONAL TOTAL	***$ 23,460,097.68***	***$ 109,172,720.47***	***$ 57,741,544.10***	***$ 30,005,427.09***	***$ 220,379,789.34***

North Plains	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Nebraska	$ 33,099,248.96	$ 154,028,985.87	$ 81,466,060.77	$ 42,333,886.03	$ 310,928,181.64
North Dakota	$ 42,684.20	$ 198,633.02	$ 105,057.17	$ 54,593.02	$ 400,967.42
South Dakota	$ 3,033,192.33	$ 14,115,109.97	$ 7,465,493.59	$ 3,879,448.10	$ 28,493,243.99
REGIONAL TOTAL	***$ 36,175,125.50***	***$ 168,342,728.86***	***$ 89,036,611.53***	***$ 46,267,927.15***	***$ 339,822,393.04***

South Plains	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Kansas	$ 27,953,619.50	$ 130,083,545.65	$ 68,801,297.20	$ 35,752,634.25	$ 262,591,096.61
Oklahoma	$ 81,780.83	$ 380,571.13	$ 201,284.39	$ 104,597.55	$ 768,233.91
Texas	$ 24,098,100.64	$ 112,141,698.67	$ 59,311,839.18	$ 30,821,431.85	$ 226,373,070.34
REGIONAL TOTAL	***$ 52,133,500.98***	***$ 242,605,815.45***	***$ 128,314,420.77***	***$ 66,678,663.65***	***$ 489,732,400.85***

Midwest	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Illinois	$ 648,347.44	$ 3,017,116.77	$ 1,595,755.61	$ 829,235.33	$ 6,090,455.15
Indiana	$ 141,548.68	$ 658,703.74	$ 348,388.96	$ 181,040.53	$ 1,329,681.91
Iowa	$ 4,415,576.45	$ 20,548,102.56	$ 10,867,908.81	$ 5,647,515.15	$ 41,479,102.97
Michigan	$ 2,533,451.17	$ 11,789,539.82	$ 6,235,497.57	$ 3,240,279.95	$ 23,798,768.51
Minnesota	$ 3,397,929.87	$ 15,812,434.07	$ 8,363,209.74	$ 4,345,946.82	$ 31,919,520.50
Missouri	$ 224,810.09	$ 1,046,164.83	$ 553,317.46	$ 287,531.74	$ 2,111,824.13
Wisconsin	$ 6,493,116.20	$ 30,216,036.14	$ 15,981,287.04	$ 8,304,685.14	$ 60,995,124.52
REGIONAL TOTAL	***$ 17,854,779.89***	***$ 83,088,097.93***	***$ 43,945,365.20***	***$ 22,836,234.68***	***$ 167,724,477.69***

Southeast	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Alabama	$ 21,201.52	$ 98,662.30	$ 52,182.57	$ 27,116.70	$ 199,163.09
Arkansas	$ 19,247.57	$ 89,569.53	$ 47,373.40	$ 24,617.62	$ 180,808.12
Florida	$ 487,292.98	$ 2,267,641.90	$ 1,199,357.72	$ 623,246.94	$ 4,577,539.54
Georgia	$ 437,737.76	$ 2,037,034.25	$ 1,077,389.14	$ 559,865.89	$ 4,112,027.04
Kentucky	$ 52,364.93	$ 243,682.79	$ 128,884.03	$ 66,974.66	$ 491,906.41
Louisiana	$ 17,322.10	$ 80,609.27	$ 42,634.31	$ 22,154.94	$ 162,720.62
Mississippi	$ 3,719.25	$ 17,307.72	$ 9,154.07	$ 4,756.92	$ 34,937.96
North Carolina	$ 302,743.54	$ 1,408,832.00	$ 745,132.43	$ 387,208.50	$ 2,843,916.48
South Carolina	$ 699,055.63	$ 3,253,089.84	$ 1,720,561.96	$ 894,091.03	$ 6,566,798.47
Tennessee	$ 168,142.22	$ 782,458.09	$ 413,842.74	$ 215,053.62	$ 1,579,496.68
Virginia	$ 45,018.96	$ 209,497.97	$ 110,803.65	$ 57,579.18	$ 422,899.76
REGIONAL TOTAL	***$ 2,253,846.48***	***$ 10,488,385.64***	***$ 5,547,316.03***	***$ 2,882,666.01***	***$ 21,172,214.16***

Northeast	**Tallow Edible**	**Bleachable Tallow**	**Meat and Bone Meal**	**Blood Meal**	**Total By Product Processing**
States:	**Output**	**Output**	**Output**	**Output**	**Output**
Deleware	$ 152,460.85	$ 709,484.10	$ 375,246.74	$ 194,997.19	$ 1,432,188.88
Maryland					
Connecticut	$ 80,115.18	$ 372,819.92	$ 197,184.77	$ 102,467.18	$ 752,587.05
Maine					
Massachusetts					
New Hampshire					
Rhode Island					
Vermont					
New Jersey	$ 131,786.08	$ 613,273.04	$ 324,360.63	$ 168,554.19	$ 1,237,973.94
New York	$ 137,217.26	$ 638,547.28	$ 337,728.20	$ 175,500.65	$ 1,288,993.39
Ohio	$ 431,084.43	$ 2,006,072.62	$ 1,061,013.50	$ 551,356.29	$ 4,049,526.84
Pennsylvania	$ 4,127,066.96	$ 19,205,509.42	$ 10,157,810.16	$ 5,278,511.98	$ 38,768,898.52
West Virginia	$ 30,771.92	$ 143,198.63	$ 75,737.87	$ 39,357.23	$ 289,065.64
REGIONAL TOTAL	***$ 5,090,502.67***	***$ 23,688,905.01***	***$ 12,529,081.87***	***$ 6,510,744.71***	***$ 47,819,234.26***