Submission for
Verification of Eco-efficiency Analysis Under NSF Protocol P352, Part B

U.S. Beef – Phase 2
Eco-efficiency Analysis
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Submitted by:

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1. Purpose and Intent of this Submission

The purpose of this submission is to provide a written report of the methods and findings of BASF Corporation's "U.S. Beef Eco-efficiency Analysis", with the intent of having it verified under the requirements of NSF Protocol P352, Part B: Verification of Eco-efficiency Analysis Studies.

The U.S. Beef – Phase 2 Eco-efficiency Analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. The one exception to the Protocol P352 for this Eco-efficiency Analysis is that it is non-comparative in nature. Due to the fact that there was no historical data available from multiple primary partners in the value chain, the study is presented as a baseline analysis. However, a web-based tool (Eco-Efficiency Manager) is being developed for the U.S. beef industry that will use the baseline results shown in this report and will allow comparative scenarios to be developed that will automatically activate the comparative nature of the Eco-efficiency methodology.

More information on BASF's methodology and the NSF validation can be obtained at http://www.nsf.org/services/by-industry/sustainability-environment/claims-validation/eco-efficiency/ or https://www.basf.com/en/company/sustainability/management-and-instruments/quantifying-sustainability/eco-efficiency-analysis.html

2. Content of this Submission

This submission outlines the study goals, procedures, and results for the U.S. Beef Eco-efficiency Analysis (EEA) study, which was conducted in accordance with BASF Corporation's EEA methodology. This submission will provide a discussion of the basis of the eco-analysis preparation and verification work.

As required under NSF P352 Part A, along with this document, BASF is submitting the final computerized model programmed in Microsoft® Excel. The computerized model, together with this document, will aid in the final review and ensure that the data and critical review findings have been satisfactorily addressed.

3. BASF's EEA Methodology

3.1 Overview

BASF EEA involves measuring the life cycle environmental impacts and life cycle costs for product alternatives for a defined level of output. At a minimum, BASF EEA evaluates the environmental impact of the production, use, and disposal of a product or process in the areas of energy and resource consumption, water consumption, emissions, toxicity, risk potential, and land use. The EEA also evaluates the life cycle costs associated with the product or process.

3.2 Preconditions

The basic preconditions of this eco-efficiency analysis are that all alternatives that are being evaluated are being compared against a common functional unit or customer benefit. This allows for an objective comparison between the various alternatives. (As mentioned, since this study is non-comparative, an objective comparison may be made in the future using this baseline life cycle data.) The scoping and definition of the customer benefit are aligned with the goals and objectives of the study. Data gathering and constructing the system boundaries are consistent with the functional unit and consider both the environmental and economic impacts of each alternative over their life cycle in order to achieve the specified customer benefit. An overview of the scope of the environmental and economic assessment carried out is defined below.

3.2.1 Environmental Burden Metrics

For BASF EEA, environmental burden is characterized using twelve categories including: primary energy consumption (expressed as cumulative energy demand), non-renewable (or abiotic) raw material consumption (expressed as abiotic depletion potential), global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), photochemical ozone creation potential (POCP), water emissions, solid waste emissions, toxicity potential, risk potential (expressed as occupational illnesses and accidents), consumptive water use, and land use. These are shown below in Figure 1. Metrics shown in blue represent the seven main categories of environmental burden that are used to construct the environmental fingerprint; burdens in green represent all elements of the emissions category; and burdens in pink represent specific air emissions impact categories considered.

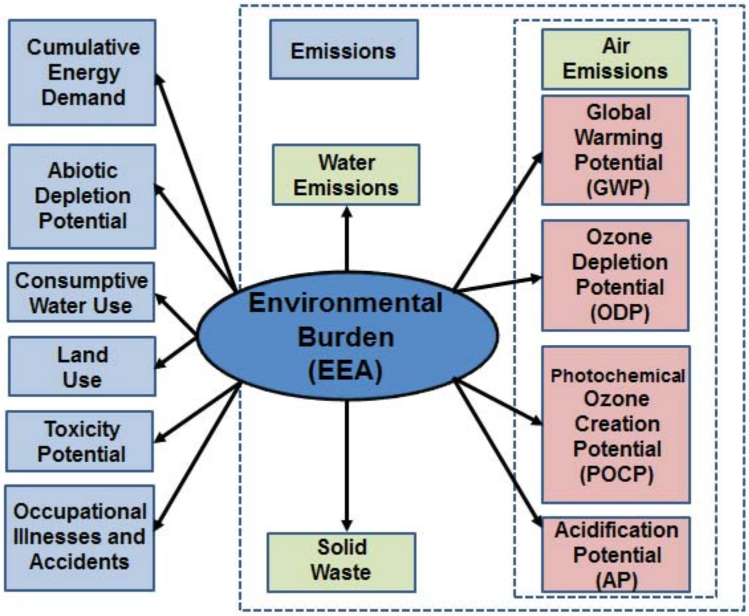

Figure 1: Environmental Burden Metrics for BASF Eco-efficiency Methodology

3.2.2 Economic Metrics

It is the intent of the BASF EEA methodology to assess the economics of products or processes over their life cycle and to determine an overall total cost of ownership for the defined customer benefit ($/CB).

3.3 Work Flow

A representative flowchart of the overall process steps and calculations conducted for this eco-efficiency analysis is summarized in Figure 2 below. Note that due to the non-comparative nature of this study, the eco-efficiency portfolio is not developed in this study.

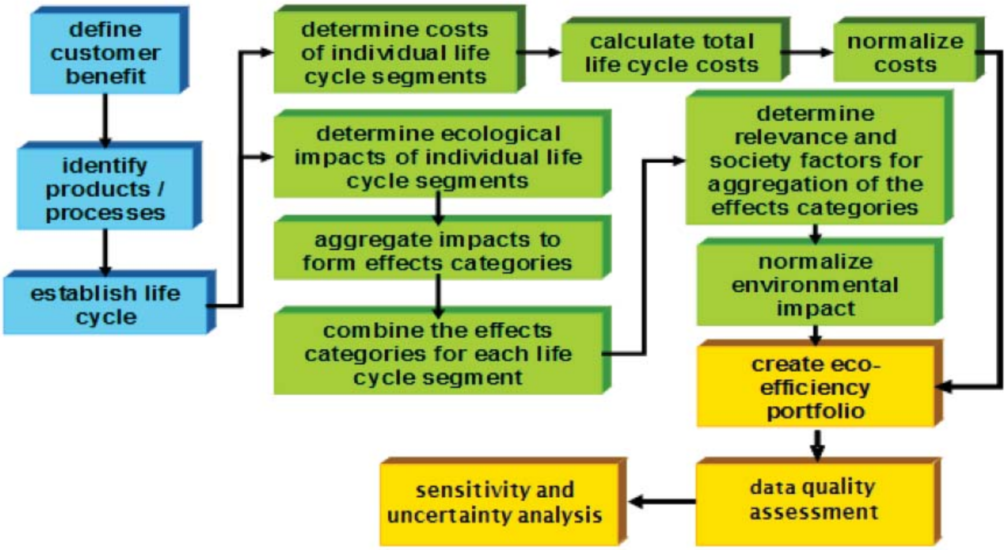

Figure 2: Overall Process Flow for U.S. Beef EEA Study

4. Study Goals, Decision Criteria and Target Audience

4.1 Study Goals

A sustainable beef industry is critically important as we work toward the goal of feeding more than 9 billion people by the year 2050[1]. Experts estimate that this future global population will require 70 percent more food with fewer available resources. The goals of this study were to benchmark the eco-efficiency of the value chain of the U.S. beef industry. This provides a starting point for ongoing analysis and a journey of continuous improvement within the industry. Any established opportunities will be used to set the U.S. beef industry on a more sustainable pathway, which may include sharing and communicating best practices, embedding improvement opportunities throughout the industry, prioritizing solutionoriented research on sustainability criteria that are determined to be critical, and empowering the industry through ongoing education.

This EEA submission is the second phase (Phase 2) of an ongoing study of the U.S. beef industry. Phase 1 established a historical perspective of the eco-efficiency of the U.S. beef industry and considered specific on-farm data from the largest research farm in the U.S. combined with post-farm data that is representative of the entire US beef industry. Phase 2 is intended to build upon the Phase 1 base case study for the year 2011 and includes refined data, additional datasets, and an expanded focus of the beef value chain for data that is representative of the period between 2011 and 2013. Individual data point timeframes are associated with when data were collected or for which year data were actually available. (Additional detail in Section 4.2.3 and Table 1 below.)

Major specific changes or additions to the Phase 1 base case study that are reflected in this Phase 2 study include:

- updated farm-level data for the U.S. Meat Animal Research Center (USMARC) that refines segregation of impacts at the actual cattle phases (Phase 1 represented total cattle impacts at the cattle phase. This study updates that data to segregate impacts according to actual operations at the USMARC facility and are represented according to the cow-calf operations and feedlot, which includes integrated backgrounding.),
- expanded aggregated data into the case-ready sector analysis from an additional case-ready partner,
- replacement of literature average data in the retail sector phase analysis to now include primary data from retail partners,
- expansion of the study to include the restaurant sector with addition of primary industry data from restaurant partners, and
- value chain scenario analysis using farm data from Pennsylvania grass-finished systems.

Phase 2 is considered to be a baseline study for the industry of current practices. There is no historical comparison as was completed in Phase 1 because historical data were not available for much of the expanded data considered in Phase 2.

The study will continue over the next few years in order to compile a complete aggregated national farm-level dataset that will consider all major beef producing regions in the U.S. Additionally, future data for the industry will continue to be collected and analyzed to better understand the changes that occur within the sustainability profile of the industry, to pinpoint opportunities for impact reduction across the industry, and to drive the sustainability performance of the U.S. beef industry.

4.2 Context & Decision Criteria

The study goals, target audience, and context for decision criteria used in this study are displayed in Figure 3.

4.2.1 Study Drivers

The purpose of the study was to quantify and baseline the current eco-efficiency profile of the U.S. beef industry in order to gauge, plan for, and implement improvements for the U.S. beef industry as discussed above in Section 4.1.

4.2.2 Geography

The study considered beef produced by the U.S. beef industry and did not include beef exported from or imported to the U.S. It is not possible to have a dataset for the full value chain that is representative of the U.S. beef industry without aggregating regionalized on-farm data. For Phase 2 of the U.S. Beef EEA, the post-farm data is representative of the U.S. beef industry. However, the on-farm data are representative of the U.S. Department of Agriculture's Roman L. Hruska Meat Animal Research Center (USMARC) located in Clay Center, Nebraska. USMARC was selected for this phase of the U.S. Beef EEA because as a research center USMARC has extensive data, which were very difficult to find in a centralized manner elsewhere in the industry.

The USMARC is a research facility so its production practices do not fully represent the beef industry as a whole. In reality, no single specific beef producing facility can represent the industry due to the considerable variation in management practices that occurs among regions and producers. The crop, feed, and animal management practices used at USMARC are typical of the practices used in this region of the U.S. except for the amount of irrigation used. This operation uses more irrigation than the overall industry and this use has increased over the years with more corn production and some irrigation of pasture. Greater use of irrigation results in increased non-precipitation water use, energy use, and carbon emissions. A major environmental benefit for the beef industry as a whole has been an increased use of dairy calves. When dairy calves are grown for beef, the environmental impact of maintaining their breeding stock is primarily allocated to the dairy industry. This allocation of resources and emissions greatly reduces the environmental footprint of cattle raised from dairy calves. Because dairy cattle are not part of the USMARC system due to the fact that it is a beef cattle research farm, no allocation is made in this study and therefore, the analysis of this USMARC system does not receive this benefit. As a result, the USMARC farm impacts of this study are considered to be likely conservative as compared to commercial operations. Other minor differences in labor and resource use will exist for this government facility, but these differences will have little effect on the environmental impact of the cattle produced.

Representative regionalized data will be collected, aggregated, and analyzed in future phases of the U.S. Beef EEA.

4.2.3 Scenario and Horizon

The study considered the eco-efficiency attributes of the total value chain for beef that was produced by the U.S. beef industry (according to the geographical scope defined in Section 4.2.2) during the period of 2011-2013. Data were selected from this period based upon availability and timing of data collection and this period is considered to be representative of current beef industry practices. Specific years for which each of the value chain phase data were analyzed are shown below in Table 1.

Phase	Source Data Year
Feed (USMARC)	2011
Cow-Calf (USMARC)	2011
Feedlot (USMARC)	2011
Harvesting	2011
Case-Ready	Combination of 2011 & 2013
Retail	2013
Consumer	2011
Restaurant	Combination of 2011 & 2013

Table 1: Source Data Year by Value Chain Phase

4.2.4 Engagement

The study is intended to be used by the entire value chain of the U.S. beef industry and shared with the stakeholders and any other interested external parties of the industry.

4.2.5 Life Cycle

The study reviewed the entire life cycle of the beef consumed at home and in restaurants that is produced by the U.S. beef industry according to the geographical scope defined in Section 4.2.2 (cradle-to-grave).

4.2.6 Product and Market

The study considered beef produced by the U.S. beef industry (per Section 4.2.2) and consumed at home and in restaurants. Future updates to the study will include regionalized on-farm data.

4.2.7 Economy

The economy considered the U.S. market, a developed economy.

4.2.8 Innovation

The study is intended to lead mainly to incremental innovation within the U.S. beef industry.

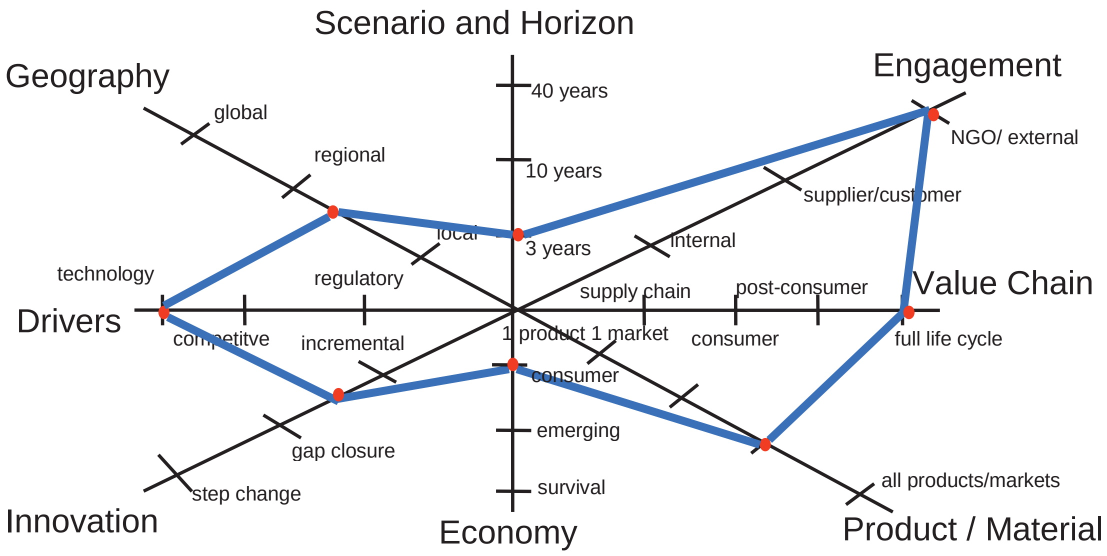

Figure 3: Context of U.S. Beef EEA Study

5. Customer Benefit, Alternatives and System Boundaries

5.1 Customer Benefit (CB)

The functional unit or Customer Benefit (identified also as CB) applied for this analysis is one pound of consumed, boneless, edible beef. This CB was selected in order to capture a relative average of the beef industry. Because there are so many different types of beef cuts and further-processed beef products, it is not reasonably feasible to analyze all types of beef produced in the U.S. Additionally, in order to understand the impacts specific to beef, boneless beef was evaluated. Finally, in order to evaluate the entire beef life cycle, the CB considers beef consumed.

5.2 Alternatives

There are no alternatives analyzed in this study. While Phase 1 evaluated the historical progression of beef, Phase 2 is considered to be a baseline study for the industry of current practices. There is no historical comparison as was completed in Phase 1 because historical data was not available for much of the expanded data that was considered in Phase 2. As a result of the study being non-comparative, there is no environmental fingerprint or eco-efficiency analysis portfolio associated with this study. As mentioned, this study can be used for future comparative scenario analysis.

5.3 System Boundaries

The system boundary for this study is presented in Figure 4 below. Dairy cattle were not included in the scope of this study because they are not included in the beef production system at USMARC. Additionally, as is common practice in life cycle analysis, capital equipment, buildings, and infrastructure and repair and maintenance material, parts, and supplies were excluded. Office & administrative impacts, employee commutes, seeds for feed, cattle veterinary medicines, and cleaning chemicals used at the retail sector were excluded according to the cut-off criteria defined in the BASF EEA Methodology. These aspects have a *de minimus* impact on study results, contributing individually less than 1% and collectively less than 3% to the overall value chain impacts in this study.

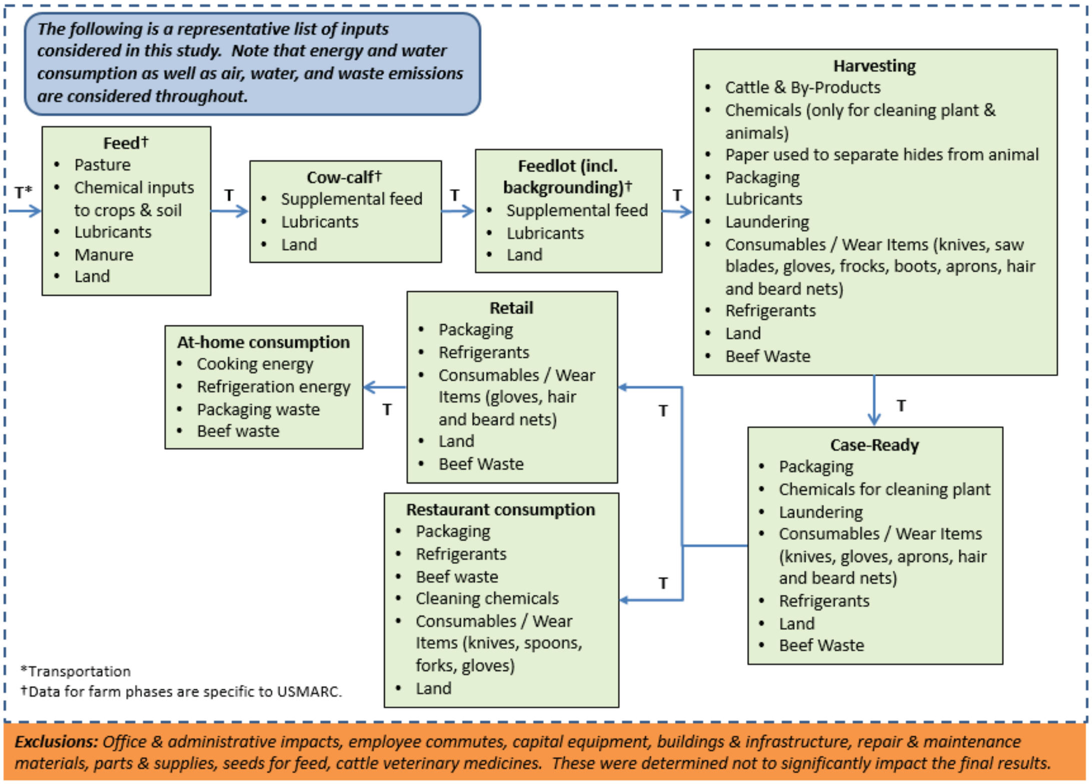

Figure 4: System boundary for U.S. Beef – Phase 2

5.4 Scenario Analyses

In addition to the base case analysis, the following scenario analyses were considered:

- Scenario #1: Analysis of Wet Distillers Grains with Solubles (WDGS) using a mass allocation.
- Scenario #2: Analysis of Wet Distillers Grains with Solubles (WDGS) using an energy content allocation.
- Scenario #3: Consumer phase refrigeration using an economic allocation.

Note that the practice of allocation is applied in life cycle analysis when impacts associated with the study boundary cannot be easily separated from impacts of products or by-products that are part of the same system. ISO defines allocation as "partitioning the input or output flows of a process or product system between the product system under study and one or more other product systems."[2] Through allocation, a percentage of impacts are assigned to the scope product system and the other integrated product system or systems through an appropriate allocation approach that can include weighting by physical attributes (mass, volume, energy content, etc.), economics, or other methods. Within this study, allocation was avoided wherever possible, but was necessary for:

- consideration of the animal by-products, which are processed in the same facility as the beef itself;
- analysis of distillers grains, which are a by-product of the bioethanol distillation process;
- analysis of retail and restaurant primary data, which were not available at a product level; and
- analysis of consumer refrigeration because refrigeration for beef in this phase is integrated with numerous other refrigerated foods.

6. Input Parameters and Assumptions

6.1 Input Parameters

Given the size and scope of this study, numerous sources were utilized for input parameters. Specifics on applicable parameters and associated assumptions for each phase of the scope of the study are included below.

6.1.1 Overall Study Assumptions

The following assumptions were used:

1. Table 2 presents the dressing percentage (yield of carcass from live animal) and value chain loss values that were applied in order to obtain the CB of weight of consumed, boneless, edible beef. The dressing percentage value was based upon an industry average of 62% with a 3% reduction to account for cull cows and bulls. Loss values used were from the USDA Economic Research Service[3], with the exception of retail loss values, which are based on primary data. Note that the total loss is not a simple sum of each individual phase loss, but instead, each loss is calculated from the previous phase.

Dressing percentage	59%
Losses at harvesting & case-ready phase (fat, bone, and shrink)	33%
Loss at retail phase (shrink & spoilage)	7%
Loss at consumer phase (cooking losses, spoilage, plate waste)	20%
Total losses from live animal weight sent from cattle phase	*71%*

Table 2: Dressing Weight and Value Chain Losses

2. Consumptive water values were taken from coefficients that are defined in the last published USGS water report that contained ranges for consumptive water for high-level sectors.[4] Mid-point values of these ranges were assumed for this study as follows:

    a. Industrial use: 25%
    b. Agriculture: 70%
    c. Livestock: 55%
    d. Thermoelectric Utilities: 50%

3. For the waste considered in this study, which is not being recycled or reused, it was assumed that 82% of the waste is disposed of in a landfill and 18% is incinerated with energy recovery. This assumption was based on 2010 EPA national waste data.[5]

4. In order to avoid allocation and the potential for double-counting credits and impacts for energy recovery outside of the study boundary, the cut-off method was applied to the 18% of the waste that is incinerated with energy recovery. Therefore, it was assumed that the impacts of the incineration process were considered to be the burden of the purchaser of the electricity that is generated from energy recovery.

5. Based upon data from study partners, the packaging used directly or indirectly for the beef product that was purchased at retail (non-restaurant) was assumed to be 63% completed in the case-ready phase (i.e., packaged into a retail-ready output) and 37% at the retail store directly.

6. Based upon industry average data, it was assumed that 47% of beef is consumed at home and 53% is consumed in a restaurant.[6] Impacts for each of these consumption points were divided accordingly.

7. For post-farm packaging that was used as direct inputs to the beef system, the following approach was taken regarding waste disposal and recycling:

    a. According to the data collected from the primary partners, 100% of corrugated cardboard is recycled. In order to avoid allocation and potential for double-counting credits and impacts of the recycling system, a closed-loop recycling process was assumed and the cut-off method was applied. Therefore, the impacts of the recycling process were considered to be the burden of the purchaser of the recycled material. For this study specifically for example, the harvesting facilities surveyed purchased corrugated cardboard that contained 30% recycled fiber content. Therefore, to be consistent, the burden of the recycling process for producing that recycled content was included in the total impacts of this study.

   b. All post-farm packaging other than cardboard was assumed to be disposed of according to the above 82%:18% landfill:incineration ratio.

   c. A modified ecoinvent profile was applied for municipal solid waste landfilling for packaging waste.

8. For cost analysis, the present value (here 2011 dollars since all data through the harvesting phase is representative of 2011) consumer price of the beef was utilized and assumed to reflect the full cost of the value chain up to the point of sale at the retailer. These values were not associated with the operational costs of the beef value chain. However, using the consumer price was seen as the best possible approach to achieve a total cost that was representative of the entire U.S. beef industry in order to align representative impacts of the post-farm value chain as discussed in Section 4. Costs were utilized from USDA Economic Research Service data.[7]

6.1.2 USMARC Feed Production and Pasture

The feed production phase accounted for the life cycle of the feed (i.e., the agricultural crops and pastureland) that was consumed by the animals raised in the beef system. Input parameters for the feed phase were considered mainly based on modeling data produced by the U.S. Department of Agriculture's (USDA) Integrated Farm Systems Model (IFSM). This approach was utilized as some primary data availability for on-farm production is limited.

The IFSM is a research tool used to assess and compare the environmental and economic sustainability of farming systems. Crop production, feed use, and the return of manure nutrients back to the land are simulated for many years of weather on a crop, beef, or dairy farm.[8] Growth and development of crops are predicted for each day based upon soil, water, and nitrogen availability, ambient temperature, and solar radiation. Simulated tillage, planting, harvest, storage, and feeding operations predict resource use, timeliness of operations, crop losses, and nutritive quality of feeds. Feed allocation and animal responses are related to the nutrient contents of available feeds and the nutrient requirements of the animal groups making up the herd. For beef operations, the animal groups can include cows, calves, replacement animals, stockers, backgrounding and finishing cattle.[9] The quantity and nutrient contents of the manure produced are a function of the feeds consumed and herd characteristics.

Nutrient flows are tracked through the farm to predict losses to the environment and potential accumulation in the soil.[10] Environmental losses include ammonia emission, denitrification and leaching losses of nitrogen, erosion of sediment across the farm boundaries, and the runoff of sediment-bound and dissolved phosphorus. The sum of the various forms of nitrogen loss provides a total reactive nitrogen loss. Carbon dioxide, methane, and nitrous oxide emissions are tracked from crop, animal, and manure sources and sinks to predict net greenhouse gas emission. Whole-farm mass balances of nitrogen, phosphorus, potassium, and carbon are determined as the sum of nutrient imports in feed, fertilizer, deposition, and legume fixation minus the nutrient exports in milk, excess feed, animals, manure, and losses leaving the farm.

The IFSM boundaries are depicted below in Figure 5.

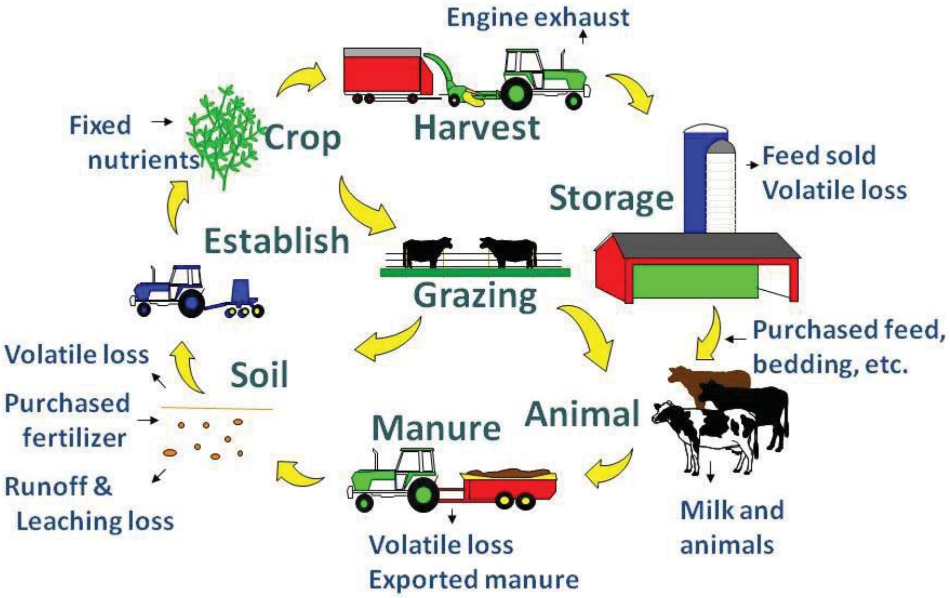

Figure 5: Boundaries, major components and nutrient flows simulated with the Integrated Farm System Model[11]

Note that while soil quality and biodiversity are important issues to agricultural sustainability, further research is necessary for quantification of these aspects. As improved data are discovered that are pertinent to this study, an expanded analysis may be performed to include these issues in the future.

The IFSM was used to model the USMARC facility, feed production, feed use and animal production. Simulation of this production system provided system inputs as well as certain emissions and outputs. IFSM data, while providing simulated process-level results, has been extensively demonstrated in this and numerous other projects to provide accurate outputs, representative of actual production systems. An example of the accuracy of the IFSM simulation capability is shown below in Table 3 with USMARC simulated data compared to actual reported feed use, which represents some of the IFSM data directly used in this study.

Feed Type	Actual tons Dry Matter	Simulated tons Dry Matter	% Difference
Alfalfa / grass hay silage	6,096	6,102	0.0
Corn silage	5,444	5,422	0.4
High moisture corn	3,092	3,109	0.5
Corn grain	1,834	1,820	0.8
Distillers grain	1,841	1,837	0.2
Total	*18,307*	*18,290*	*0.0*

Table 3: Actual reported vs. IFSM Simulated feed production at USMARC for 2011 [12]

All IFSM data related to feed that was used for this analysis are on a dry matter (DM) basis. Where necessary, the DM values were converted to wet matter based on moisture content. IFSM data were used for all direct system inputs and direct emissions where the IFSM provided data necessary to fulfill the BASF EEA methodology. Other sources of data, as discussed further in Section 7, were used for all pre-chain emission life cycle inventory analyses as well as for some additional direct emissions.

The USMARC facility included about 5,000 acres of irrigated farmland used for feed production.

Feed production at USMARC included alfalfa/grass (preserved as silage or hay), corn silage, corn grain (high moisture corn grain, dry grain), and soybeans. A strip tillage system was used for corn and soybean production within the USMARC facility. However, the soybeans were not fed to the cattle but were sold for use outside of the beef system. Any aspects of USMARC such as soybeans as well as other animals that were not part of the beef cattle system boundaries were removed from the boundary conditions so that only the beef system and the associated feed production required were considered.

While most feed used at USMARC was produced directly on-site, some feed was purchased from off-site sources and was also considered in this study. The purchased feed consisted of 1,790 tons of Wet Distillers Grains with Solubles (WDGS).

The following is a list of additional assumptions for the feed phase that were necessary to complete this study:

1. USMARC raises other species of animals for which some of the feed is used. Resource use and emissions from feed crop production were allocated among the animal species at USMARC using mass allocation. The ratio of the mass of feed dry matter fed to cattle over the total feed dry matter produced provides the allocation factor. Through simulation of the various production systems with the IFSM, the portion of the total feed used by

cattle within the USMARC system and assigned as the associated allocation factor was found to be 82.5%.

2. Manure was considered in this study, including that from the cow-calf operation on pastureland. Manure from within USMARC was used as fertilizer within USMARC. Emissions from the manure were considered.

3. Primary data from the IFSM simulations was used to obtain the following emission factors for corn production:

Runoff loss	lb P/ton P applied	0.3
	lb N/ton N applied	1.2
Air emissions (direct + crop residue)	lb N_2O/ton N applied	0.41

Table 4: Corn Direct Emissions

Table 5 presents emission factors used to calculate additional emissions from USMARC not included in the IFSM simulations. Note that for N_2O emissions, direct emissions were analyzed with IFSM in the above point. Indirect N_2O emissions related to leaching and volatilization are shown below as N direct conversion and volatilization to NH_3-N and conversion to N_2O.

Emission	Factors[13]
Leached N to N_2O-N	0.75% (0.00225 kg N_2O-N / kg fertilizer-N)
CO_2 from urea	0.20 kg CO_2-C / kg $(NH_2)_2CO$
CO_2 from limestone	0.12 kg CO_2-C / kg $CaCO_3$
Volatilization of NH_3 from fertilizer-N	10%

Table 5: Additional Field Emission Factors

Note that direct N_2O background emissions from soil were not included in the N2O emissions in this study. Only emissions associated with manure and fertilizer N application to soil were considered.

Chemical Oxygen Demand (COD) for pesticides was calculated based on the chemical formula of a substance (i.e., C, O, N and H stoichiometry) while COD for other inputs was considered directly from the eco-profiles used.

4. For heavy metal water emissions associated with fertilizers, the Swiss Agricultural Life Cycle Assessment (SALCA) calulator was used. All heavy metals considered in the BASF methodology were analyzed with the SALCA tool. While soil type and characteristics specific to the USMARC region were used to determine most aspects of feed production, the SALCA tool does

not include U.S. soil physics values. German values for soil heavy metal dynamics values such as heavy metal percolation, deposition, and leaching rates were assumed as representative values and this asssumption would have a *de minimus* impact on the overall results. The analysis includes both runoff and leaching of heavy metals.[14]

5. With the exception of enteric methane, biogenic carbon was not modeled in this study as it was assumed that for the full life cycle of the beef, any carbon that is taken into the animal (through feed) is again emitted to the atmosphere at some point along the chain. However, because enteric methane is modeled in the cattle phase, a 1 CO_2-eq credit was applied to the global warming potential (GWP) factor of methane (thus utilizing a GWP of 24 CO_2-eq for methane as opposed to the standard factor of 25 CO_2-eq). While all other biogenic carbon within the beef system is assumed to have a net-neutral impact on GWP, this reduction considered that the enteric methane is simply the conversion of the feed to methane and is being released with the higher GWP factor of methane as opposed to carbon dioxide.

6. The only impacts associated with irrigation within the USMARC system were the consumptive water value itself (since the water was well water from within the USMARC facility) and the energy required for pumping the water. Power for the pumps used for the pivot irrigation systems require electric or natural gas.

7. Transport distance was assumed to be an average of 20 miles from the distillery to the feedlot for the WDGS based on the location of the distillery from where USMARC purchased WDGS (assumed average of 250 miles for corn to distillery for the WDGS).

8. WDGS is a by-product of the bioethanol distillation process (from corn). In order to derive an appropriate impact analysis of just the WDGS, since the impacts of the WDGS alone are not easily separated from the full bioethanol distillation process, an economic allocation was performed as follows:

    a. Utilizing the ecoinvent corn ethanol profile, the distillation process results in the production of 1 kg of ethanol and 1 kg of Dried Distillers Grains with Solubles (DDGS). The drying energy was then deducted from the DDGS profile (according to the distillation ecoinvent profile) to derive an appropriate profile for WDGS.

    b. Additionally, the corn profile in ecoinvent associated with the bioethanol profile was replaced with a non-irrigated corn profile from Iowa. Yield of the corn was adjusted to 2011 yield values shown above of 168 bu/acre.

c. An adjustment factor of 1.55 was then applied to the profile to account for the fact that 1.55 times the weight of WDGS is produced compared to DDGS from the distillation process.[15]

d. The final profile of WDGS was then created by assuming an economic allocation associated with the current pricing of ethanol and WDGS, which resulted in 21% of the burden of the distillation process (and pre-chain impacts) being allocated to WDGS.

9. Gross bioenergy, or the energy released if the feed biomass were combusted, was accounted for in all crops used for feed. While the amount of feed was based on IFSM simulated outputs and includes losses from production to consumption, the gross bioenergy content was based upon ecoinvent profiles with values shown below. Note that the ecoinvent biomass content in the original profile was conveyed on a wet matter basis and therefore was converted to a dry matter basis as shown in Table 6 to correspond with feed inputs already on a DM basis.

Crop ecoinvent Profile	**Gross Bioenergy (MJ/kg DM)**
Silage maize IP, at farm/CH S	18.6
Corn, at farm/US U	18.5
Hay intensive IP, at farm	17.8
Grass from natural meadow extensive IP, at field/CH S	18.5

Table 6: Gross Bioenergy of Crops

10. For the Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the feed category were assessed using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of “Oilseed and Grain Farming”.[16]

6.1.3 USMARC Cattle Production

Parameters for the cattle production operations at USMARC were considered mainly based on modeling data extracted from the USDA’s Integrated Farm Systems Model (IFSM). The IFSM was used to model the USMARC facility and provide system inputs as well as certain emission outputs.

Due to the integrated nature of the USMARC operations, it is difficult to separately model the impacts associated with backgrounding as both the backgrounding and finish phases occur at the same feedlot. Therefore, the backgrounding/finish phases are integrated in the analysis of this study and identified as Feedlot Operations.

1. The impacts of all calves, heifers, cows, bulls, and beef cattle were included in the study.

2. All harvested and grazed forage and grains used as feed were included in the feed phase of the study. Only supplementary feeds were included in the cattle phase.

3. Emissions from the cattle operations were modeled in IFSM including:

    a. CH_4 emissions – enteric and manure emissions. The manure emissions in the feed phase were a result of manure being applied to the cropland, while manure emissions in the cattle operations included manure deposits on the pastureland and feedlot.
    b. N_2O emission – pastureland and manure emission from feedlot.
    c. NH_3 emission – urine and manure emission on pastureland and feedlot.

    Note that these emissions were predicted through simulation of the biological and physical processes modeled within the IFSM.

4. Transport within USMARC was included with an average distance of 5 miles for cows and 6 miles for calves. Transport of the cattle to the harvesting plant was included within the harvesting phase.

5. For Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the cattle category were assessed using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of “Cattle Ranching and Farming”.

6. Standard BASF risk analysis methodology considers occupational accidents and illnesses and allows for customized risks to be considered as appropriate. There was one additional risk (beyond the occupational illnesses and accidents) considered for the cattle phase, which was animal welfare. Expert opinion, supported by the national Beef Quality Assurance (BQA) program[17], evaluated this additional risk category on a scale of 1:10 with 1 representing the most risk and 10 the least risk.[18] The expert opinion scale score applied to the animal welfare category was 7.5. The total risk weighting for animal welfare was considered to be 8.5% and this weighting was split between the cattle and harvesting phases at 4.25% in each phase.

6.1.3.1 Cow-Calf Operations

The cow-calf operation is used to describe the portion of the cattle phase in which a herd of cows is maintained for the specific purpose of producing calves. The calves remain at the cow-calf operation until they are weaned and are then sent to the backgrounding program on the feedlot. The USMARC cow-calf operations handled about 6,600 cows on 24,000 acres of grazing pasture, some of which was irrigated. The animals were fed hay and silage during the winter months. Note that pasture inputs were included in the feed phase of this analysis.

6.1.3.2 Feedlot Operations

The USMARC facility also included a 3,700 head feedlot operation. Cattle were backgrounded (i.e., taken from weaned calves to yearlings) for 3 months on a high forage diet (hay silage and distillers grain) and finished in the feedlot (confined drylot) for 7 months on a high grain diet (corn silage, corn, and distillers grain). The cattle were finished at 16 months of age with an average weight of 1,280 pounds. All manure from the feedlot was returned to the USMARC cropland as a fertilizer input.

The mass value of body weight of the cattle sent to harvesting included finished cattle, cull cows, and cull bulls.

6.1.4 Harvesting

The harvesting phase considered the input of the live animal through the output of edible beef ready to be packaged for consumption, so it is essentially where the beef that consumers purchase is processed.

Primary data was collected for the harvesting phase from three beef producers, whose operations represented approximately 60% of the U.S. beef industry for the harvesting phase. These data were collected through on-site facility visits and follow-up discussion and were based on measured data for primary inputs as well as measured or calculated data for operational emissions and waste. The producers selected represented both large and small operations so that scale of operations was properly considered. Data were then aggregated in a weighted-average manner. Beef requiring further-processing (smoked, cured, or seasoned) was not included in this study.

Transportation data for all raw material and supply inputs were included in the scope of the study for the harvesting phase. Primary data associated with the transportation of cattle, waste, paper, plastics (packaging), and liquid carbon dioxide were used. For all other raw material and supply inputs, an average transport value of 1,263 miles was assigned based on the average of these 5 categories of primary transportation data.

The following is a list of additional assumptions for the harvesting phase that were necessary to complete this study:

1. An economic allocation that credits the final beef produced for the by-products of the harvesting process was applied to the study. By-products of the animal included hides, offal, blood, tallow, bones, and bonemeal. The economic allocation was based upon primary sales data for both the by-products and edible beef received from the packing sector collaborators. The allocation credit applied to the beef value chain was 11.7%, respectively (i.e.

11.7% of the harvesting impacts were allocated to the beef system by-products).

2. Corrugated cardboard used for packaging had a recycled fiber content of 30%.

3. Of the packaging used as inputs to the product system (corrugated cardboard and plastics), 96% went directly to either the case-ready or retail phase. Therefore, end-of-life impacts for this 96% were included at the respective phase. The remaining 4% of packaging plastic consumed in the harvesting plant was included as part of the total facility waste profile for end-of-life impact analysis. For the 4% corrugated cardboard intended for recycling, it was assumed there was no impact from recycling within the scope boundary as discussed in the overall study assumptions in Section 6.1.1.

4. For the Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the harvesting category were assessed using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of “Animal Slaughtering and Processing”.

5. Three additional risks (beyond the occupational illnesses and accidents) were considered for the harvesting phase. Expert opinion evaluated each risk category on a scale of 1:10 with 1 representing the most risk and 10 representing the least risk. Standard BASF risk analysis methodology considers occupational accidents and illnesses and allows for customized risks to be considered as appropriate. This study considered the expert opinion weightings and scoring scales to be a total of 20.75% of the harvesting risk analysis.

    a. *Food Safety:* Food safety was measured as contamination from pathogens as well as recalls. Based on data from the Centers for Disease Control[19] and expert opinion, the scale scoring applied to the food safety category was 8 out of a possible score of 10.[20] The risk weighting for food safety was considered to be 14% of the total harvesting risk.

    b. *Animal Welfare:* Treatment of animals was considered through various auditing programs.[21] The expert opinion scale scoring applied to the animal welfare category was 7.5 out of a possible score of 10.[22] The total risk weighting for animal welfare was considered to be 8.5% and this weighting was split between the cattle and the harvesting phases at 4.25% in each phase.

    c. *Community Nuisance Dust and Odors:* Impact of non-regulated dust and odors from the harvesting plants themselves was considered through trends observed as voluntary best practices to mitigate these community impacts in the industry over time. The expert opinion scale scoring applied to the community nuisance dust and odors was

7 out of a possible score of 10.[23] The risk weighting for community nuisance dust and odors was considered to be 2.5% of the total harvesting risk.

6.1.5 Case-Ready

The case-ready phase is where the beef produced in the harvesting phase is packaged into a retail-ready output. As mentioned earlier, for purposes of this study, 63% of the U.S. beef was assumed to be packaged in a case-ready system.

Primary data were collected for the case-ready phase of the study from one of the harvesting partners (the other two did not have case-ready operations) as well as an additional stand-alone case-ready and distribution operation. For the harvesting partner with case-ready operations, the primary data collected included inputs for energy, packaging, waste, and consumable items. Based on industry expert opinion and direct operations knowledge from this partner, certain other data values, such as certain cleaning chemicals and waste, were assumed to be 10% of the average of the harvesting facility data from the three producers surveyed. For the partner with separate case-ready operations, primary data were applied for the entire operation.

It was also assumed that for packaging used as inputs to the case-ready system, 96.5% of this packaging went on to the retailer or end-consumer. As with the harvesting phase, the remaining 3.5% was included in the case-ready facility waste profile. For the 3.5% corrugated cardboard intended for recycling, it was assumed there was no impact from recycling in scope boundary as discussed in the overall study assumptions in Section 6.1.1.

For the Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the case-ready category were assessed using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of “Animal Slaughtering and Processing”.

6.1.6 Retail

The retail phase considers the operations where packaged beef is sold to the consumer.

Primary data were collected from three retail partners, which range in size from small to large. Primary data was representative of total retail sales from these partners. Retail data that was collected represents 8% of the total beef sold in the U.S. at a retail level.

Because retailers sell more than just beef, in order to derive beef-specific retail values, an economic allocation was performed based on beef:total store sales. Additionally, since refrigeration energy and leakage are only associated with refrigerated perishable retail sales (that include beef), these aspects were further refined with average industry factors regarding retail refrigeration energy[24] and perishable sales[25].

As mentioned earlier, the packaging used directly or indirectly for the beef product that was purchased at retail was assumed to be 63% completed in the case-ready phase (i.e., packaged into a retail-ready output) and 37% at the retail store directly.

For the Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the retail category were assessed using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of "Grocery Stores".

6.1.7 Consumer

The consumer phase considers the impacts by the consumer from transportation to the retail store through consumption of the beef at the consumer's home. Based on industry sales data, it was assumed that 47% of U.S. beef is consumed at home (from retail purchase).

No primary data were used since a targeted consumer survey and study were not conducted. Literature and other publicly-available sources of information were used to construct average consumer eco-efficiency profiles that included transportation,[26] electricity consumption associated with refrigeration,[27] repackaging of beef by the consumer,[28] cooking energy,[29] and consumer beef waste[30].

A volumetric allocation based on the average U.S. diet was applied in order to determine an appropriate allocation for consumer refrigeration associated with beef. The volumetric allocation was derived from an analysis of USDA Economic Research Service data on U.S. food consumption at home and associated densities.[31]

6.1.8 Restaurant

The restaurant phase considers beef that is sold to the consumer at the restaurant level. This includes both quick service restaurants and sit-down restaurants. The data used within the study at the restaurant level is primary data from three restaurant partners (two quick service restaurants and one casual sit-down restaurant). Restaurant data that was collected represents approximately 6% of the total beef sold in the U.S. at the restaurant level.

Since restaurants sell more than just beef, in order to derive beef-specific restaurant values, an economic allocation was performed based on beef:total restaurant sales.

Based on industry data, it was assumed that 53% of beef is consumed in restaurants.

7. Data Sources

The environmental impacts for the production, use, and disposal of the various alternatives were calculated from eco-profiles (i.e. life cycle inventories) for the individual components and for fuel usage and material disposal. Life cycle inventory data for these eco-profiles were from several data sources, including BASF specific manufacturing data, Boustead[32], and ecoinvent[33]. Overall, the quality of the data was considered medium-high to high. None of the eco-profiles data were considered to be of low data quality. A summary of the eco-profiles used by phase is provided below in Table 7.

Note that an asterisk (*) in the General Utility & Waste Profiles, Feed, and Cow-calf Phases in the below eco-profile names designates that the eco-profile was also used for the Pennsylvania Grass-finished Scenario that is reviewed below in Section 9 of this report.

Eco-Profile	Source, Year	Comments
General Utility & Waste Profiles		
Water from well*	BASF, 2010	
Electricity use*	BASF, 2011	Profile based on 2011 U.S. Energy Information Administration electricity grid profile data.
Natural gas use	BASF, 1999	
Diesel use*	BASF, 1999	
Gasoline use*	BASF, 1999	
Lubricating oils*	BASF, 1999	
Transportation (diesel; long-haul)*	US LCI, 2011[34]	
Municipal wastewater treatment	Ecoinvent 2.2, 2010	Ecoinvent profile: Treatment, sewage, to wastewater treatment, class 3/CH U
Municipal solid waste landfill	Ecoinvent 2.2, 2010	Ecoinvent profile: municipal solid waste, 22.9% water, to sanitary landfill/CH U
Feed Phase		
Urea fertilizer*	BASF, 2005	
Glyphosate	BASF, 1997	
Dicamba	BASF, 1999	
Dimethenamide pesticide	Ecoinvent 2.2, 2010	Ecoinvent profile: Pesticide unspecified, at regional storehouse/RER U
Atrazine	Ecoinvent 2.2, 2010	Ecoinvent profile: Atrazine, at regional storehouse/RER U
Metolachlor	BASF, 1997	
Acetochlor	BASF, 2011	
Pyraclostrobin	BASF, 2006	
Single superphosphate fertilizer*	BASF, 1997	
Potassium fertilizer*	BASF, 1997	
Fludioxinol fungicide	Ecoinvent 2.2, 2010	Ecoinvent profile: Nitrile compounds, at regional storehouse/RER U
Mefanoxam fungicide	Ecoinvent 2.2, 2010	Ecoinvent profile: Pyretroid compounds, at regional storehouse/RER U
Clothianidin insecticide	Ecoinvent 2.2, 2010	Ecoinvent profile: Organophosphorus compounds, at regional storehouse/RER U
2,4-Dichlorophenoxyacetic acid*	Ecoinvent 2.2, 2010	Ecoinvent profile: 2,4-D, at regional storehouse/RER U
Chlorpyrifos insecticide	Ecoinvent 2.2, 2010	Ecoinvent profile: Organophosphorus compounds, at regional storehouse/RER U
Paraquat dichloride	Ecoinvent 2.2, 2010	Ecoinvent profile: Pesticide unspecified, at regional storehouse/RER U
Clopyralid herbicide	Ecoinvent 2.2, 2010	Ecoinvent profile: Pesticide unspecified, at

Eco-Profile	Source, Year	Comments
		regional storehouse/RER U
Picloram herbicide	Ecoinvent 2.2, 2010	Ecoinvent profile: Pesticide unspecified, at regional storehouse/RER U
Carbaryl insecticide	BASF, 2002	
Ammonium sulfate	BASF, 1996	
Calcium oxide*	BASF, 1997	
Bioethanol from corn	Ecoinvent 2.2, 2010	Ecoinvent profile: Ethanol, 95% in H2O, from corn, at distillery/US
Corn	BASF, 2011	
Cow-Calf Phase		
Calcium oxide*	BASF, 1997	
Magnesium oxide*	Boustead, 1996	
Sodium chloride*	Boustead, 1996	
Zinc sulfate*	BASF, 2003	
Molasses*	BASF, 2000	
Corn	BASF, 2011	
Dicalcium phosphate*	BASF, 2003	
Potassium fertilizer*	BASF, 1997	
Iodine*	BASF, 2006	
Feedlot Phase		
Urea	BASF, 2005	
Copper chloride	BASF, 1998	
Sodium selenite	BASF, 2003	
Thiamine mononitrate	BASF, 2003	
Calcium oxide	BASF, 1997	
Magnesium oxide	Boustead, 1996	
Sodium chloride	Boustead, 1996	
Zinc sulfate	BASF, 2003	
Molasses	BASF, 2000	
Harvesting Phase		
Propane	Boustead, 1996	
Biogas	Ecoinvent 2.2, 2010	Ecoinvent profile: Biogas, from slurry, at agricultural co-fermentation, covered/CH U
Tallow	Food LCA db, 2008	
Phosphoric acid	Boustead, 1996	
Acetic acid	Boustead, 1996	
Lactic acid	BASF, 2003	
Nitric acid	Boustead, 1996	
Sulfamic acid	Boustead, 1996	
Chlorine	Boustead, 1990	
Detergent	BASF, 1996	
Sodium hypochlorite	BASF, 2002	
Sodium chlorite	Boustead, 1996	
Sodium hydroxide	BASF, 2003	
Antifoam	BASF, 2002	
Silica	Boustead, 2000	
Citric acid	BASF, 1998	
Calcium hypochlorite	BASF, 2013	
Hydrogen peroxide	Boustead, 1996	
Carbon dioxide	BASF, 1996	
Sodium chloride	Boustead, 2000	
Anhydrous ammonia	Boustead, 1996	
Sodium bicarbonate	BASF, 1999	
Triazine pesticide	Ecoinvent, 1996	
HDPE	BASF, 2007	

Eco-Profile	Source, Year	Comments
Steel	BASF, 2010	
PVC	BASF, 1996	
Cotton	BASF, 2003	
Nylon	BASF, 2002	
Iron	BASF, 1999	
Laundering	BASF, 2005	
LDPE	BASF, 2005	
Aluminum alloy	BASF, 1996	
Cardboard, virgin	Ecoinvent 2.2, 2010	Ecoinvent profile: Corrugated board, fresh fibre, single wall, at plant/RER U
Cardboard, recycled	Ecoinvent 2.2, 2010	Ecoinvent profile: Corrugated board, recycling fibre, double wall, at plant/RER U
Paper	Ecoinvent 2.2, 2010	Ecoinvent profile: Paper, woodfree, uncoated, at non-integrated mill/RER U
Polypropylene	BASF, 1996	
Wood pallets	Ecoinvent 2.2, 2010	Ecoinvent profile: Wood container and pallet manufacturing (of project USA Input Output Database)
Case-Ready Phase		
Nitric acid	Boustead, 1996	
Sodium hydroxide	BASF, 2003	
Antifoam	BASF, 2002	
Silica	Boustead, 2000	
Steel	BASF, 2010	
Cotton	BASF, 2003	
Nylon	BASF, 2002	
Laundering	BASF, 2005	
LDPE	BASF, 2005	
Aluminum alloy	BASF, 1996	
Cardboard, virgin	Ecoinvent 2.2, 2010	Ecoinvent profile: Corrugated board, fresh fibre, single wall, at plant/RER U
Cardboard, recycled	Ecoinvent 2.2, 2010	Ecoinvent profile: Corrugated board, recycling fibre, double wall, at plant/RER U
Paper	Ecoinvent 2.2, 2010	Ecoinvent profile: Paper, woodfree, uncoated, at non-integrated mill/RER U
Polypropylene	BASF, 1996	
Wood pallets	Ecoinvent 2.2, 2010	Ecoinvent profile: Wood container and pallet manufacturing (of project USA Input Output Database)
R-134a Refrigerant	Ecoinvent 2.2, 2010	Ecoinvent profile: Refrigerant R134a, at plant/RER S
Alcohols, C13-C15, ethoxylated	BASF, 2008	
N,N-Dimethylcyclohexylamine	BASF, 2005	
Paraffin	Ecoinvent 2.2, 2010	Ecoinvent profile: Paraffin, at plant/RER S
Phosphoric acid	Boustead, 1996	
Potassium silicate	Boustead, 1996	
Propylene glycol	BASF, 2010	
Sodium hypochlorite	BASF, 2002	
Alkylbenzene sulfonate	BASF, 2008	
Latex	Ecoinvent 2.2, 2010	Ecoinvent profile: Latex, at plant/RER S
Retail Phase		
R-143a Refrigerant	BASF, 2002	
R-134a Refrigerant	Ecoinvent 2.2, 2010	Ecoinvent profile: Refrigerant R134a, at plant/RER S
Propane	Boustead, 1996	

Eco-Profile	Source, Year	Comments
Polypropylene	BASF, 1996	
LDPE	BASF, 2005	
Cardboard, virgin	Ecoinvent 2.2, 2010	Ecoinvent profile: Corrugated board, fresh fibre, single wall, at plant/RER U
Paper	Ecoinvent 2.2, 2010	Ecoinvent profile: Paper, woodfree, uncoated, at non-integrated mill/RER U
Polystyrene	BASF, 2009	
Nylon	BASF, 2002	
Consumer Phase		
LDPE	BASF, 2005	
Restaurant Phase		
Polypropylene	BASF, 1996	
LDPE	BASF, 2005	
HDPE	BASF, 2007	
Cardboard, virgin	Ecoinvent 2.2, 2010	Ecoinvent profile: Corrugated board, fresh fibre, single wall, at plant/RER U
Aluminum	Boustead, 1996	
Polystyrene	BASF, 2009	
Polyvinyl chloride	Boustead, 1996	
Alcohols, C13-C15, ethoxylated	BASF, 2008	
Citric acid	BASF, 1998	
Coco trimethyl ammonium chloride	BASF, 2000	
Sodium hypochlorite	BASF, 2002	
Sodium hydroxide	BASF, 2003	
Urea	BASF, 2005	
Alkylbenzene sulfonate	BASF, 2008	
Sodium tripolyphosphate	Ecoinvent 2.2, 2010	Ecoinvent profile: Sodium tripolyphosphate, at plant/RER
Potassium carbonate	Ecoinvent 2.2, 2010	Ecoinvent profile: Potassium carbonate, at plant/GLO
Sodium lauryl sulphate	BASF, 2007	
Glass oxide	BASF, 2011	
Propane	Boustead, 1996	
R-134a Refrigerant	Ecoinvent 2.2, 2010	Ecoinvent profile: Refrigerant R134a, at plant/RER S
Steel	BASF, 2010	
Cotton	BASF, 2003	
BASF data sources are internal data, while the others are external to BASF. Internal data is confidential to BASF; however, full disclosure was provided to NSF International for verification purposes.		

Table 7: Eco-profile Data Sources

8. Eco-efficiency Analysis Results and Discussion

8.1. Environmental Impact Results

The environmental impact results for this U.S. Beef EEA are generated as defined in Section 6 of the BASF EEA methodology. Figure 6 below summarizes the environmental impact results as represented by percent contribution from each value chain phase. As can be readily seen in Figure 6, the majority of the environmental impacts occur within the feed and animal phases.

Absolute environmental impact data are then presented below with further discussion in Sections 8.1.1 through 8.1.10.

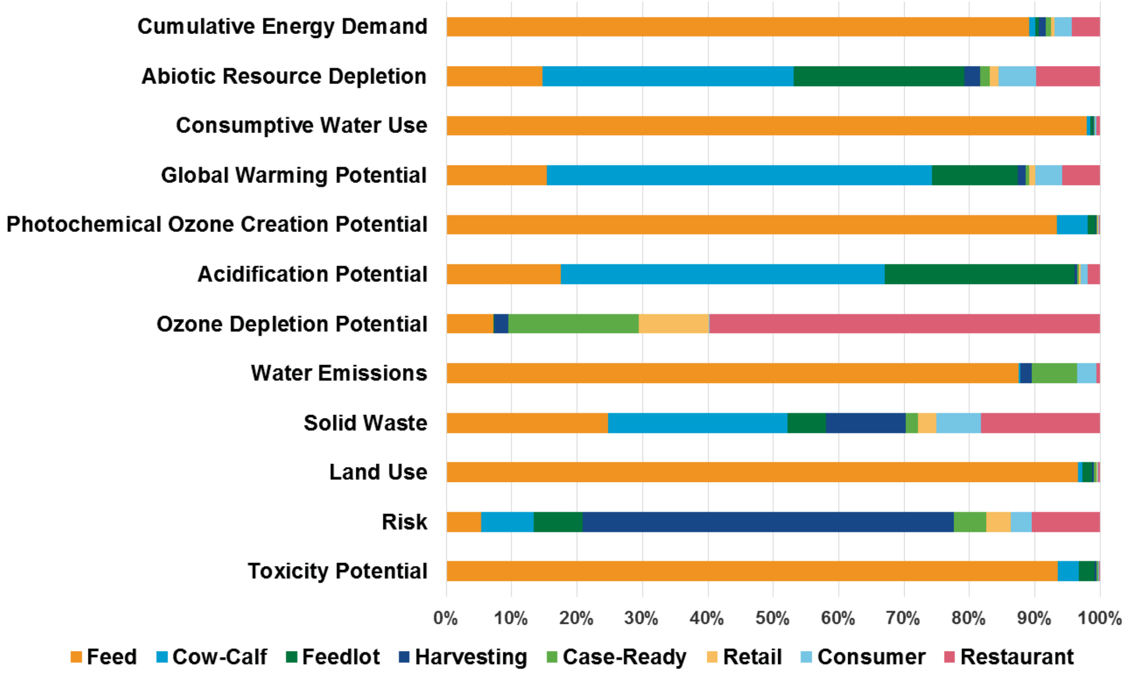

Figure 6: Summary of environmental impact data on percentage basis.

8.1.1. Cumulative Energy Demand

The bulk of the energy consumed by the beef system was the gross bioenergy contained within the feed used for the animals, which represented 83% of the total Cumulative Energy Demand (CED). Additionally, while all phases of the beef value chain contributed to CED through fossil energy consumed for utilities and transportation, the retail and consumer energy requirements were clearly higher as a result of more energy required per pound of beef due to scale (associated with refrigeration, cooking, and transport).

As can be seen below in Figure 7, CED was 503 MJ/CB. Figure 8 demonstrates the impact of the gross bioenergy from the feed as represented by the majority of the contribution from renewable bio-based energy. Since this energy is a biological requirement for the animals and cannot be changed, it is important to recognize that the main opportunities for energy reduction are found with the remaining energy (most of which is currently non-renewable as is associated with the current U.S. energy grid and transportation system).

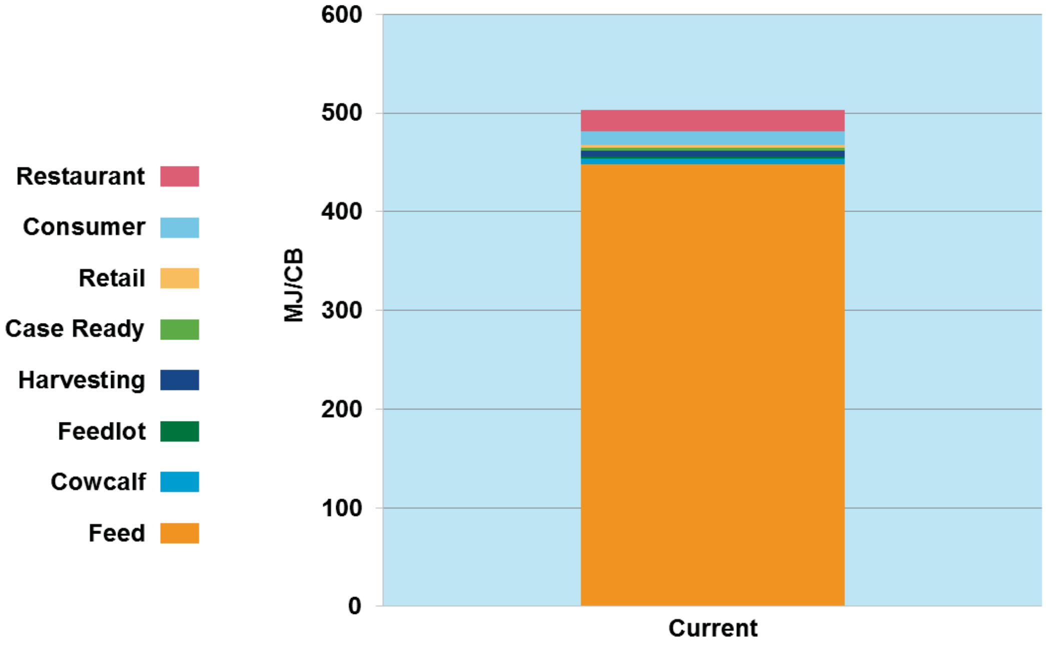

Figure 7: Cumulative Energy Demand where current is represented by data from the period 2011-2013 as defined in Table 1.

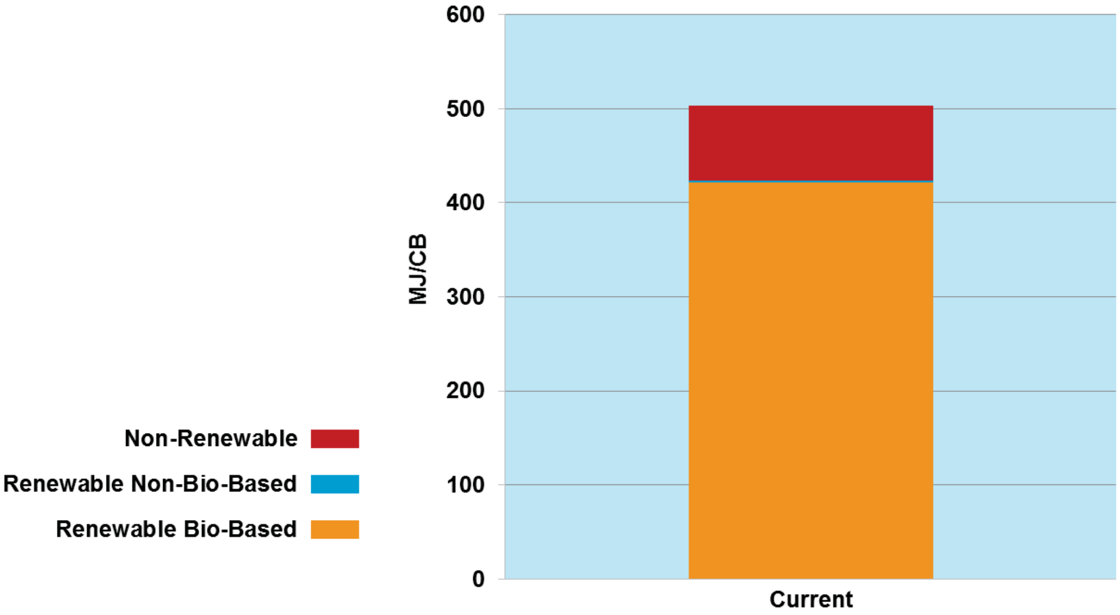

Figure 8: Renewable and Non-Renewable Energy Breakout where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.2. Abiotic Depletion Potential (ADP)

Zinc in the cattle phase (used as an essential mineral supplement) was the most dominant abiotic depletion factor on a weighted basis in the entire beef value chain. While the amount of zinc/CB was very small (<1 gram as zinc sulfate/CB), the global reserves that are currently economically available coupled with the current rates of extraction cause zinc to be weighted with high significance. The bulk of the remaining ADP was a result of fossil energy (natural gas, oil, and coal) that was used for fertilizers in the feed phase and throughout the entire beef value chain for utilities and transportation fuels.

ADP was 4.7 mg Ag-eq/CB. Figure 9 represents the ADP by phase while Figure 10 represents the ADP by resource.

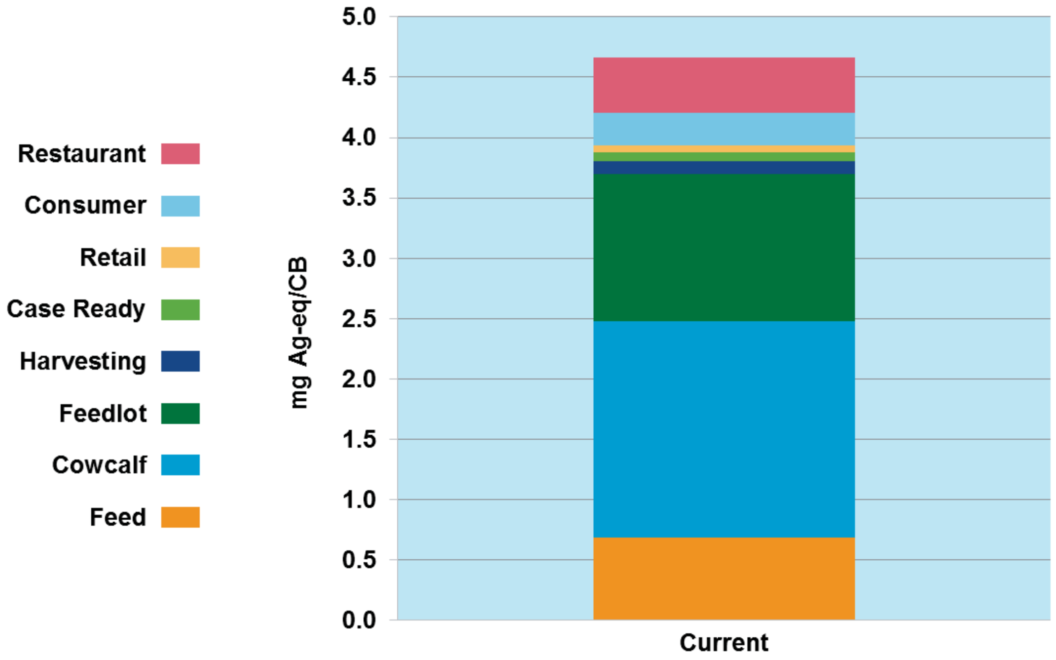

Figure 9: Abiotic Depletion Potential by phase where current is represented by data from the period 2011-2013 as defined in Table 1.

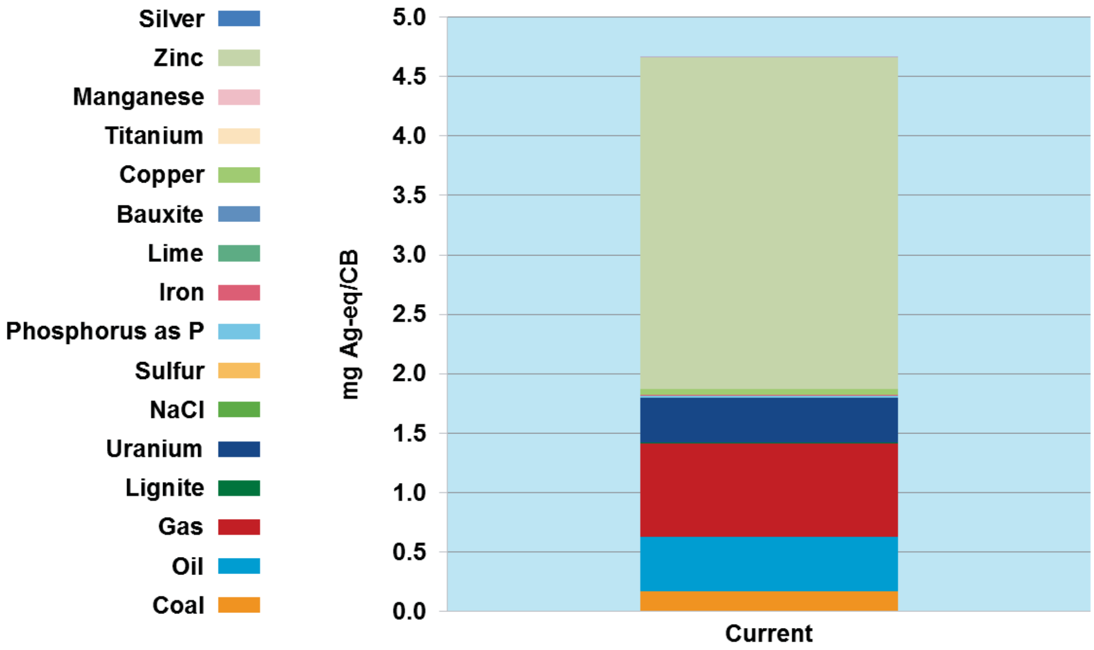

Figure 10: Abiotic Depletion Potential by resource where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.3 Consumptive Water Use

Nearly 98% of the consumptive water was consumed in the feed phase and this was associated mainly with the irrigation of crops. Electricity and pre-chain water consumption (especially from pre-chain impacts from materials such as corrugated cardboard) had a significant contribution on consumptive water as well as direct water consumption within the harvesting process.

The assessed consumptive water use was 1,160 L-eq/CB and the absolute consumptive water use is 2,325 L/CB.

The consumptive water use is shown both at an assessed value as well as an absolute value in Figures 11 and 12 below. Consistent with the BASF EEA methodology, a damage factor was applied to the absolute consumptive water use in order to determine the assessed consumptive water. The damage factor applied to the water consumed in the study was 0.499, which is representative of the entire U.S. as a midpoint indicator (note that this factor was modified from application of an endpoint characterization factor in Phase 1 in order to decrease uncertainty and to maintain better consistency from a methodological standpoint that considers midpoint factors as the norm).[35]

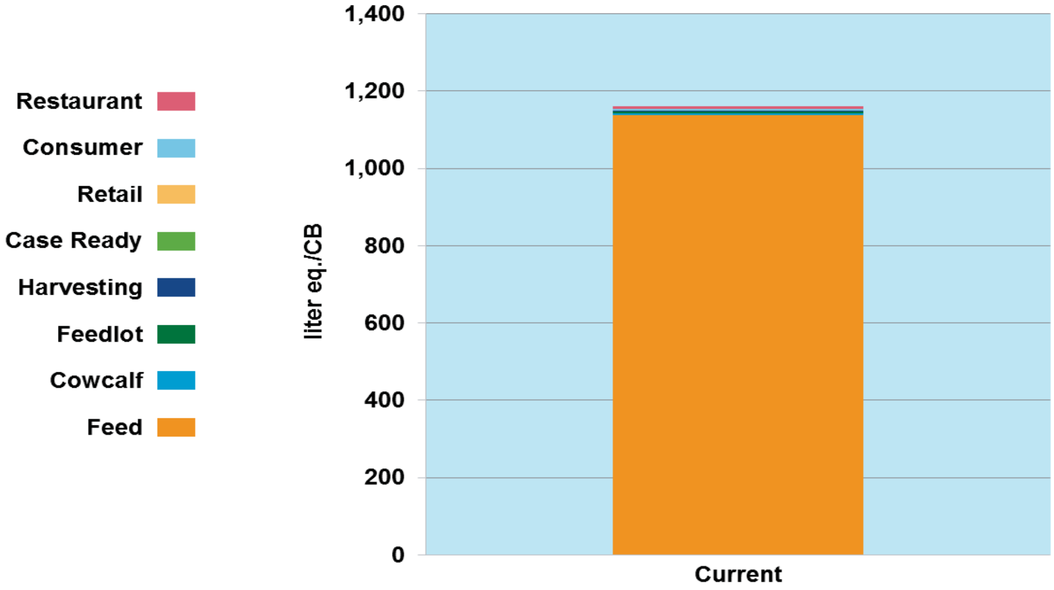

Figure 11: Assessed Consumptive Water Use where current is represented by data from the period 2011-2013 as defined in Table 1.

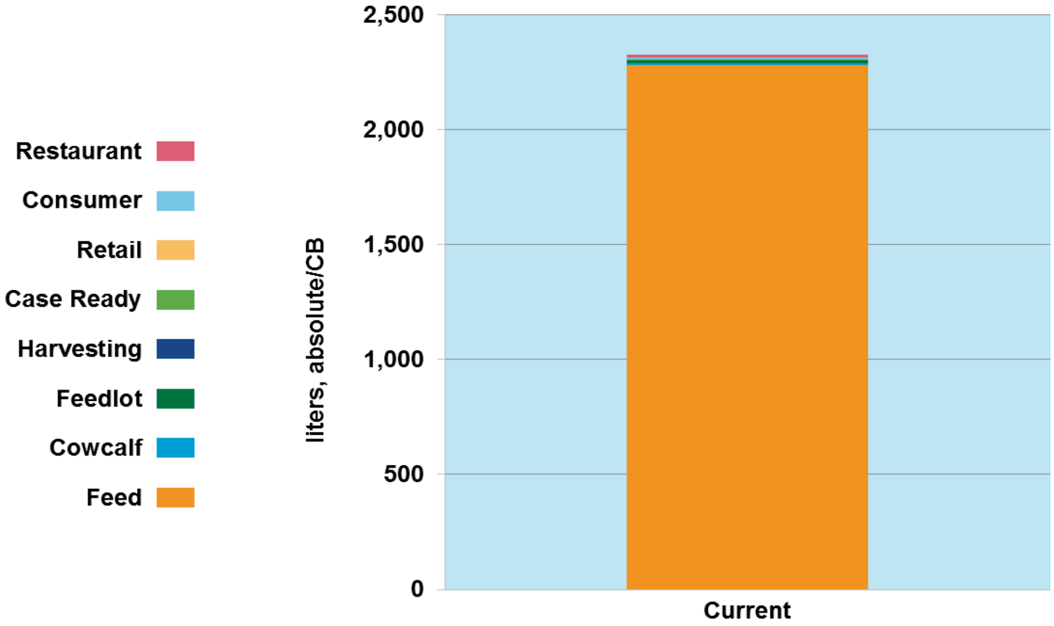

Figure 12: Absolute Consumptive Water Use where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.4 Air Emissions

8.1.4.1 Global Warming Potential (GWP)

Enteric methane emissions in the cattle phase were the largest contributor to GWP in the beef value chain, representing 47% of total GWP. N_2O from manure on the feedlots and pastureland was the second largest contributor, with 27% of the total value chain emissions. Other significant contributors included field emissions from fertilizers on the feed phase, refrigerant leakage on the retail and restaurant phases, and cooking on the consumer and restaurant phases. Less significant GWP contributors included corrugated cardboard and LDPE packaging pre-chain emissions.

As can be seen in Figure 13, the GWP was 22.0 kg/CB.

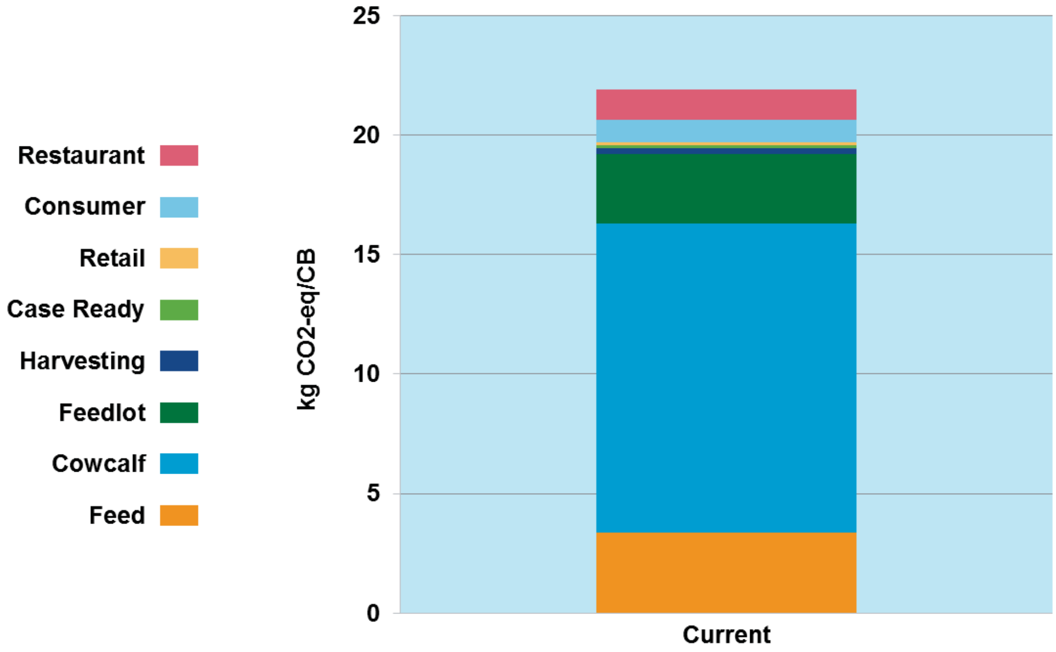

Figure 13: Global Warming Potential (GWP) where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.4.2 Photochemical ozone creation potential (POCP)

The main contributors to POCP included VOCs from silage feed (as well as some contribution from high moisture corn and WDGS), enteric methane, fossil energy emissions (especially diesel), and packaging pre-chain emissions from corrugated cardboard and LDPE.

As can be seen in Figure 14, the POCP was 66 g C_2H_4-eq/CB.

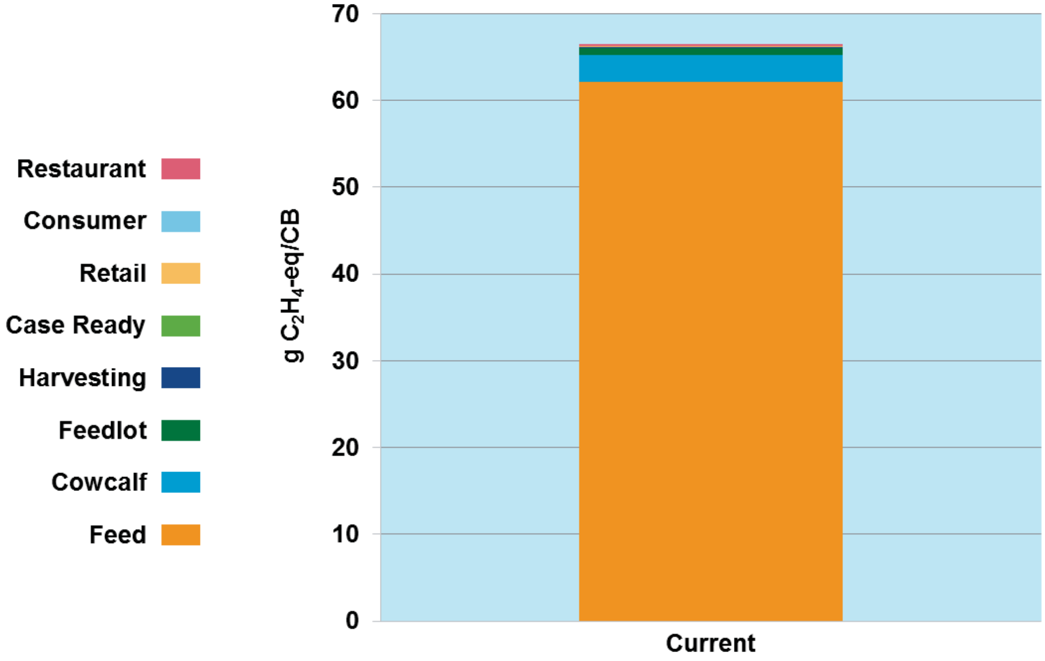

Figure 14: Photochemical Ozone Creation Potential (POCP) where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.4.3 Ozone depletion potential (ODP)

While ODP was a small overall value, the most significant contributors to ODP were halogenated hydrocarbons used for refrigerants in the case-ready, restaurant and retail sectors, vinyl gloves used in the restaurant sector, and LDPE pre-chain emissions.

As can be seen in Figure 15 below, ODP was 0.76 mg CFC-eq/CB.

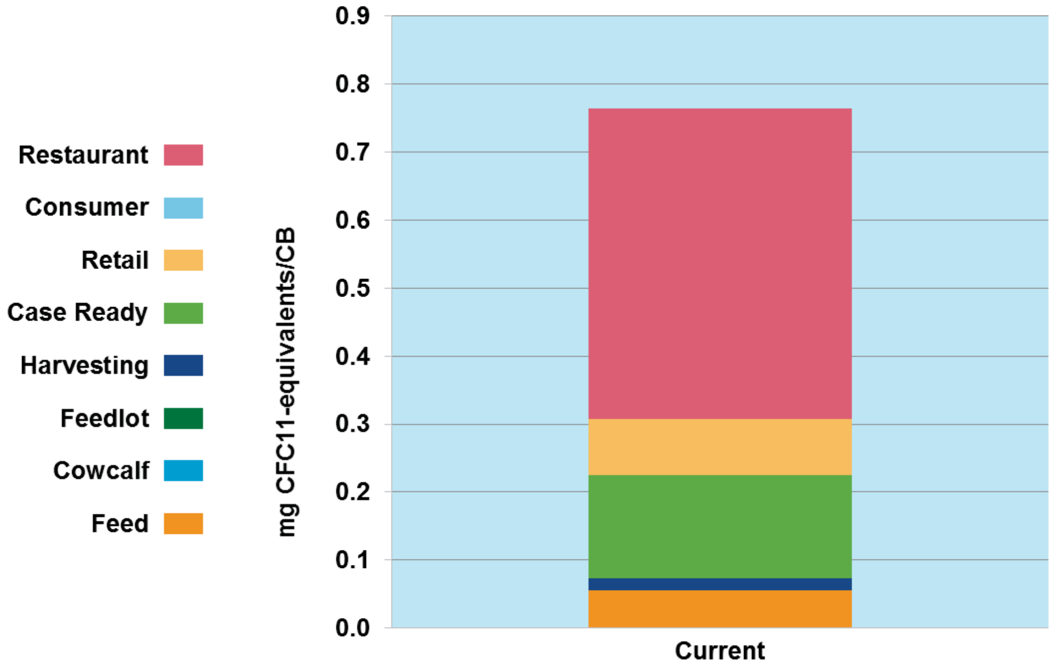

Figure 15: Ozone Depletion Potential (ODP) where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.4.4 Acidification potential (AP)

Most of the AP contribution comes from the feed and cattle phases. Specifically, ammonia from fertilizers used on feed crops and manure and urine from cattle were the major causes. Other contributors to AP included emissions from combustion in electricity production and on-site boiler use, transportation, and pre-chain impacts from corrugated cardboard.

As can be seen in Figure 16 below, AP was 329 g SO_2-eq/CB.

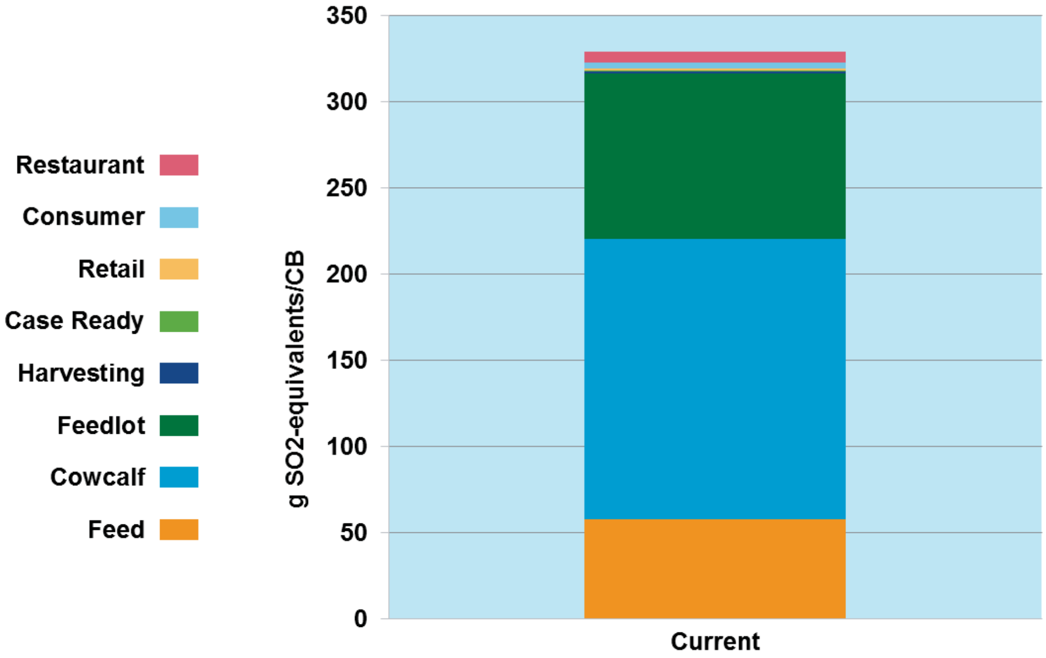

Figure 16: Acidification Potential (AP) where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.5 Water emissions

The main water emissions from the beef value chain were from the feed phase, which accounted for 90% of total water emissions. Of the feed emissions, approximately 34% was a result of nitrogen runoff and leaching, 19% from phosphorous runoff, and 33% from heavy metal runoff and leaching (associated with fertilizers). Other main water emissions were a result of runoff and leaching from cattle pastureland, direct wastewater emissions from the harvesting and case-ready facilities, pre-chain impacts from cardboard packaging production, and water emissions associated with end-of-life landfill disposal for production waste and packaging waste at all phases of the post-farm value chain.

As shown below in Figure 17, were 3,095 L diluted water-eq/CB.

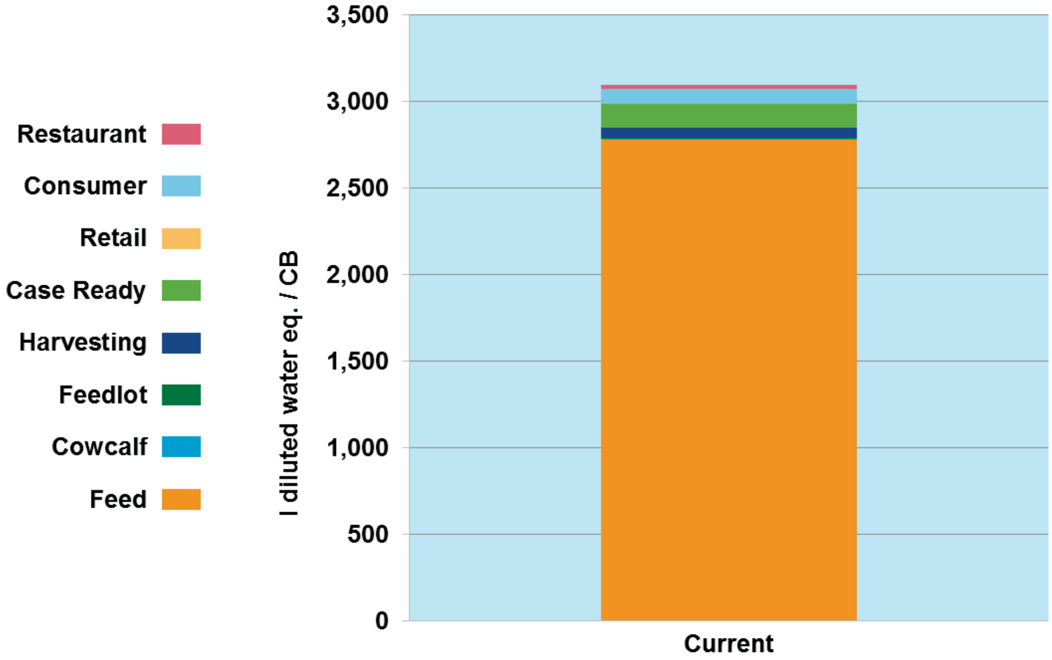

Figure 17: Water Emissions where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.6 Solid waste generation

Since waste that was directly generated throughout the beef value chain was analyzed according to ultimate disposal (recycling, incineration, or landfilling), all of the solid waste shown below in Figure 18 was associated with pre-chain waste. All direct waste was therefore evaluated above for final ecosphere emissions to water and air based on final fate degradation. The most significant contributions came from the pre-chain waste associated with dicalcium phosphate (for supplements), transport fuels (diesel and gasoline), and electricity.

The solid waste generated was 0.17 kg municipal waste-eq/CB.

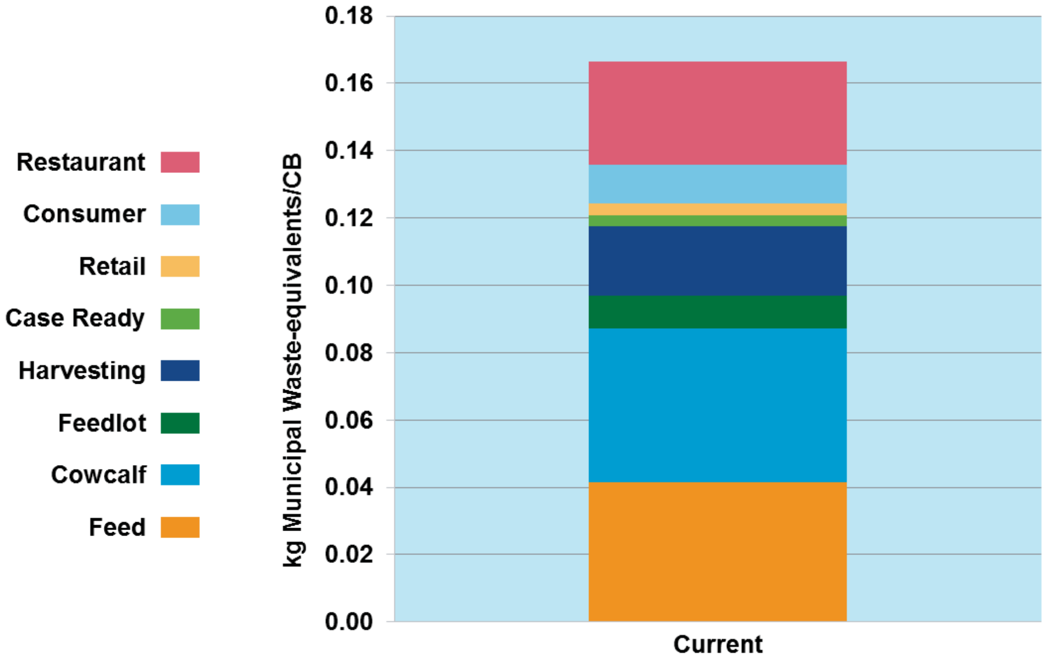

Figure 18: Solid Waste Generation where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.7 Land use

The most significant phase associated with land use was the feed phase due to the pasture and crop land required to grow the feed, and this represented approximately 95% of the land required for the total beef value chain. Of that 95%, 70% was solely from pastureland (two-thirds of land requirements for the total beef value chain). Other notable impacts associated with land use were the pre-chain impacts associated with packaging (cardboard) and diesel consumption.

As can be seen below in Figure 19, land use was 21.5 m^2a-eq/CB. The units are expressed first in m^2a (where a = time in years) and are then weighted. As outlined in the BASF EEA Methodology, the absolute land use values are weighted according to land use occupation and transformation type in order to account for ecosystem damage and biodiversity factors.

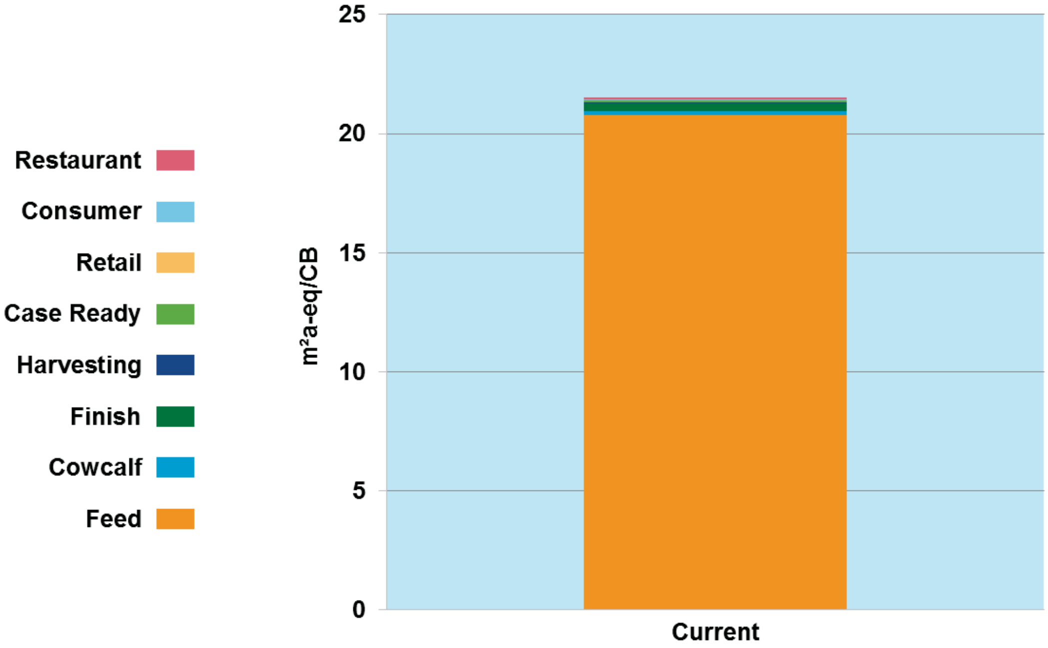

Figure 19: Land Use where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.8 Toxicity potential

Inventories of all relevant materials were quantified in a manner consistent with the BASF EEA methodology for assessing the human health impact of these materials (ref. Section 6.8 of Part A submittal). This toxicity potential analysis included consideration of the production of all materials that are in the study boundary scope, the use of all materials used as direct inputs to the beef value chain (i.e., human health exposure to employees of the beef value chain), as well as toxicity of materials disposed of throughout the value chain according to the boundary scope. A detailed scoring table was developed for each alternative broken into life cycle stages. This scoring table with all relevant material quantities considered the H-phrase and pre-chain toxicity potential scores and was provided to NSF International as part of the EEA model submitted as part of this verification. Figure 20 shows how each phase contributed to the overall toxicity potential score for each alternative. The values have been normalized and weighted.

The major influencing factor for toxicity potential was the manufacturing impact of agricultural chemicals (fertilizers, especially urea and lime, and pesticides) and the impacts from application. Other major contributors to toxicity potential included fossil energy (natural gas, coal, and diesel) pre-chain and use factors that were utilized throughout the beef value chain for utilities and transportation.

The normalized and weighted toxicity potential values are shown below in Figure 20.

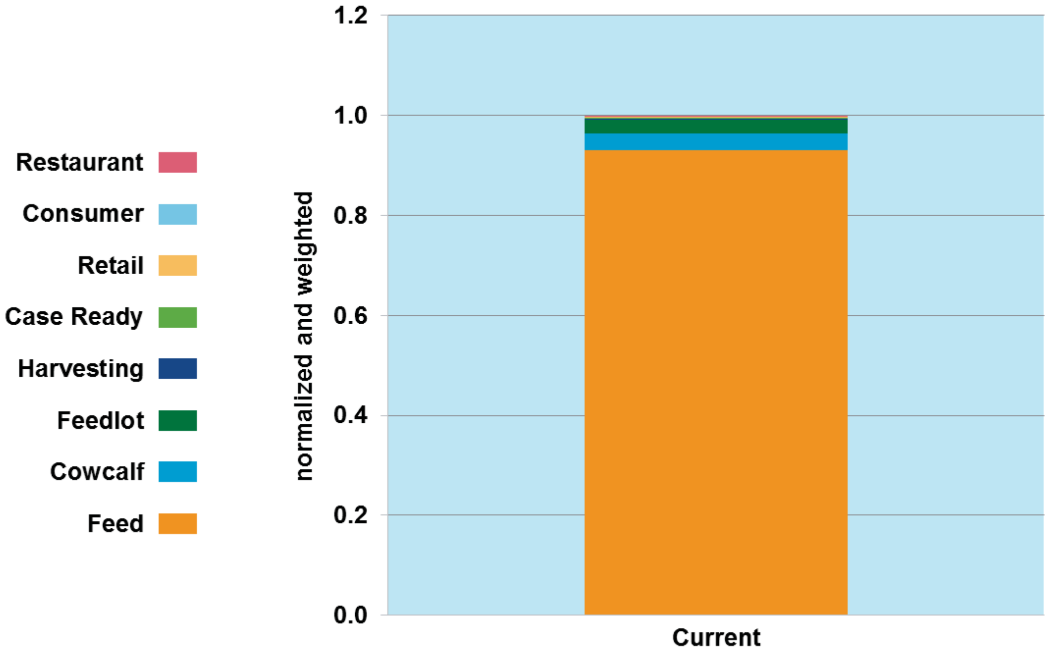

Figure 20: Toxicity Potential where current is represented by data from the period 2011-2013 as defined in Table 1.

8.1.9 Risk Potential (Occupational Illnesses and Accidents)

All of the materials and activities in the various life cycle stages were assigned specific NACE codes[36]. NACE (Nomenclature des Activities Economiques) is a European nomenclature which is very similar to the NAICS codes in North America. The NACE codes are used in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the business economy and is broken down by specific industries. Specific to this impact category, the NACE codes track, among other metrics, the number of working accidents, fatalities, illnesses and diseases associated with certain industries (e.g. chemical manufacturing, petroleum refinery, inorganics etc.) per defined unit of output. By applying these incident rates to the amount of materials required for each alternative, a quantitative assessment of risk was achieved.

In addition to the NACE analysis for all of the inputs, in order to derive a better representation of Occupational Illnesses and Accidents potential, U.S. Bureau of Labor (BLS) data were analyzed for the direct industry activity in each of the beef value chain phases as outlined in the assumptions discussion above in Section 6.

As also discussed above in the assumptions discussion in Section 6, additional risk categories of Animal Welfare (on both the cattle and harvesting phases), Food Safety (on the harvesting phase), and Community Nuisance Odors and Emissions (on the harvesting phase) were considered as part of the total risk analysis in this study. While these additional risks were considered as the percentages in the applicable phases outlined in Section 6, in the total study, these additional risks were weighted as follows: 1) Food Safety: 7.2%; 2) Animal Welfare: 3.1%; and 3) Community Nuisance Odors and Emissions: 1.3%. These final weightings were a result of the aggregated phase risk weightings.

Occupational Diseases were weighted at 48.5%, Fatal Accidents at 25.2%, and Non-fatal Accidents at 14.8% of total study risk.

The normalized Risk Potential values are shown below in Figure 21. The majority of the risk is associated with direct accidents and illnesses with each phase.

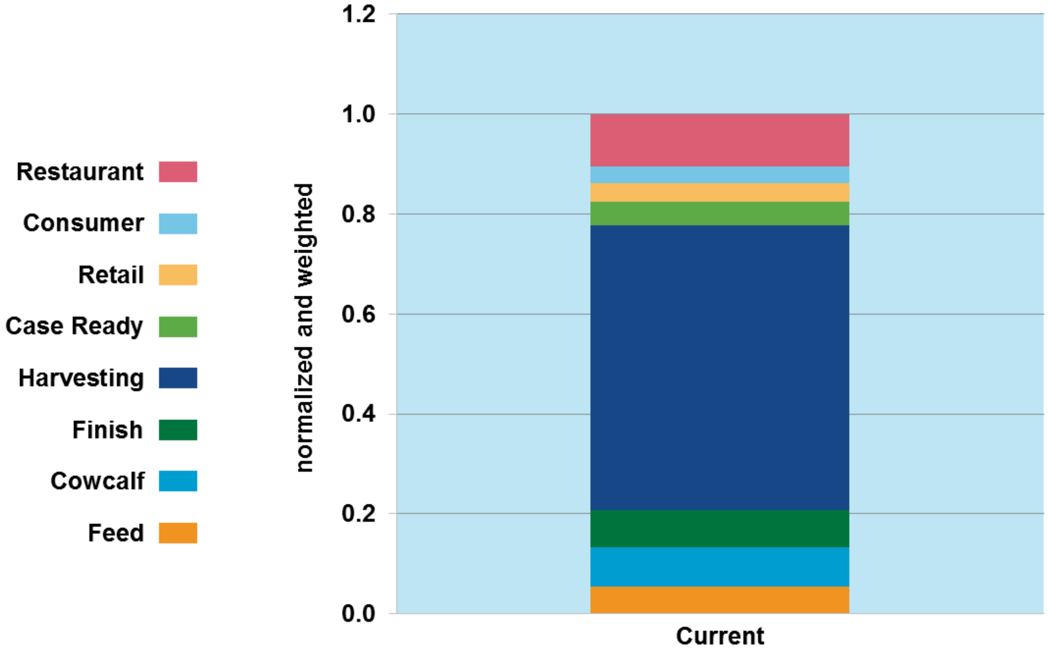

Figure 21: Risk Potential (Occupational Illnesses and Accidents) where current is represented by data from the period 2011-2013 as defined in Table 1.

8.2. Economic Cost Results

The life cycle cost data for the U.S. Beef EEA were generated as described in the overall study assumptions in Section 6 of this report. As shown in Figure 22, the life cycle costs in 2011 were $5.55/CB.

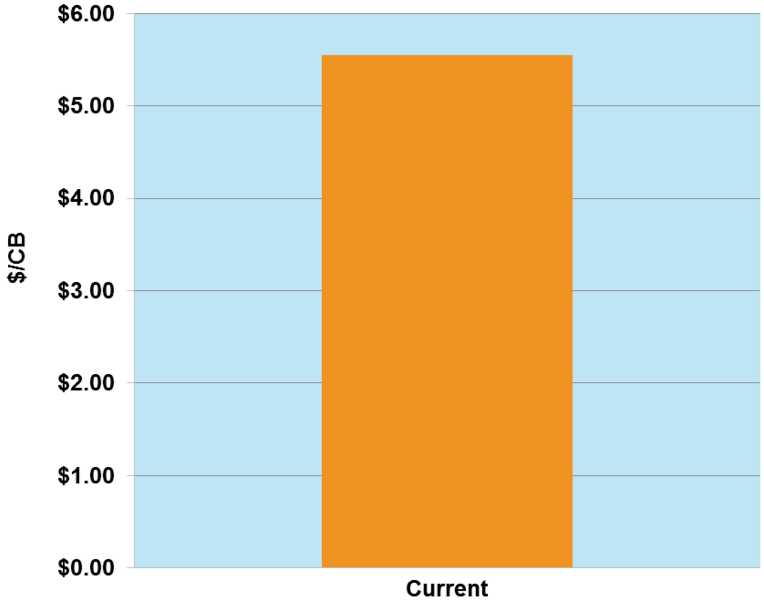

Figure 22: Life Cycle Costs where current costs are consumer prices of beef in 2011.

9. Pennsylvania Grass-finished Beef Scenario

9.1 Overview

The representative Pennsylvania grass-finishing operations were modeled based upon data collected from a combination of 17 survey responses and 4 farm visits to grass-finished beef producers in the state. The survey responses indicated that the average operation was 44.5 ha in size, with a range from 1.6 to 170 ha. The average number of cows on each farm was 22 (range: 2 to 60) and the average number of finishing animals was 13 (range: 1 to 49).

Grass-finished beef (also referred to as grass-fed, forage-fed, and forage-finished) is defined as a meat product from cattle who, for the duration of their life, consumed only forages with the exception of the mother's milk. From the data collected, representative farms were modeled using the Integrated Farm System Model and environmental impact results were compiled using weighted average values for grass-finished beef production in the state. Weighting factors were developed based upon the number of cows represented by the modeled management scheme, the number of cows within the region of the state being modeled, the age at finish, the use of manure or fertilizer, and the inclusion of a small grain forage in the feeding strategy. Six systems were developed according to common management schemes identified in the survey data. Descriptions of the modeled systems follow.

Results of these simulations should not be extrapolated to be representative of national grass finished beef production due to regional climate, management, animal, and scale differences. These results should be interpreted in a regional context, understanding that water, energy use, and productivity values are only meaningful in regional contexts based upon the environmental, economic, and social factors influencing agricultural production in a given landscape. In general, farms in the northeastern U.S. tend to be smaller—in terms of land area and herd size—than those in the central U.S. due to greater variability in the terrain in the region. Smaller land area per farm has implications on impacts such as energy use efficiencies, as the land base may limit the number of animals that can be produced using the same quantities of resources. In addition, beef cattle are often maintained on marginal soils or sloping terrain which may be less suitable for row crop production. A final consideration is that agriculture in the northeastern U.S. is rainfed with no irrigation use due to high precipitation and low evapotranspiration rates in the region.

9.2 Description of systems

In all systems, cattle are assumed to be grazed in some form of a managed rotation through multiple paddocks in order to allow rest for plant regrowth after the grazing period. Animal characteristics, herd composition, and stocking rates are set according to averages calculated from producer survey responses. All systems with the exception of System 1 and System 6 produce all of the forage consumed by the animals produced.

Many of these systems are managed to meet organic standards. As such, chemical fertilizer and pesticide inputs are limited. To represent the small amounts of urea use reported in the survey and farm visits, urea was applied to 3% of perennial pasture, 3% of perennial hay land, 13% of annual pasture, and 13% of annual hay land. Pesticide use is typically limited to fence line application and spot spraying for treatment of weeds which are difficult to control using grazing and clipping. 2,4-Dichlorophenoxyacetic acid was applied to 1% of perennial and annual pasture each to represent the minimal use reported.

- **System 1:** All of the grazed forage required is produced on the farm and alfalfa silage is purchased to meet supplemental feed requirements. No haying operations are conducted. Lime, imported manure, or chemical fertilizers are not applied to pastures. Cattle are finished at 30 months of age. This system is simulated in western Pennsylvania using historical daily weather data from Pittsburgh (1981-2005), and the weighting factor is 17.5%.

- **System 2:** Hay is produced from the same land base where cattle are grazed. Neither lime nor chemical fertilizers are applied to pastures. Cattle are finished at 24 months of age. This system is simulated in western Pennsylvania using weather data from Pittsburgh, and the weighting factor is 18.5%.

- **System 3:** Similar to System 2, grazing and haying is done on the same land base. In addition to hay produced from the grazed land, hay is also produced from a separate, non-grazed hay field. Cattle are finished at 24 months of age. This system is simulated in western Pennsylvania using weather data from Pittsburgh, and the weighting factor is 18.5%.

- **System 4:** All feed required is produced on the farm, which includes grazed forage, perennial grass hay and silage, alfalfa hay, and oat bale silage. Some of the perennial hay fields are ungrazed, and the alfalfa and oat fields are harvested and fed as preserved forage. The oat field is fertilized with poultry manure to meet N requirements for the oats. Cattle are finished at 24 months of age. This system is simulated in central Pennsylvania using weather data from State College (1986-2010), and the weighting factor is 12.9%.

- **System 5:** The operation is the same as that in System 4 with the exception of the application of poultry manure. Instead of poultry manure, this system is applying synthetic P and K fertilizers to the oat field. Residual N from the preceding grazed or fertilized perennial grass crop is the sole N source for oat production in this system. The weighting factor is 11.9%.

- **System 6:** Some supplemental feed is produced as perennial grass hay from the grazed land base. In addition to grazing perennial pastures, a rye crop is also grazed before head emergence. A small amount of alfalfa silage is purchased as supplemental feed, and cattle are finished at 24 months of age. This system is simulated in eastern PA using historical weather data for Lancaster, PA (1979-2003), and the weighting factor is 20.7%.

Assumptions about dressing percentages and other value chain losses are identical to those used for traditional beef production. Though the processing of grass-finished beef carcasses is assumed to be the same as that of traditional beef, these data may be updated in future analyses as postharvest data specific to grass-finished beef carcasses become available.

9.3 Pennsylvania Grass-finished Eco-Efficiency Analysis Results

The sources of the main impacts are essentially the same as what are discussed above in the baseline scenario with USMARC data (simply different scale of contribution for each phase in many cases). Therefore, the results for this Pennsylvania Grass-finished scenario are presented below. The inputs considered in the boundary scope are the same as those defined in Figure 4 for the USMARC analysis. As mentioned, the data for the post-farm phases of the value chain are assumed to be the same as that associated with traditional beef (and used in the baseline analysis that considered the USMARC data). The data collected to represent the feed and cattle phases of the Pennsylvania Grass-finished scenario were from 2014. Specific years for which each of the value chain phase data were analyzed for the Pennsylvania Grass-finished scenario are shown below in Table 8.

Phase	Source Data Year
Feed (PA Grass-finished)	2014
Cattle (PA Grass-finished)	2014
Harvesting	2011
Case-Ready	Combination of 2011 & 2013
Retail	2013
Consumer	2011
Restaurant	Combination of 2011 & 2013

Table 8: Pennsylvania Grass-finished Source Data Year by Value Chain Phase

9.3.1 Cumulative Energy Demand

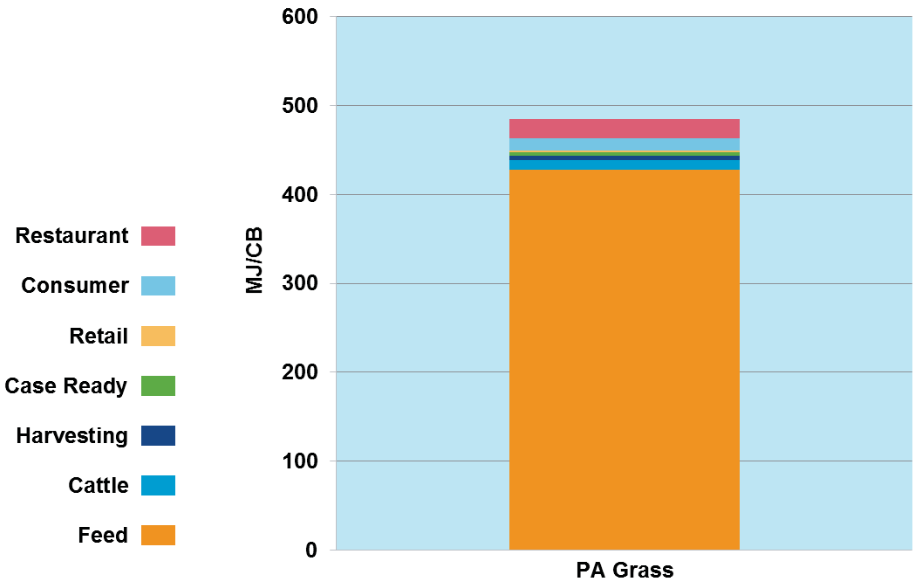

Figure 23: Cumulative Energy Demand, 486 MJ/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

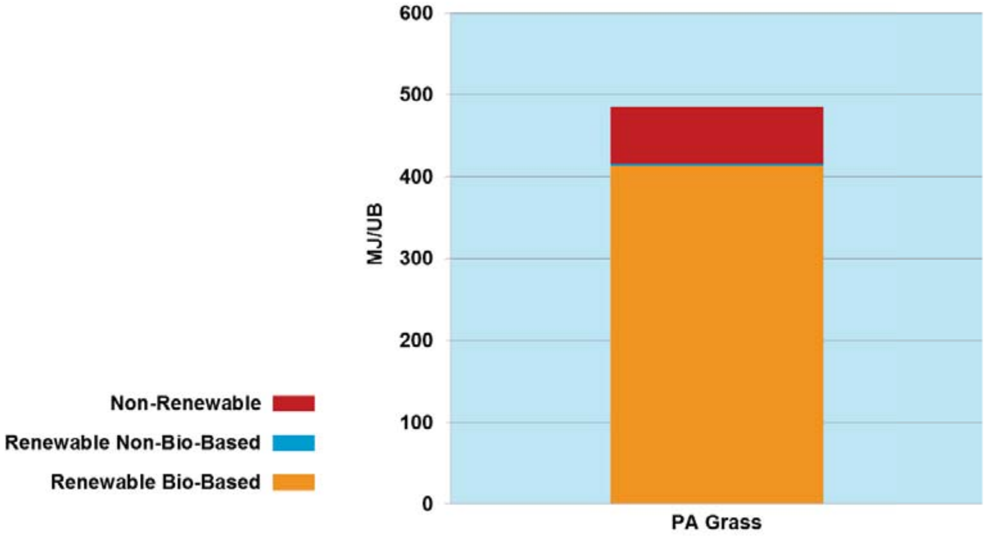

Figure 24: Cumulative Energy Demand, Renewable vs. Non-renewable, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.2 Abiotic Depletion Potential (ADP)

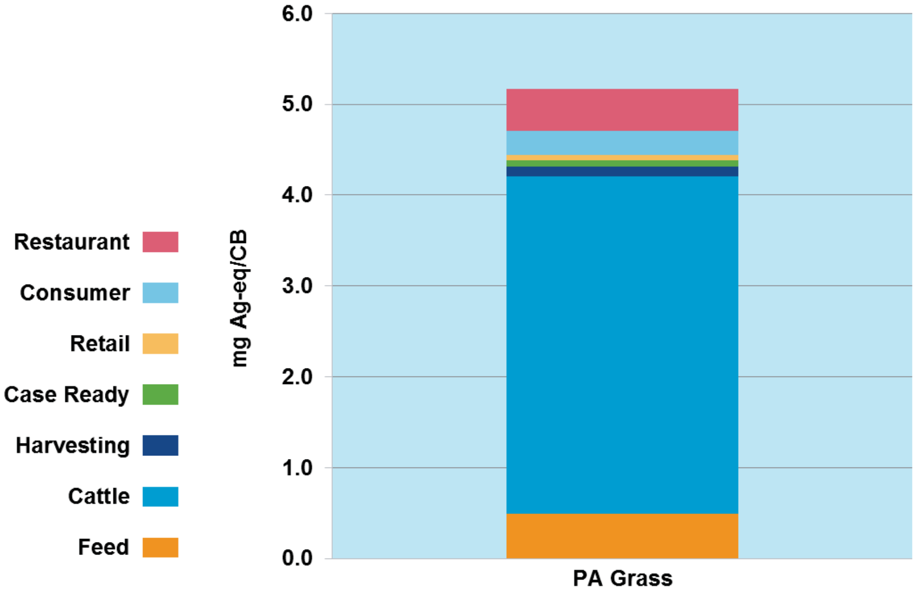

Figure 25: Abiotic Depletion Potential, 5.2 mg Ag-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

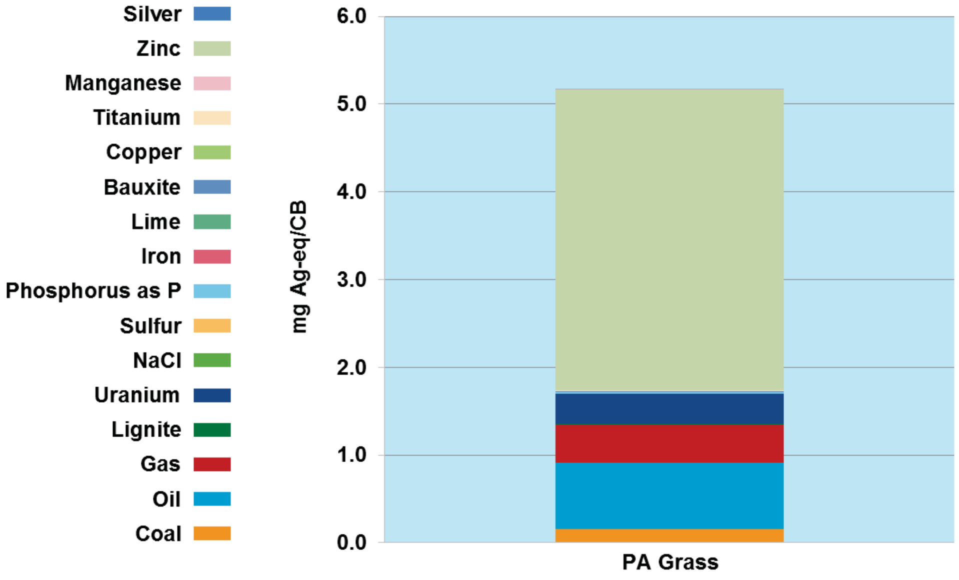

Figure 26: Abiotic Depletion Potential by resource, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.3 Consumptive Water Use

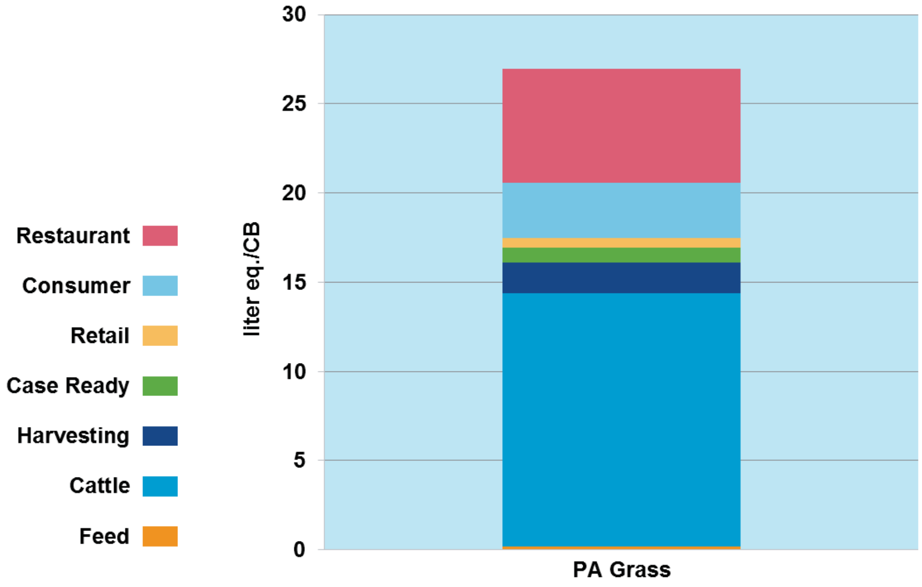

Figure 27: Consumptive Water Use, 27 L-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

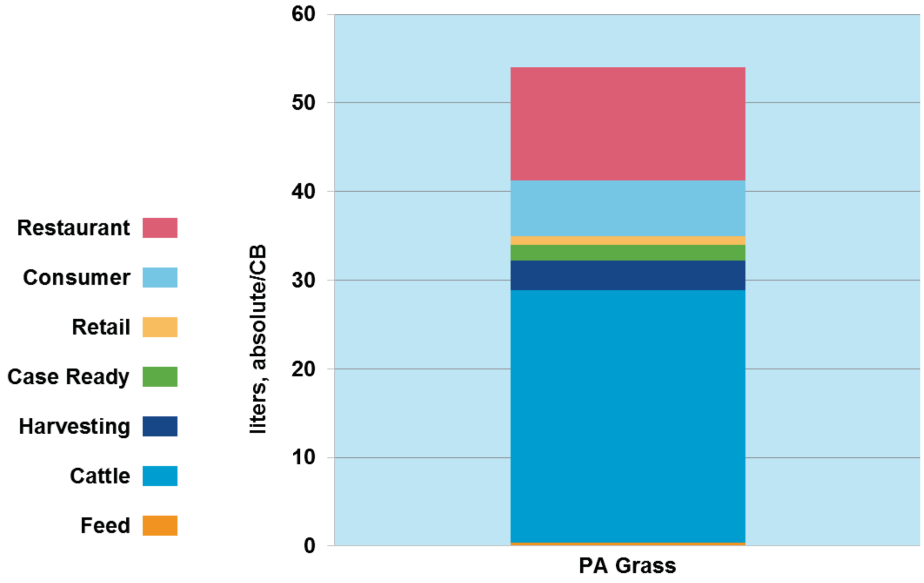

Figure 28: Consumptive Water Use, Absolute, 55 L/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.4 Air Emissions

9.3.4.1 Global Warming Potential (GWP)

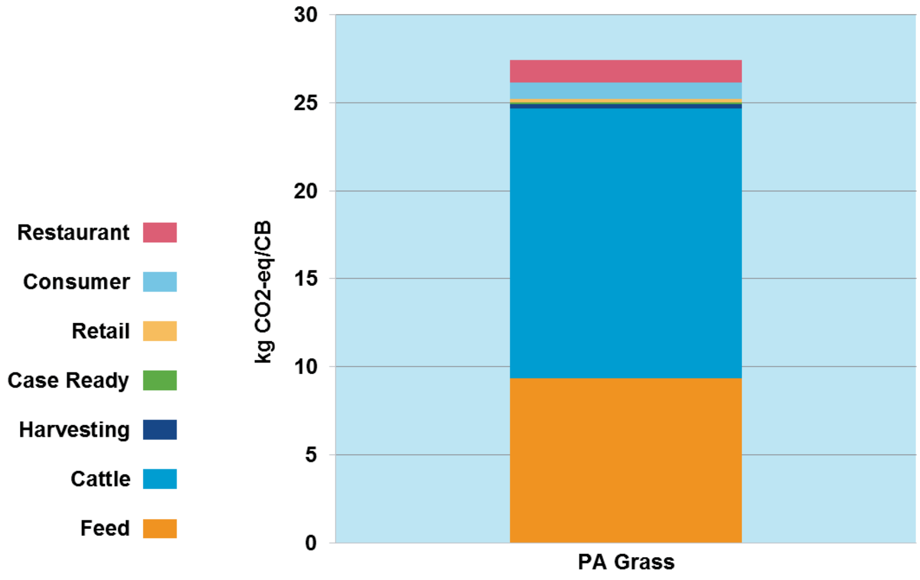

Figure 29: Global Warming Potential, 27.4 kg CO_2-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.4.2 Photochemical Ozone Creation Potential (POCP)

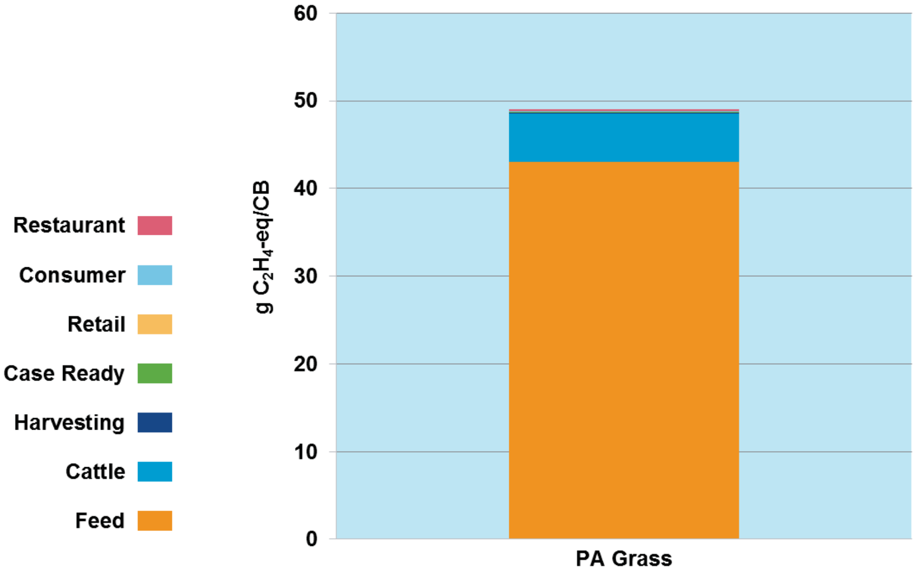

Figure 30: Photochemical Ozone Creation Potential, 49 g C_2H_4-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.4.3 Ozone Depletion Potential (ODP)

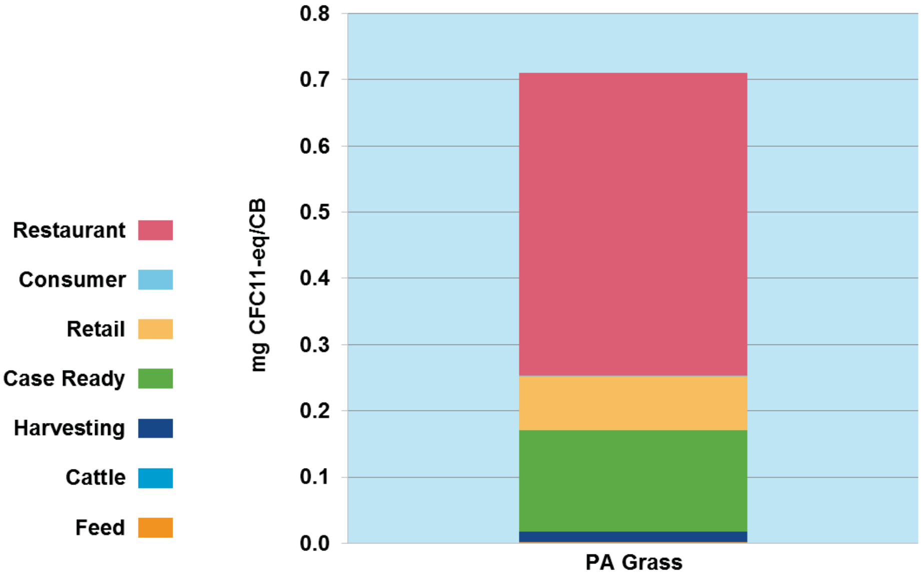

Figure 31: Ozone Depletion Potential, 0.71 mg CFC11-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.4.4 Acidification Potential (AP)

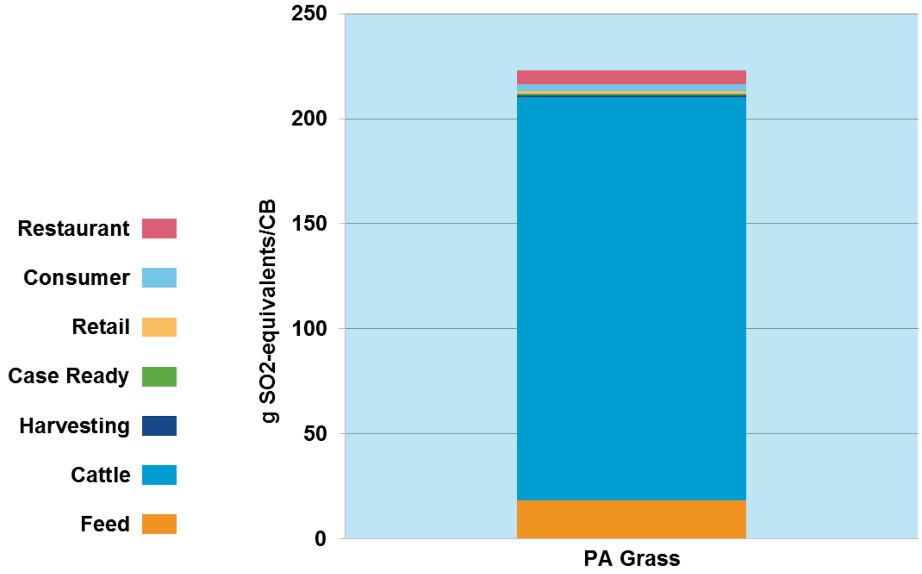

Figure 32: Acidification Potential, 223 g SO_2-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.5 Water Emissions

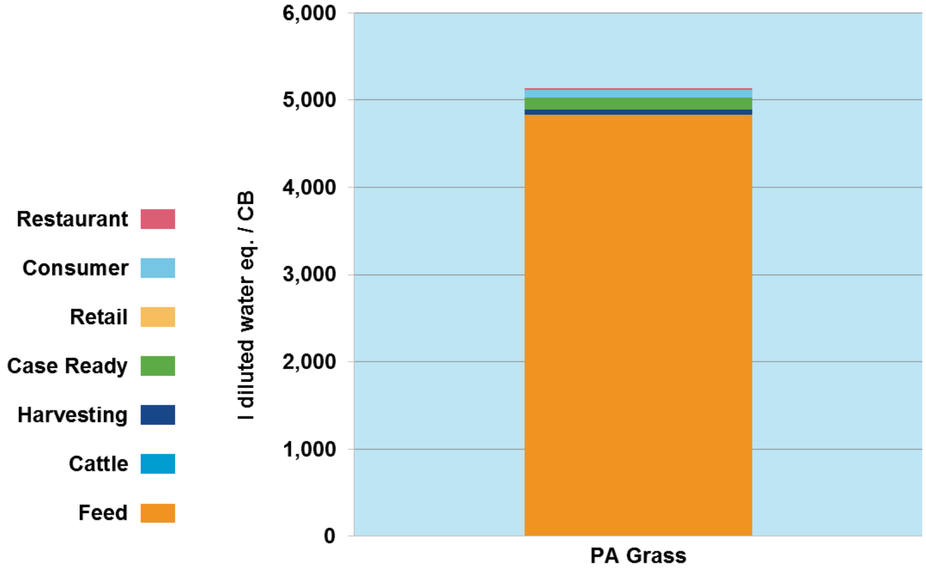

Figure 33: Water Emissions, 5,141 L diluted water-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.6 Solid Waste Generation

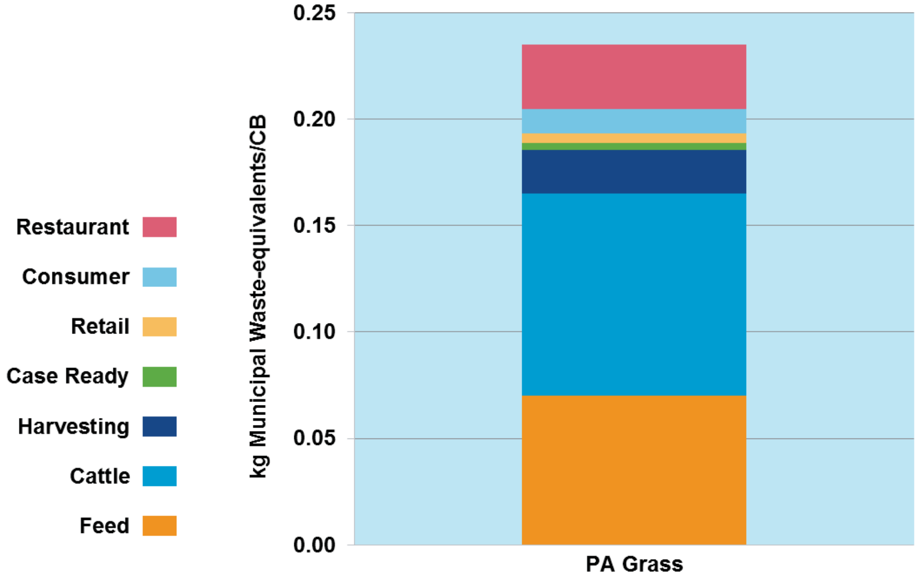

Figure 34: Solid Waste Generation, 0.24 kg municipal waste-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.7 Land Use

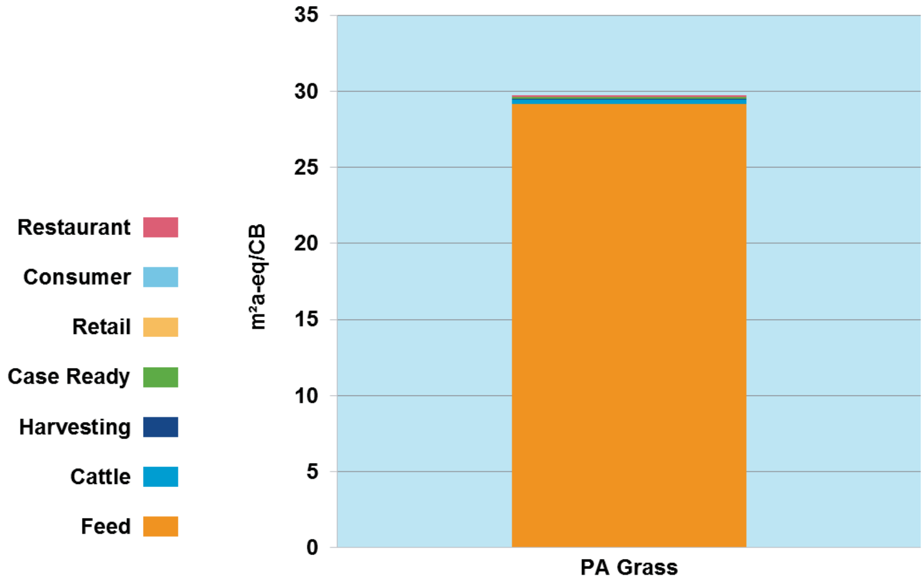

Figure 35: Land Use, 29.7 m2a-eq/CB, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.8 Toxicity Potential

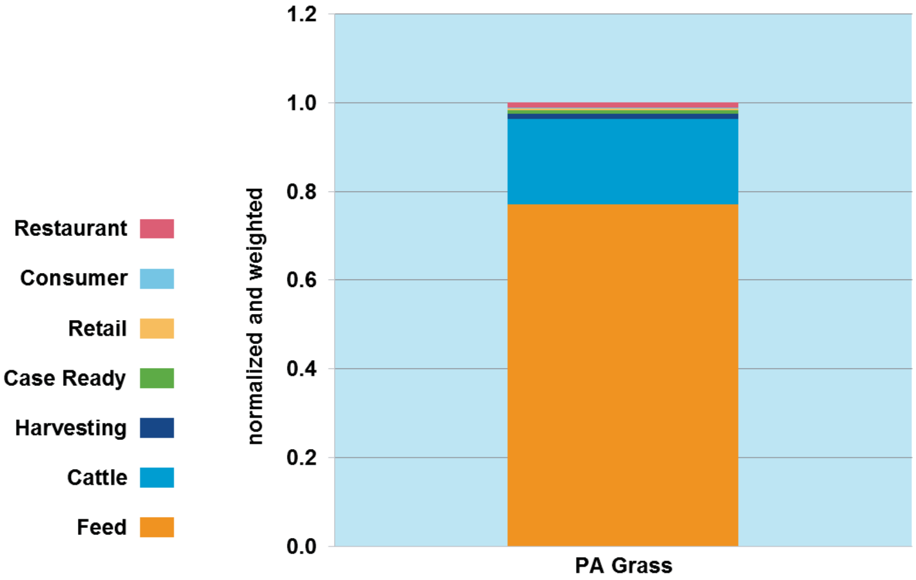

Figure 36: Toxicity Potential, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.3.9 Risk (Occupational Illnesses & Accidents)

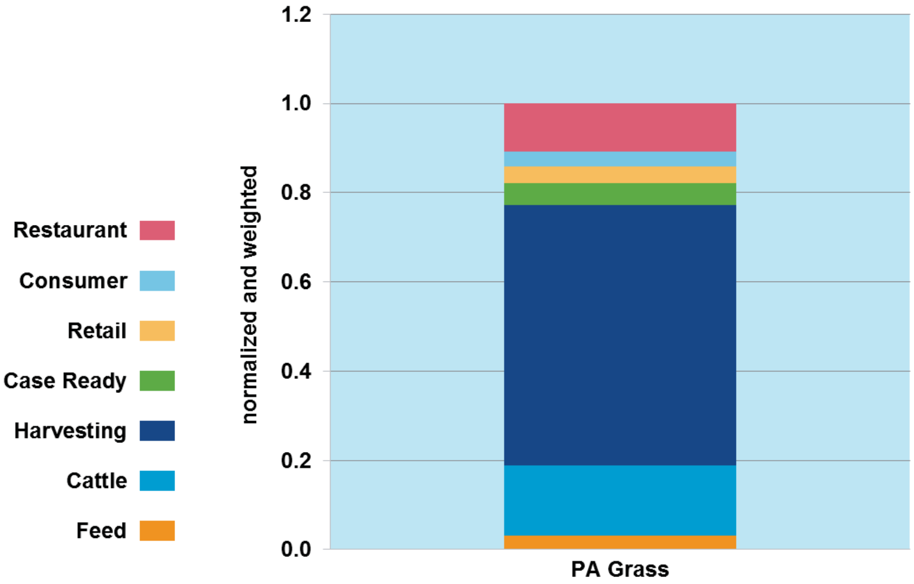

Figure 37: Risk, where PA Grass is represented by data from the period 2011-2014 as defined in Table 8.

9.4 *Economic Cost Results*

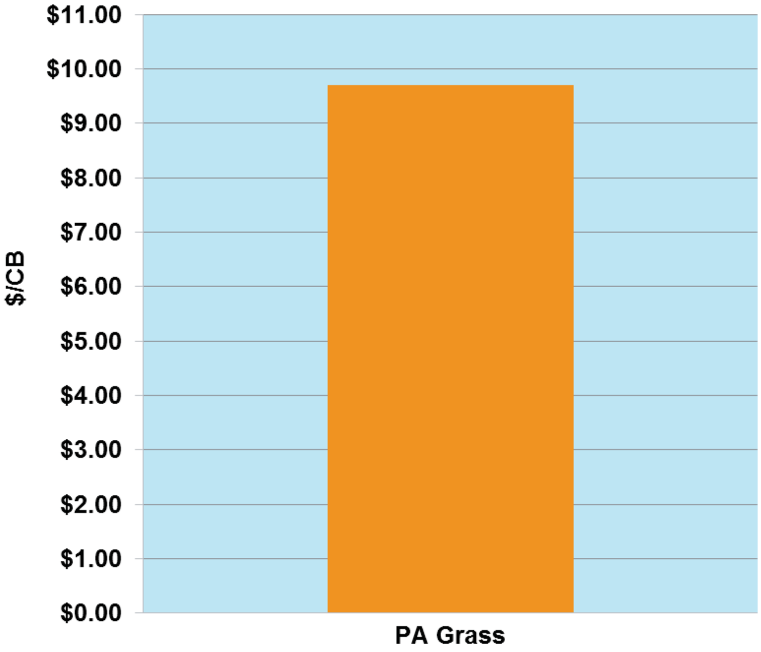

Figure 38: Life Cycle Costs, $9.71/CB (Industry Data), where PA Grass costs are consumer prices of grass-finished beef in 2011.

10. Data Quality Assessment

10.1 *Data Quality Statement*

The data used for parameterization of the EEA was sufficient with most parameters of high to medium data quality. Moderate (medium) data is where industry average values or assumptions pre-dominate the value. No critical uncertainties or significant data gaps were identified within the parameters and assumptions that could have a significant effect on the results and conclusions. Inputs to the study were comprehensive and the exclusions to the study described in Section 5.3 and noted in Figure 4 would not have a significant impact on the overall study. Eco-profiles used for the study as represented in Table 7 were reviewed for completeness and appropriateness. Eco-profiles that are greater than 10 years old were deemed to be still reflective of current technology and industry practices. Table 9 provides a summary of the data input quality used for the EEA.

Phase	Quality Statement	Comments
Feed	High-Medium	Mainly IFSM data of high quality.
Cow-Calf	High-Medium	Mainly IFSM data of high quality.
Feedlot	High-Medium	Mainly IFSM data of high quality.
Harvesting	High	Primary data from harvesters whose facilities represent 60% of the industry.
Case-Ready	High	Primary data specific to beef from case-ready sector.
Retail	High-Medium	Primary data from the retail sector but data had to be allocated on an economic basis in order to assign beef-specific values.
Consumer	Medium	None of the consumer data was primary data but was based off of averages from literature and industry reports.
Restaurant	High-Medium	Primary data from the restaurant sector but some data had to be allocated on an economic basis in order to assign beef-specific values.

Table 9: Data Quality Evaluation for EEA Parameters

11. Sensitivity and Uncertainty Analysis

11.1 Sensitivity and Uncertainty Considerations

There were no significant critical uncertainties from this study that would limit the findings or interpretations of the study. The data quality, relevance and sensitivity of the study support that the input parameters and assumptions are appropriate and justified.

11.2 Sensitivity Analyses

11.2.1 Scenario #1: WDGS Mass Allocation

As represented in the base case analysis, an economic allocation was used that placed 21% of the bioethanol distillation environmental burden onto WDGS. For this scenario, a mass allocation was used instead and this resulted in 62% of the bioethanol distillation process environmental burden being allocated to the WDGS. This 62% was based upon a distillation conversion factor ratio of 479 kg WDGS : 378 L bioethanol[37] (or 299 kg with a density for ethanol of 0.79 kg/L).

As expected, the results using a mass allocation of the WDGS were significantly changed in the feed phase compared to the base case economic allocation that would have a direct noticeable impact on the total beef value chain results. For example, Figure 39 below demonstrates a near 4% increase in total value chain GWP when applying a mass allocation. At the same time, Figure 40 shows a 53% increase in total value chain water emissions with application of a mass allocation.

While there is significant variation with the mass allocation, since we are considering all of the harvesting by-products with an economic allocation and since WDGS is a by-product of the distillation process, we maintained the economic allocation in order to keep consistent with allocation of all by-products. Additionally, with current pricing used in the economic allocation, as is demonstrated in Section 11.3.2 below, a scenario that considered energy allocation further validated the 21% economic allocation factor.

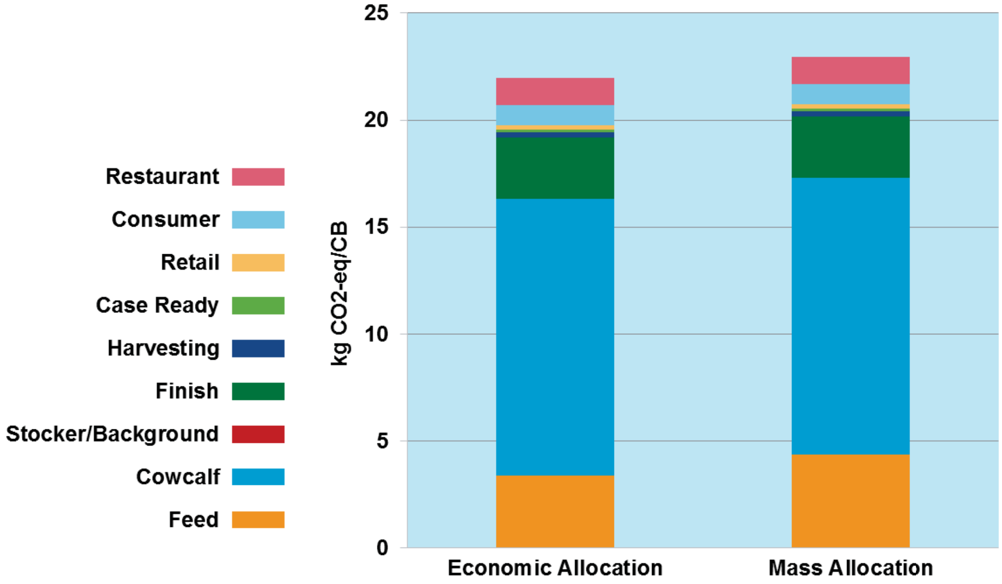

Figure 39: GWP for WDGS Mass Allocation Scenario

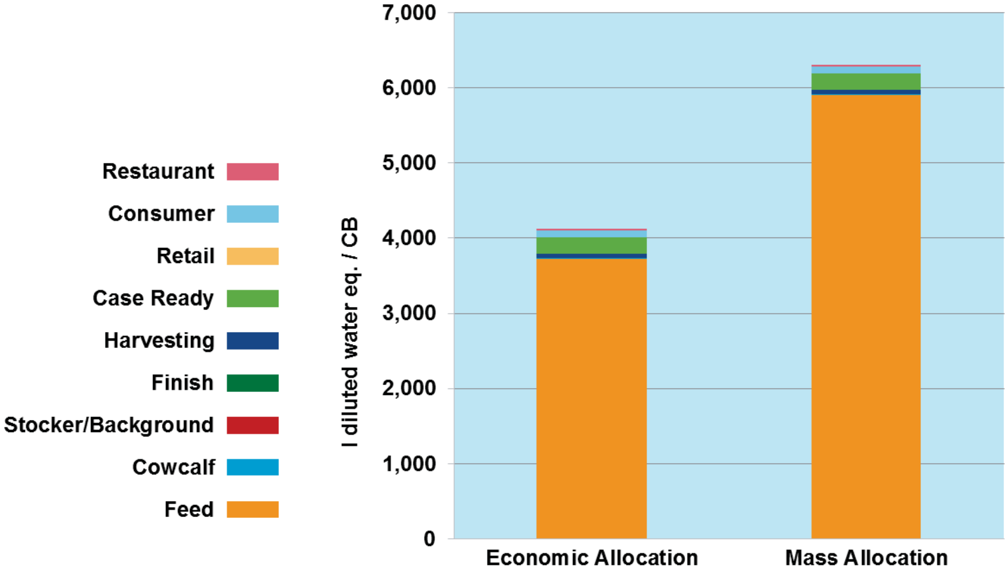

Figure 40: Water Emissions for WDGS Mass Allocation Scenario

11.2.2 Scenario #2: WDGS Energy Content Allocation

As represented in the base case analysis, an economic allocation was used that placed 21% of the bioethanol distillation process environmental burden onto WDGS. For this scenario, an energy content allocation was used instead and this resulted in 21% of the bioethanol distillation process environmental burden being allocated to WDGS.[38] Because this value was essentially the same as the economic allocation factor, no further analysis was completed to study the impact of using the energy content allocation approach.

One could make the argument that energy content is a constant physical attribute that should be used for calculating the allocation of the WDGS, as opposed to economics, which exhibits fluctuation. However, since we are considering all of the harvesting by-products with an economic allocation and since WDGS is a by-product of the distillation process, we maintained the economic allocation in order to keep consistent with allocation of all by-products. Additionally, with current pricing used in the economic allocation, the energy allocation result further validated the 21% economic allocation factor.

11.2.3 Scenario #3: Economic Allocation for Consumer Refrigeration

As represented in the base case analysis, a volumetric allocation was used to analyze the burden of the consumer phase refrigeration.

The results of using an economic allocation of the retail and consumer phase refrigeration and the retail refrigerant leakage resulted in some small but material changes in environmental impacts. For example, Figure 41 below demonstrates a near 2% increase in total value chain CED as compared to the volumetric allocation base case analysis. At the same time, Figure 42 shows a 3% increase in total value chain GWP compared to the volumetric allocation base case analysis. The largest change with this alternate allocation method was on GWP. However, GWP is only weighted 3.8% of total beef value chain environmental impacts.

While there are differences between the economic and volumetric allocation for consumer refrigeration as demonstrated, the volumetric allocation provided a physical allocation metric that was a more realistic representation of the refrigeration associated specifically with beef. Because an alternate physical allocation metric was not reasonably possible or logical for the other impacts analyzed for the consumer phase, the economic allocation is presented since this was the only alternative available.

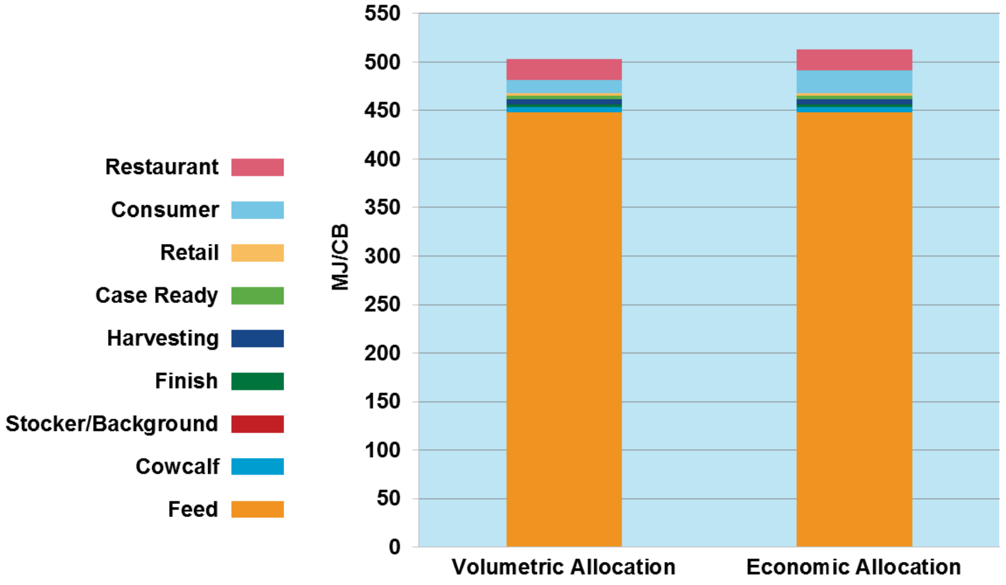

Figure 41: CED for Consumer Economic Allocation Scenario

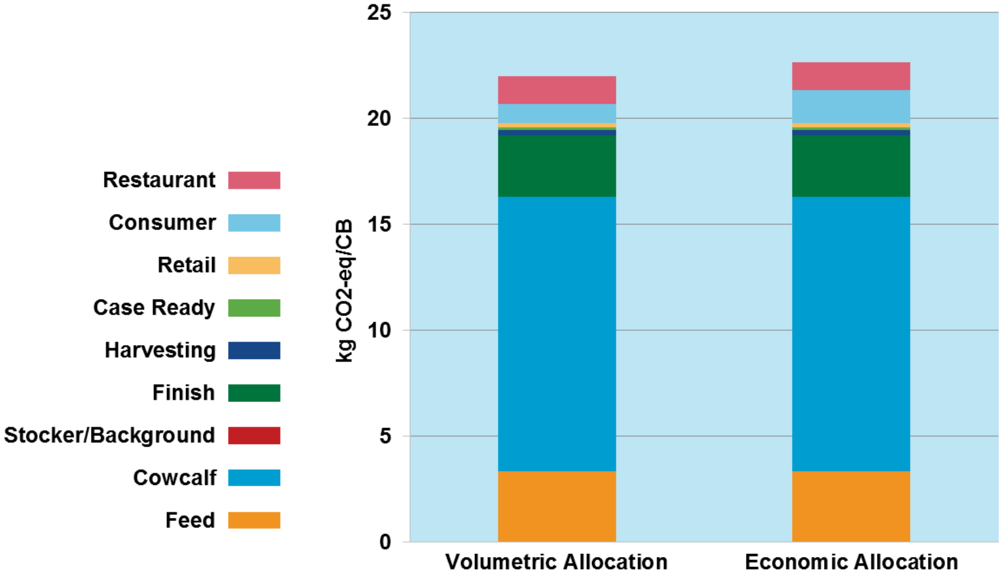

Figure 42: GWP for Consumer Economic Allocation Scenario

12. Conclusions

While environmental impacts stem from all phases of the beef value chain as represented throughout the study analysis and in Figure 6, the majority of the impacts are attributed to on-farm processes in the feed and cattle phases.

The impacts associated with the post-farm phases of harvesting, case-ready, retail, consumer, and restaurant, while generally contributing less overall value chain impacts, present material opportunities for improvement. Additionally, these opportunities generally may be more straightforward in terms of implementation. One very significant opportunity to which the entire value chain can contribute is on the issue of food waste. Based on the loss data analyzed, spoilage at the point of sale (retail and restaurant sectors) as well as spoilage and plate waste at the point of consumption (at-home consumption and in restaurant) are estimated to represent more than 10% of the edible beef that is processed. This is a huge opportunity if one considers all of the value chain inputs that are necessary to make this wasted beef. Additionally, it is a huge opportunity to contribute positively to the ever-growing global food supply demand. While reducing this impact will entail consumer behavior change, eliminating or at least greatly reducing this impact is likely one of the largest single opportunities for impact reduction.

In terms of the Pennsylvania Grass-finished scenario presented here, while not directly comparable to the baseline farm data from USMARC due to regional differences, there are trade-offs for both conventional and grass-finished beef. Additional data and research is needed for both conventional and grass-finished beef, which should include an expanded focus on lesser understood but longer-horizon sustainability issues such as biodiversity and soil integrity.

This eco-efficiency analysis of current U.S. beef industry value chain practices provides the baseline data that can be used to benchmark value chain improvements in the future. Future research is already underway to better understand some of the regional differences in the feed and cattle phase as well as to gather more specific data points to obtain an even higher quality dataset for ongoing measurement and improvement of the U.S. beef industry. Planned ongoing sustainability programs within the industry will result in future communications as data continues to be refined.

13. Limitations of EEA Study Results

These eco-efficiency analysis results and its conclusions are based on the specific comparison of the production, use, and disposal, for the described customer benefit, alternatives and system boundaries. Transfer of these results and conclusions to other production methods or products is expressly prohibited. In particular, partial results may not be communicated so as to alter the meaning, nor may arbitrary generalizations be made regarding the results and conclusions.

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