BASF
The Chemical Company

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

U.S. Beef – Phase 1
Eco-efficiency Analysis
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NSF®

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Contents

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 Eco-efficiency Analysis was performed by BASF according to the methodology validated by NSF International under the requirements of Protocol P352. More information on BASF's methodology and the NSF validation can be obtained at http://www.nsf.org/business/eco_efficiency/models.asp?program=EcoEff or http://www.basf.com/group/corporate/en/sustainability/eco-efficiency-analysis/index

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 by calculating the costs including materials, labor, manufacturing, waste disposal, and energy.

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. 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.

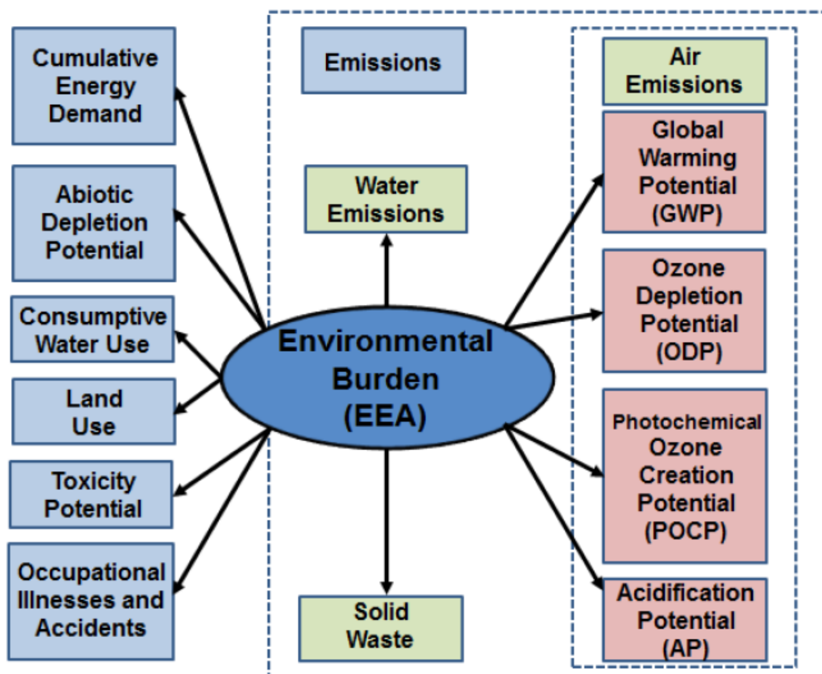

Figure 1: Environmental Burden Metrics for BASF Eco-efficiency Methodology

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). The approach for calculating costs varies from study to study. When chemical products of manufacturing are being compared, the sale price paid by the customer is predominately used followed by any subsequent costs incurred by its use and disposal. When different production methods are compared, the relevant costs include the purchase and installation of capital equipment, depreciation, and operating costs. The costs incurred are summed and combined without additional weighting of individual financial amounts. The BASF EEA methodology incorporates:

- the real costs that occur in the process of creating and delivering the product to the consumer;
- the subsequent costs which may occur in the future (due to tax policy changes, for example) with appropriate consideration for the time value of money; and
- costs having ecological aspect, such as the costs involved to treat wastewater generated during the manufacturing process.

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.

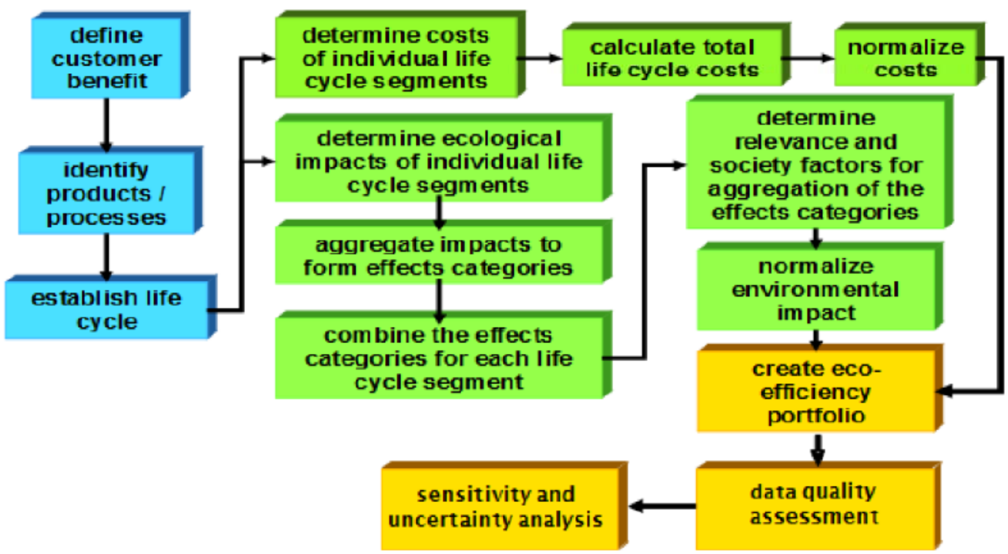

Figure 2: Overall Process Flow for U.S. Beef EEA Study

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 U.S. beef industry and to analyze the positive and negative trends associated with changes in practices over time. This provides a starting point for ongoing analysis and a journey of continuous improvement within the industry. Any established trends will be used to set the U.S. beef industry on a more sustainable pathway through various opportunities, which may include sharing and communicating best practices, embedding improvement opportunities throughout the industry, prioritizing solution-oriented research on sustainability criteria that are determined to be critical, and empowering the industry through ongoing education.

This EEA submission is the first phase (Phase 1) of an ongoing study of the U.S. beef industry. Phase 1 is intended to provide 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 of the life cycle assessment will require additional on-farm data to be collected at a regional level to provide complete value chain data that is representative of the whole 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 changes in the sustainability attributes of beef over time 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. As mentioned in Section 4.1, 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 1 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 Phase 1 of the U.S. Beef EEA because as a research center USMARC has extensive data, including some back to 1970, which would be 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. Really, 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, the analysis of their system does not receive this benefit. 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 beef value chain for beef that was produced by the U.S. beef industry (according to the geographical scope defined in Section 4.2.2) in 2005 and 2011 and for the on-farm phases in 1970, 2005, and 2011.

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 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. Future updates to the study will include regionalized on-farm data, cattle management techniques, and other out-of-home dining venues such as restaurants.

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.

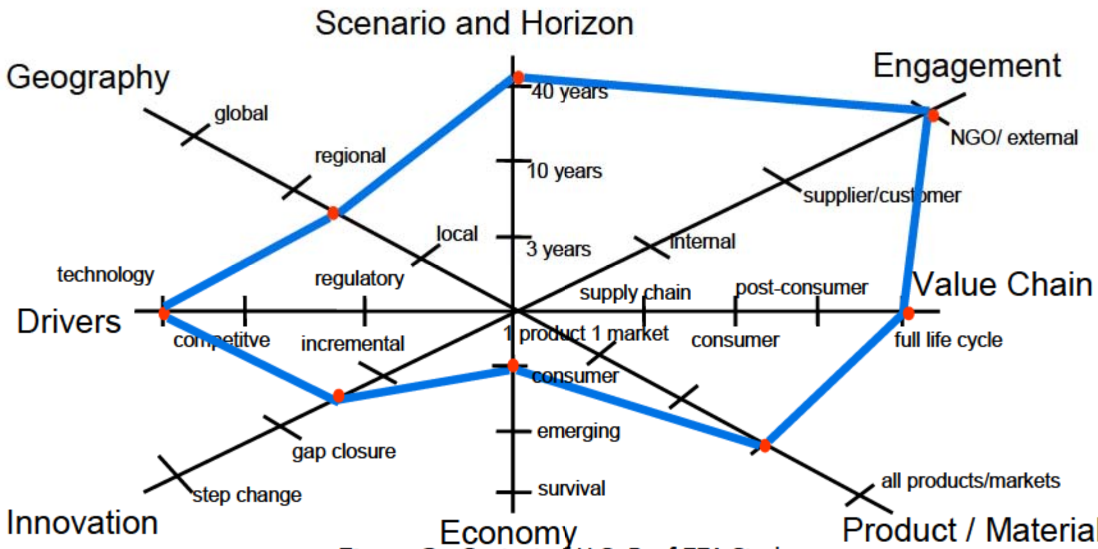

Figure 3: Context of U.S. Beef EEA Study

5. Customer Benefit, Alternatives and System Boundaries

5.1. Customer Benefit (CB)

The Customer Benefit (identified also as CB), Functional Unit (FU) or User Benefit (UB) applied to all alternatives for the base case 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 assumed. Finally, in order to evaluate the entire beef life cycle, the CB considers beef consumed.

5.2. Alternatives

This is a study over time to demonstrate changes in the eco-efficiency attributes of the U.S. beef industry associated with the CB defined above in Section 5.1. The study considered the periods 2005 and 2011 for the entire life cycle of beef and the periods 1970, 2005, and 2011 for the on-farm phases of the U.S. beef industry (feed and cattle). Reliable data could not be constructed at this time for the 1970 timeline for post-farm phases of the beef life cycle.

Reasoning for selection of the three alternative periods is as follows:

- 1970 represents the largest herd of cattle in the U.S. Additionally, during 1970, swinging sides were used as the main mode of transport to the point of retail sale. After this, the industry moved to boxed beef, so this represents a significant change in operations for the beef industry.

- 2005 represents the onset of distillers grains used as feed (so for the data set in this study, this was the last year before mainstream use of distillers grains in the industry).

- 2011 is present-day analysis and considers the use of distillers grains.

Note that because the 1970 alternative could not be evaluated for the entire value chain, full study results and analysis in Section 8 do not include the 1970 alternative. Instead, the 1970 on-farm (feed and cattle phase) analysis is overviewed in a scenario in Section 9.

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. Individually, these impacts have less than a 1% contribution or collectively less than a 3% contribution to the overall value chain impacts in this study.

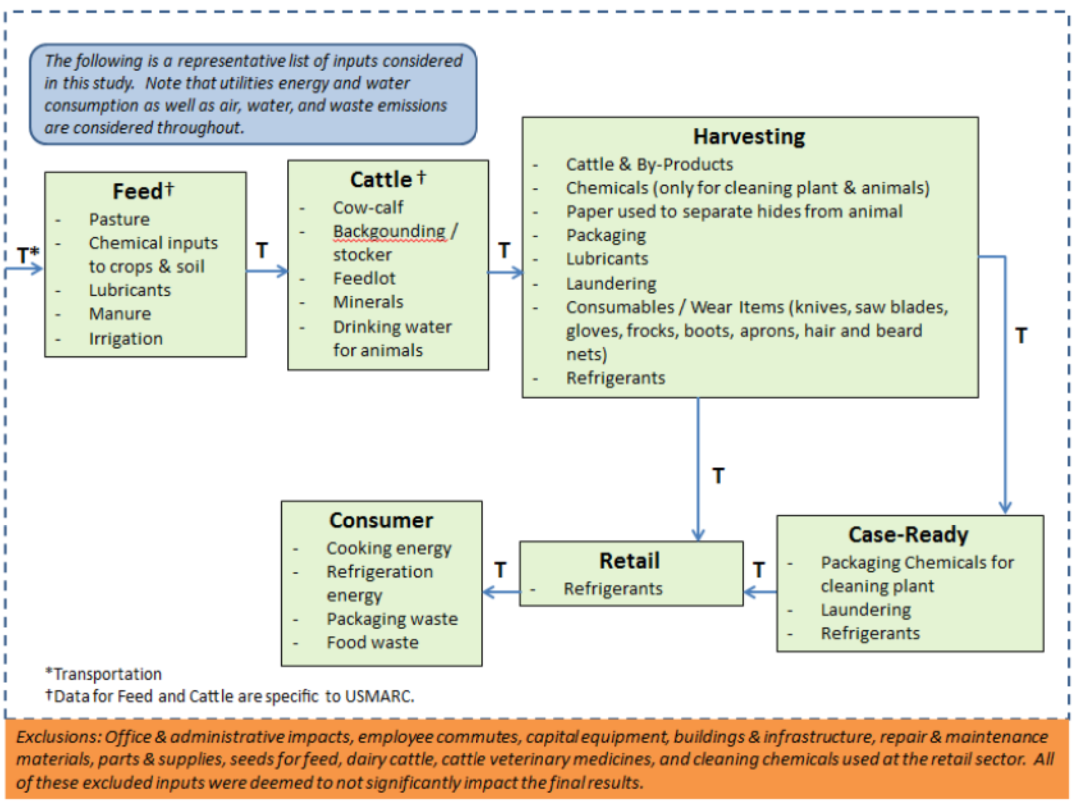

Figure 4: System boundary for U.S. Beef – Phase 1

5.4 Scenario Analyses

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

- Scenario #1: On-farm (feed and cattle phases) base case analysis with 1970 data.
- Scenario #2: Analysis of Wet Distillers Grains with Solubles (WDGS) using a mass allocation.
- Scenario #3: Analysis of Wet Distillers Grains with Solubles (WDGS) using an energy content allocation.
- Scenario #4: Retail and consumer phase refrigeration and retail refrigerant leakage 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; and
- analysis of retail and consumer refrigeration and refrigerant leakage from retail refrigeration because refrigeration for beef in these two phases 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 1 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] 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 (fat, bone, shrink)	4%
Loss as consumer phase (cooking losses, spoilage, plate waste)	20%
Total losses from live animal weight sent from cattle phase	*70%*

Table 1: 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. Packaging used directly or indirectly for the beef product was assumed to be 100% completed in the case-ready phase (i.e., packaged into a retail-ready output). While this assumption was not fully representative of the reality of the beef industry (as there are other packaging modalities including the butcher shop), it provided an initial outlook on the packaging phase due to lack of primary data. The goal is to amend the study with some additional primary data in Phase 2 of the study.

4. 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]

5. 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.

6. 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. 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.

7. For cost analysis, the present value (2011 dollars) 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 USMARC. 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.[6]

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, particularly from past years.

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.[7] 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, and finishing cattle.[8] 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.[9] 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.

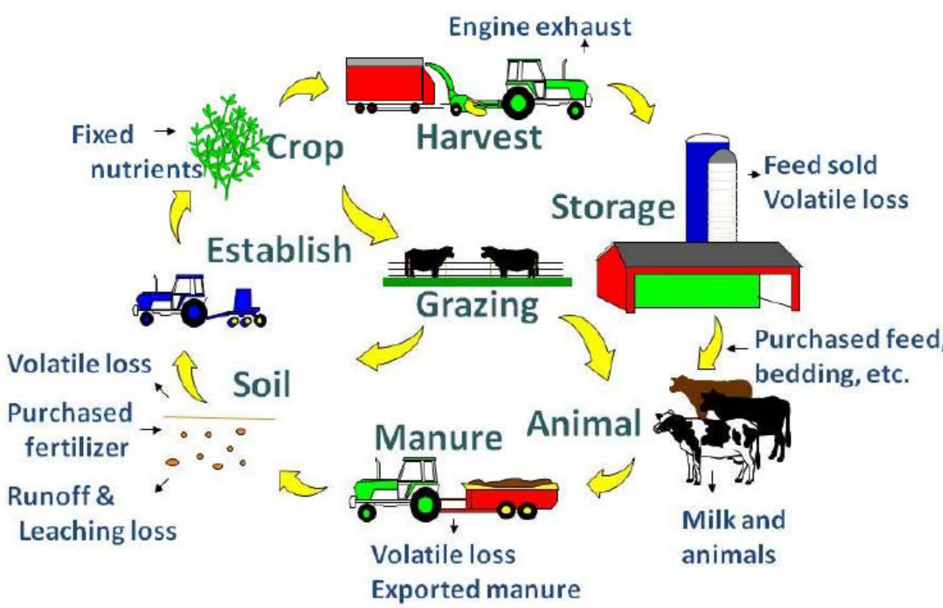

Figure 5: Boundaries, major components and nutrient flows simulated with the Integrated Farm System Model[10]

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 2 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 2: Actual reported vs. IFSM Simulated feed production at USMARC for 2011 [11]

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 eco-portfolios as well as for some additional direct emissions.

The USMARC facility included about 5,000 acres of irrigated farmland used for feed production. Note that in 1970, irrigation was less common. Only about 1,000 acres were irrigated for corn and irrigation was not used at all on pasture at USMARC. This has changed significantly to the current day as can be seen in the consumptive water values in Section 8 of this report.

Feed production at USMARC included alfalfa/grass (and associated silage), 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.

For the data utilized for the 1970 scenario in this study, adjustments were made from 2011 data by the USDA research team based on available knowledge of the historical USMARC system and overall feed production, including the following:

- Some of the corn currently used was replaced with bromegrass hay;
- Alfalfa yield was decreased 12% and corn yield was decreased by 40% (to represent genetic improvements that have occurred since 1970);
- No irrigation of pasture was used; and
- Smaller equipment and additional tillage operations were used to reflect the technology of 1970.

Additionally, for the 2005 data, adjustments were made from 2011 data by the USDA research team based on available knowledge of the USMARC system and overall feed production, including the following:

- Reduced corn yield by 6% (to represent genetic improvement); and
- Replaced WDGS with corn and a small amount of urea to meet energy and protein requirements of the animals.

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, as shown below in Table 3.

Purchased Feed Type	**ton DM**		
	1970	***2005***	***2011***
Corn	4,528	1,411	0
Wet Distillers Grains with Solubles (WDGS)	0	0	1,790

Table 3: Purchased Feed considered in MARC system

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

1. The profile used for purchased corn and WDGS is representative of the corn-belt area in Iowa and is non-irrigated. The Iowa profile represents the region from which USMARC purchases corn (as opposed to the corn grown by USMARC and included in the system considered, which is irrigated). Note that the profile for the USMARC corn was established by primary data from the IFSM based on specific USMARC system simulations.
2. Yields of purchased corn were assumed to be as follows in Table 4 as simulated from the IFSM.

	1970	2005	2011
bu/acre	101	158	168

Table 4: Purchased Corn Yields

3. Historical records show little change in the application rates of fertilizer in this region. Essentially improvements in fertilizer use efficiency (requiring less fertilizer) have been offset by increased yields requiring more fertilizer per acre. So although application rates have not changed, nutrient use efficiency has improved substantially. USMARC now harvests about 40% more corn using the same fertilizer application rate as in 1970.[12] Based upon this historical data for the region, fertilizer application rates for purchased corn were held constant across all three periods (1970, 2005, and 2011) as follows:

    a. 160 lb N/acre
    b. 90 lb P_2O_5/acre
    c. 90 lb K_2O/acre
    d. 920 lb lime/acre

    An eco-profile for urea was used to represent the applied N and an eco-profile for single superphosphate was used to represent the applied P_2O_5 in order to complete a full assessment of pre-chain impacts of the appropriate nutrients.

4. Insufficient information on the type and amount of pesticides was available in a specific and quantifiable manner for 1970. For purposes of this study, the type and amount of pesticides applied to the feed crops in 1970 and 2005 were considered to be equivalent to that used in 2011.[13]

5. 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:
    a. 1970: 85.8%
    b. 2005: 85.3%
    c. 2011: 82.5%

6. 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. Therefore, no pre-chain impacts were considered for these plant nutrients. Emissions from the manure were considered.

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

		1970	2005	2011
Runoff loss	lb P/ton P applied	0.6	0.32	0.3
	lb N/ton N applied	2.4	1.28	1.2
Air emissions (direct + crop residue)	lb N_2O/ton N applied	0.68	0.43	0.41

Table 5: Corn Direct Emissions

Table 6 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[14]
N fertilizer leaching	30%
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 6: Additional Field Emission Factors

Note that direct N_2O background emissions from soil were not considered in this study.

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.

8. 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 not have a significant impact on the overall results. The analysis includes both runoff and leaching of heavy metals.[15]

9. 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.

10. 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.

11. Transport distance was assumed to be an average of 20 miles from the distillery to the feedlot for the WDGS and 500 miles roundtrip for the purchased corn (250 miles for corn to distillery for the WDGS).

12. 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 the corn profile from Iowa that was assumed in the rest of this study for purchased corn (in order to maintain a consistent profile). Yield of the corn was adjusted to 2011 yield values shown above of 168 bu/acre.

    c. An adjustment factor was then applied to the profile of 1.55 to account for the fact that 1.55 times the weight of WDGS is produced compared to DDGS from the distillation process.[16]

    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.

13. 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 7 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 7: Gross Bioenergy of Crops

14. For the Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the feed category were assessed for change over time according to the three period alternatives using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of "Oilseed and Grain Farming".[17] Also, for the 1970's scenario, illness and accident values were extrapolated based on 2005 and 2011 data using general OSHA total industry trends since 1970. This was necessary because the industry categories in 1970 and their associated data were segregated in a much broader classification system and as a result, direct data for the same industry codes used in 2005 and 2011 were not available.

6.1.3 USMARC Cattle Production

The cattle phase considered the life cycle of the living animal from birth until it leaves the feedlot and is transported to the beef harvesting facility. Input parameters for the cattle phase 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.

The USMARC data included inputs and outputs for the cow-calf and feedlot operations. Note that pasture inputs were included in the feed phase. 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.

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.

For the data utilized for 1970 in this study, adjustments were made from 2011 data by the USDA research team based on available knowledge and publications of the historical USMARC system and overall cattle production, including:

- Finishing weight was decreased by 19% (to represent genetic improvements) and correspondingly, animal numbers were increased by 19% to produce the same finished weight; and
- Finishing was completed with a corn grain and corn silage diet.

Additionally, for the data utilized for 2005 in this study, the following adjustment was made from 2011 data by the USDA research team based on available knowledge of the USMARC system and overall cattle production:

- Finishing weight was decreased by 3% and correspondingly, animal numbers were increased by 3%.

The following is a list of additional assumptions that were applied for the cattle phase of this study:

1. The impacts of all calves, heifers, cows, bulls, and beef cattle were included in the study.
2. The mass value of body weight of the cattle sent to harvesting and included in the cattle phase analysis was held constant over the three periods analyzed. This total weight included finished cattle, cull cows, and cull bulls used for harvest.
3. There was a reduction in the animal numbers over time within the system to offset increases in overall body size over time (higher yields per head).
4. 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.
5. As with the feed phase, IFSM data were used wherever available. This included inputs associated with supplementary feed as well as the following emissions:
    a. P water emission from pastureland, which was different from the cropland analyzed in the feed phase.
    b. CH_4 emissions – enteric and manure emissions. The manure emissions were different in the feed phase where manure was applied

to the cropland, while the cattle phase included manure deposits on the pastureland.

c. N_2O emission – pastureland and manure emission.
d. NH_3 emission – urine and manure emission on pastureland.

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

6. Drinking water for livestock was included. Since this water came directly from the USMARC wells, the only impact was the energy for pumping. As shown in the general assumptions, a value of 55% was applied for consumptive water related to this drinking water.

7. 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.

8. For Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the cattle category were assessed for change over time according to the three period alternatives using the U.S. Bureau of Labor Statistics (BLS) data for the industry category of "Cattle Ranching and Farming". Also, for the 1970's scenario, illness and accident values were extrapolated based on 2005 and 2011 data using general OSHA total industry trends since 1970. This was necessary because the industry categories in 1970 and their associated data were segregated in a much broader classification system and as a result, direct data for the same industry codes used in 2005 and 2011 were not available.

9. 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[18],, evaluated this additional risk category on a scale of 1:10 with 1 representing the most risk and 10 the least risk.[19] The expert opinion scale score applied to the animal welfare category was 2.5, 5.5, and 7.5 for 1970, 2005, and 2011 respectively. 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.

6.1.4 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 the full 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 credits to the beef value chain for 2005 and 2011 were 9.6% and 11.7%, respectively (i.e. 9.6% and 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 for change over time according to the two period alternatives (2005 and 2011) 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[20] and expert opinion, the scale scoring applied to the food safety category was 1, 6, and 8 for 1970, 2005, and 2011, respectively.[21] 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.[22] The expert opinion scale scoring applied to the animal welfare category was 2.5, 5.5, and 7.5 for 1970, 2005, and 2011 respectively. 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 1, 5, and 7 for 1970, 2005, and 2011 respectively.[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, 100% 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). This primary data included inputs for energy, packaging, waste, and consumable items (as shown in Figure 4). Based on industry expert opinion and direct operations knowledge from the case-ready data providers, all other data values, such as water, cleaning chemicals, and waste, were assumed to be 10% of the average of the harvesting facility data from the three producers surveyed.

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 for change over time according to the two period alternatives (2005 and 2011) 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 the packaged beef from the case-ready phase is sold. For this study, no primary data were obtained from retailers, but this will be included in a future second phase of the study. For this submission, literature and other publicly-available sources of information, including from the EPA,[24,25] USDA,[26] and the Food Marketing Institute[27] were used to construct average retail eco-efficiency profiles that included retail electricity consumption, refrigerant leakage, natural gas consumption, and beef waste.

Because average data were only published periodically or in some instances only analyzed for one point in time, the same data were assumed for 2005 and 2011 for all inputs, with the exception of refrigeration energy and refrigerant leakage. For these impacts, a volumetric allocation based on the average U.S. diet was applied (which is also applied to consumer refrigeration). The volumetric allocation was derived from an analysis of USDA Economic Research Service data on U.S. food consumption at home and associated densities.[28]

For the Occupational Illnesses and Accidents risk values, in addition to the standard pre-chain impacts, direct impacts for the retail category were assessed for change over time according to the two period alternatives (2005 and 2011) 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. As with the retail phase, 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,[29] electricity consumption associated with refrigeration,[30] repackaging of beef by the consumer,[31] cooking energy,[32] and consumer beef waste[33]. Data for repackaging and cooking energy were assumed to be equivalent for both 2005 and 2011 as data for these inputs was not published regularly.

As with the retail phase, 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.[34]

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[35], and ecoinvent[36]. 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 8.

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[37]	
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	
Glyphosphate	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, 1997 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 regional storehouse/RER U
Picloram herbicide	Ecoinvent 2.2, 2010	Ecoinvent profile: Pesticide unspecified, at regional storehouse/RER U

Eco-Profile	Source, Year	Comments
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	
Cattle Phase		
Urea fertilizer	BASF, 2005	
Calcium oxide	BASF, 1997	
Magnesium oxide	Boustead, 1996	
Sodium chloride	Boustead, 1996	
Copper chloride	BASF, 1998	
Sodium selenite	BASF, 2003	
Zinc sulfate	BASF, 2003	
Thiamine mononitrate	BASF, 2003	
Molasses	BASF, 2000	
Corn	BASF, 2011	
Dicalcium phosphate	BASF, 2003	
Potassium fertilizer	BASF, 1997	
Iodine	BASF, 2006	
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	
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,

Eco-Profile	Source, Year	Comments
		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)
Retail Phase		
R-143a Refrigerant	BASF, 2002	
R-134a Refrigerant	Ecoinvent 2.2, 2010	Ecoinvent profile: Refrigerant R134a, at plant/RER S
Consumer Phase		
LDPE	BASF, 2005	
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 8: 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 and are presented below in Sections 8.1.1 through 8.1.10. Note that the results presented in Section 8 are for the alternatives 2005 and 2011, while the 1970 on-farm scenario is discussed in some detail in Section 9.

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 nearly 80% of the total Cumulative Energy Demand (CED). There were some minor added energy requirements associated with the use of WDGS in 2011. 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).

CED declined slightly from 521 MJ/CB to 511 MJ/CB between 2005 and 2011 as shown below in Figure 6. Figure 7 demonstrates the impact of the gross bioenergy from the feed. 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). To this point, the main drivers of the slight reduction in CED between the two periods included energy efficiency and conservation improvements related to the following:

- utilities and transportation energy consumed per CB throughout the value chain;
- increased crop yields and thus less fossil energy consumed per unit of feed produced;
- increased use of biogas generated and captured from on-site wastewater lagoons at the harvesting facilities (which allowed a decreased purchase of off-site fossil energy);
- fuel switching for boilers at the harvesting facilities from diesel to natural gas; and
- packaging consumption reduction due to optimizations in the harvesting and case-ready phases that resulted in decreased transportation of packaging supplied as well as reduced pre-chain energy impacts.

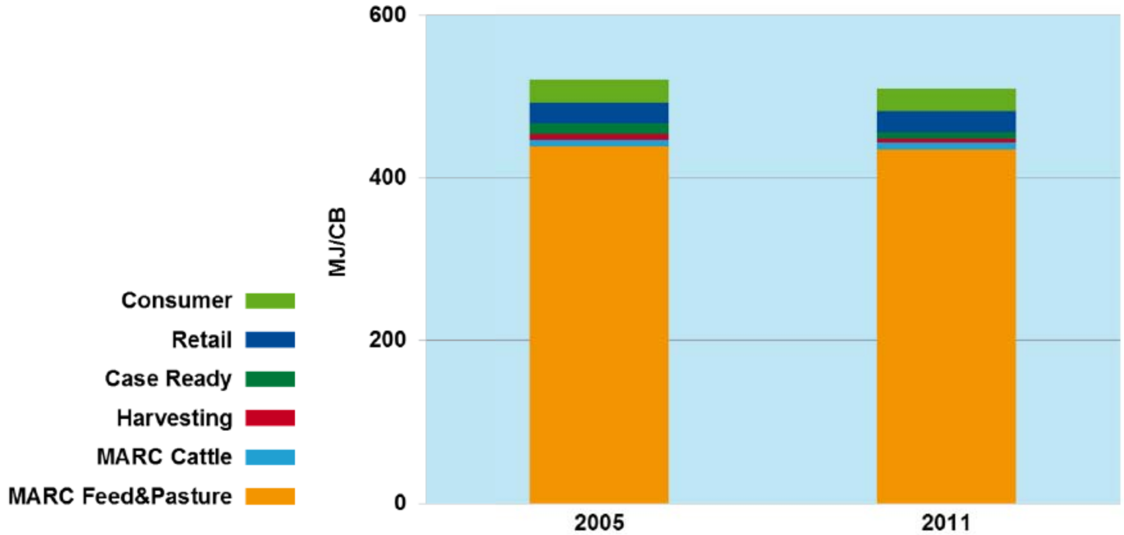

Figure 6: Cumulative Energy Demand

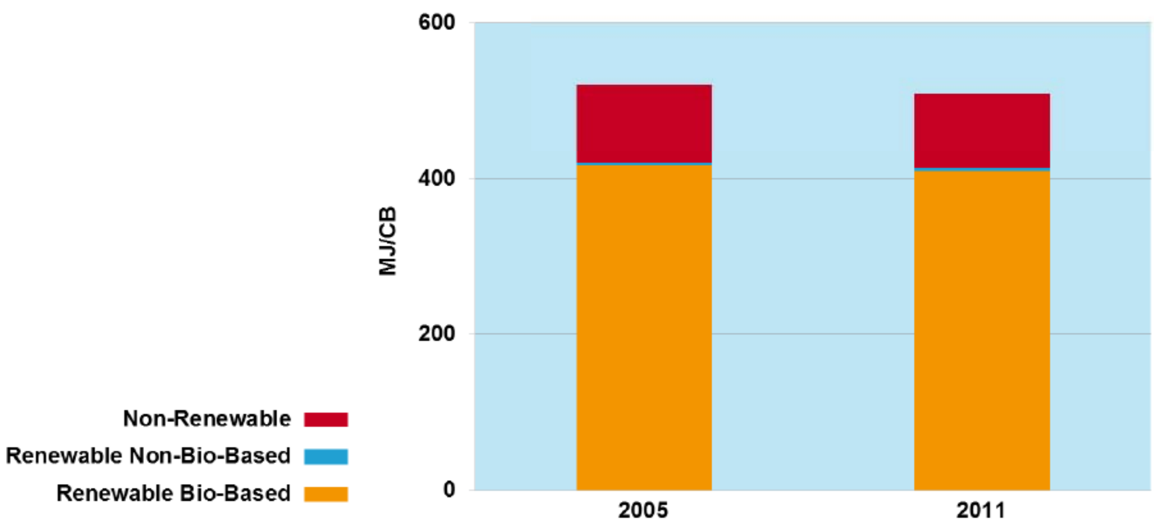

Figure 7: Renewable and Non-Renewable Energy Breakout

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.

While use of WDGS caused a slight increase in ADP, as can be seen below in Figure 8, there was a small total beef value chain decline from 5.05 to 4.96 mg Ag-eq/CB between 2005 and 2011. The main reduction factors included increased yields of feed crops, an increased use of recovered biogas from wastewater lagoons at the harvesting facilities (resulting in decreased need for diesel purchases for boilers), and energy efficiency improvements throughout the value chain.

Figure 8 represents the ADP by phase while Figure 9 represents the ADP by resource.

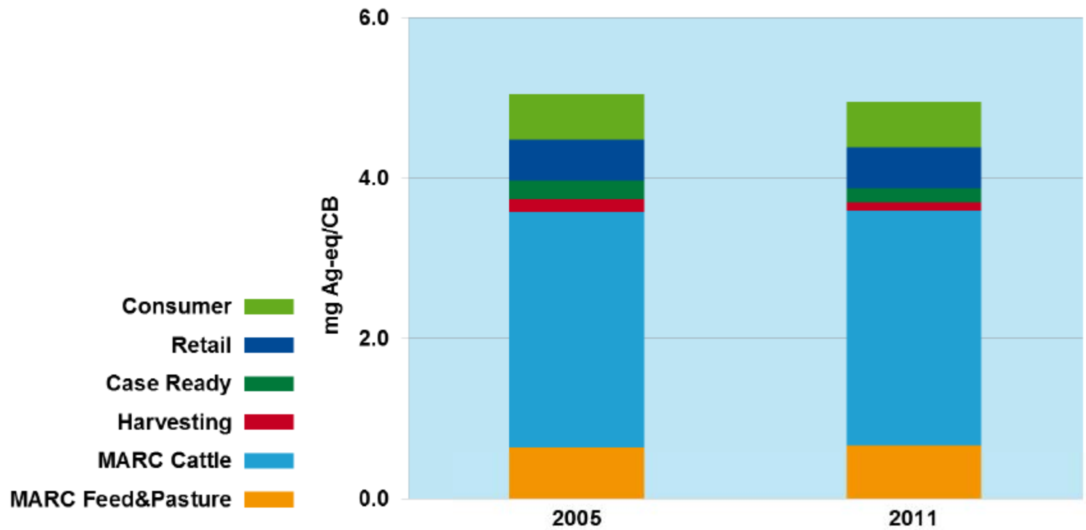

Figure 8: Abiotic Depletion Potential by Phase

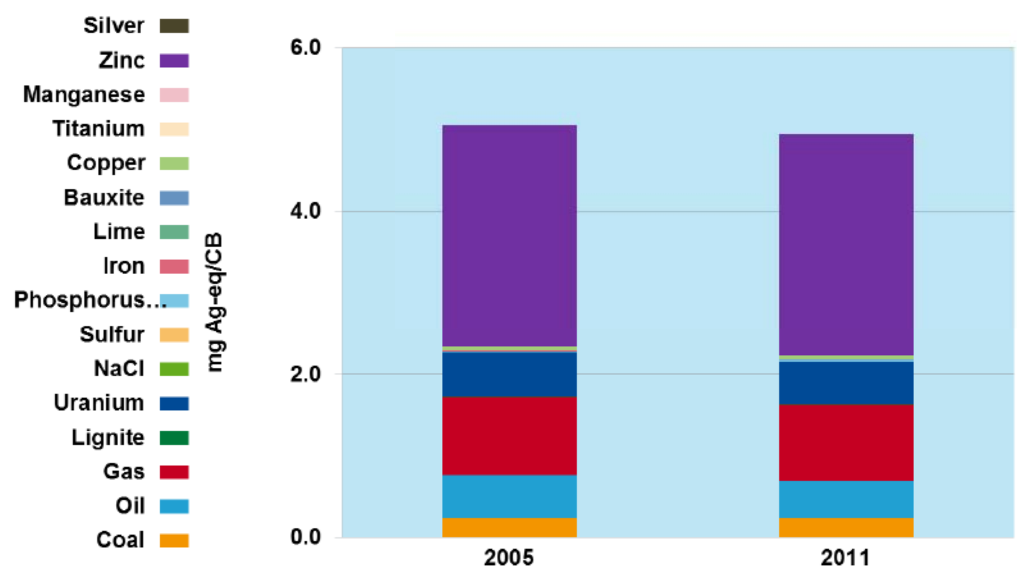

Figure 9: Abiotic Depletion Potential by Resource

8.1.3 Consumptive Water Use

Nearly 95% of the consumptive water was consumed in the feed phase and this was associated mainly with the irrigation of crops. Utility 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 total consumptive water use declined 3% from 82,103 to 79,251 L-eq/CB (2,418 to 2,336 L absolute consumptive water) between 2005 and 2011 and this is mainly on account of a reduction in USMARC irrigation water per unit of feed due to increased efficiencies as well as a reduction that can be attributed to use of the WDGS. Some more minor additional points of reduction include those related to harvesting plant water efficiency improvements as well as optimizations in the case-ready phase that lead to packaging reductions. Energy efficiency improvements throughout the value chain also resulted in some additional consumptive water use reductions from reduced pre-chain impacts.

The consumptive water use is shown both at an assessed value as well as an absolute value in Figures 10 and 11 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 direct consumptive water and pre-chain electricity consumptive water used for the feed and cattle phases represents the region in which USMARC is located (Nebraska) and is 33.4. The factor applied to the rest of the study, including all other outside inputs to the USMARC modeled in the feed and cattle phases, was 68.7, which is representative of the entire U.S.[38]

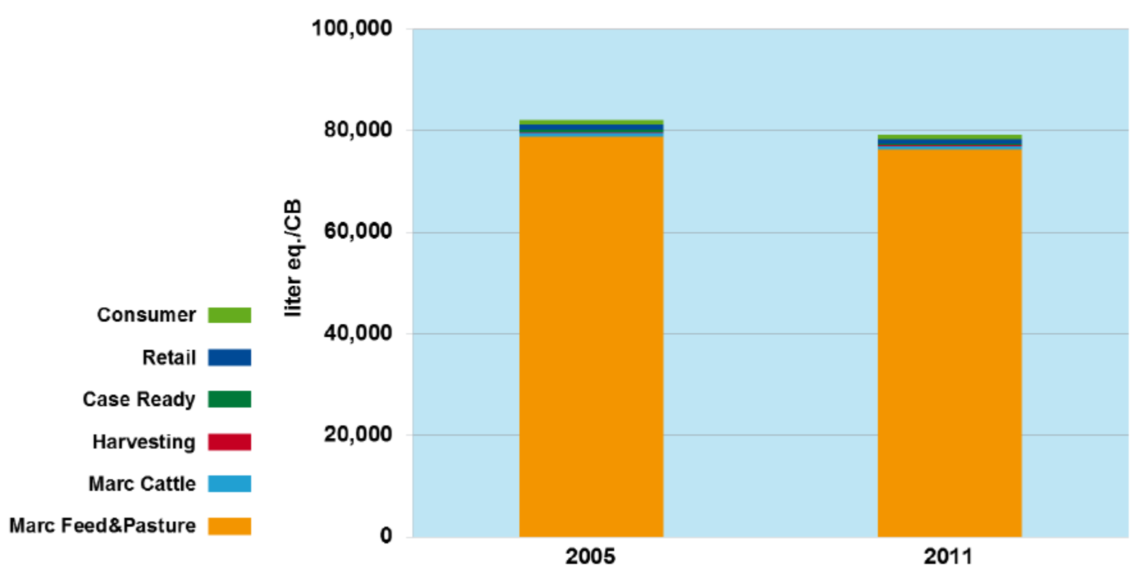

Figure 10: Assessed Consumptive Water Use

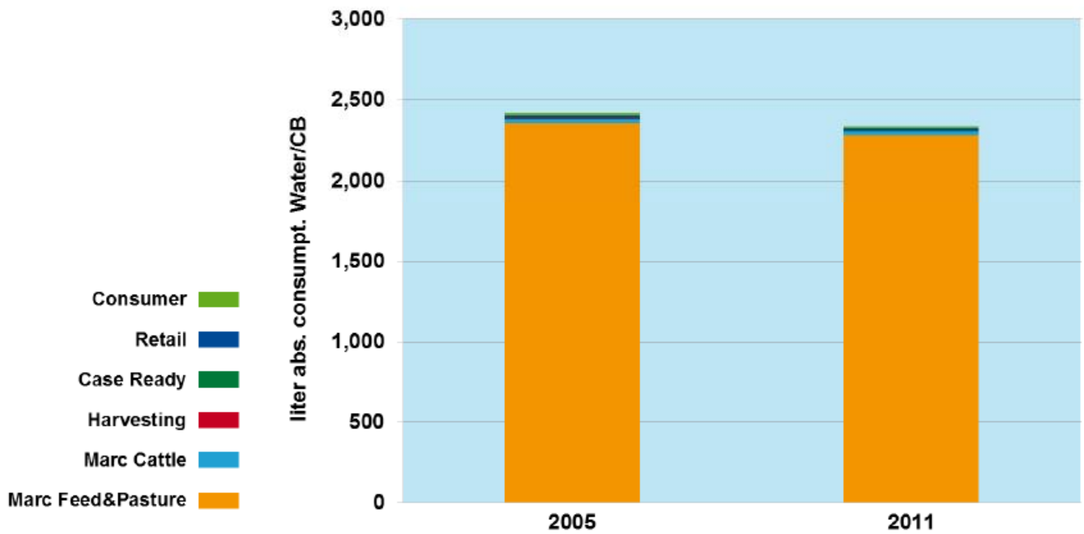

Figure 11: Absolute Consumptive Water Use

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 42% of total GWP. N_2O from manure on the feedlots and pastureland was the second largest contributor, with 20% of the total value chain emissions. Other significant contributors included field emissions from fertilizers on the feed phase, refrigerant leakage on the retail phase, and cooking on the consumer phase. Less significant GWP contributors included corrugated cardboard and LDPE packaging pre-chain emissions.

As shown below in Figure 12, GWP had little change with values of 23.7 kg CO_2-eq/CB in 2005 and 23.6 kg CO_2-eq/CB in 2011. Most of this reduction was a result of energy efficiency improvements throughout the value chain as well as increased use of recovered biogas in the harvesting phase and packaging optimizations (reduced pre-chain emissions reductions). There was some reduction realized from increased crop yields over time, which resulted in greater efficiency per hectare of feed as well as reduced fertilizer use with this increased efficiency. Some increases in GWP on the feed side cancelled out and caused a very slight increase over any gains in the feed phase from crop yield improvements as a result of using WDGS, which has a higher GWP footprint from the associated bioethanol distillation process.

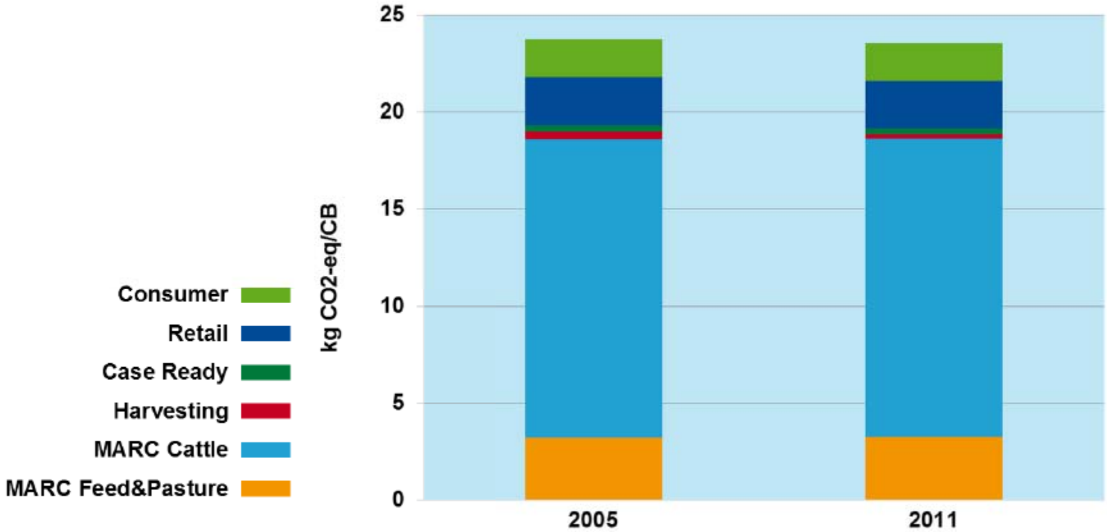

Figure 12: Global Warming Potential (GWP)

8.1.4.2 Photochemical ozone creation potential (POCP)

The main contributors to POCP included VOCs from feed silage (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 shown below in Figure 13, there was a negligible reduction in POCP with values nearly constant at 0.026 kg C_2H_4-eq/CB for 2005 and 2011. There was a reduction in POCP from increased use of recovered biogas in the harvesting phase as well as other less significant reduction contributions from plant utilization optimizations and packaging optimizations on the case-ready phase. However, these reductions were mainly offset by increased use of high moisture corn and silage. The overall change in POCP due to WDGS use in 2011 was negligible.

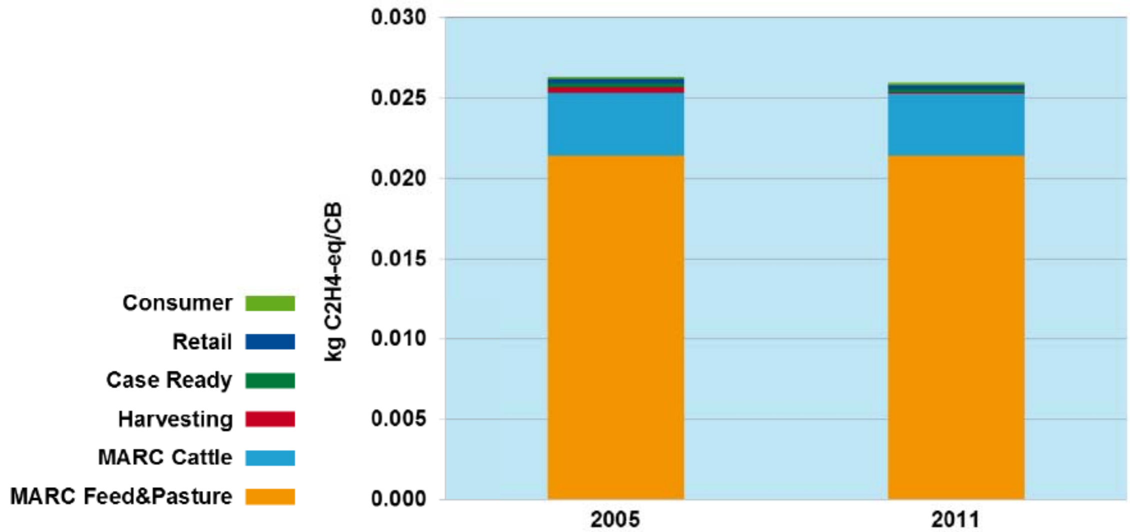

Figure 13: Photochemical Ozone Creation Potential (POCP)

8.1.4.3 Ozone depletion potential (ODP)

The most significant contributors to ODP were halogenated hydrocarbons in the retail refrigerant and LDPE pre-chain emissions.

As can be seen in Figure 14 below, ODP values were essentially constant between 2005 and 2011 with values in both years of 0.013 g CFC11-eq/CB. There was a small reduction realized from LDPE packaging optimizations. However, the total value chain emissions remained stable due to some increased emissions associated with the WDGS and the associated bioethanol distillation process.

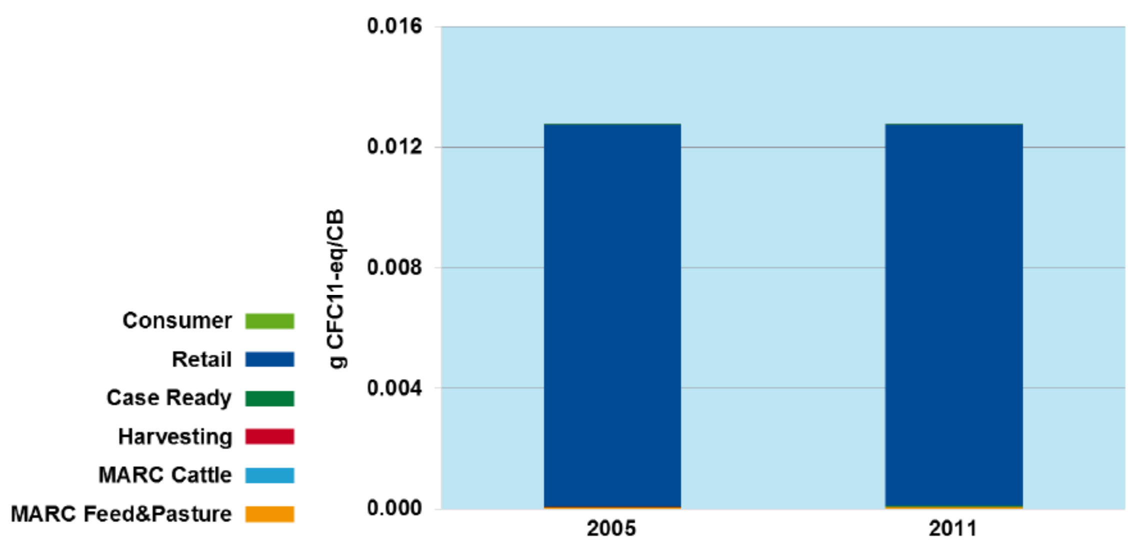

Figure 14: Ozone Depletion Potential (ODP)

8.1.4.4 Acidification potential (AP)

Most of the AP contribution comes from the feed and cattle phases. Specifically, 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 15 below, AP declined 3% from 336 to 327 g SO_2-eq/CB between 2005 and 2011. There was an increase in AP from the cattle phase as a result of WDGS being used in the cattle diets, which results in increased NH_3 emissions from cattle urine. However, decreases in AP associated with the use of WDGS in the feed phase negated the increase in the cattle phase and resulted in an overall slight reducing effect on AP from WDGS use. Additionally, there were significant decreases in AP in the feed phase as a result of increased crop yields (and corresponding decreased fertilizer use and associated field emissions as well as fertilizer pre-chain energy emissions per unit of feed produced). Additionally, other smaller AP reductions were realized from energy efficiency improvements across the value chain, increased use of recovered biogas in the harvesting phase, and packaging optimizations resulting in decreased pre-chain emissions.

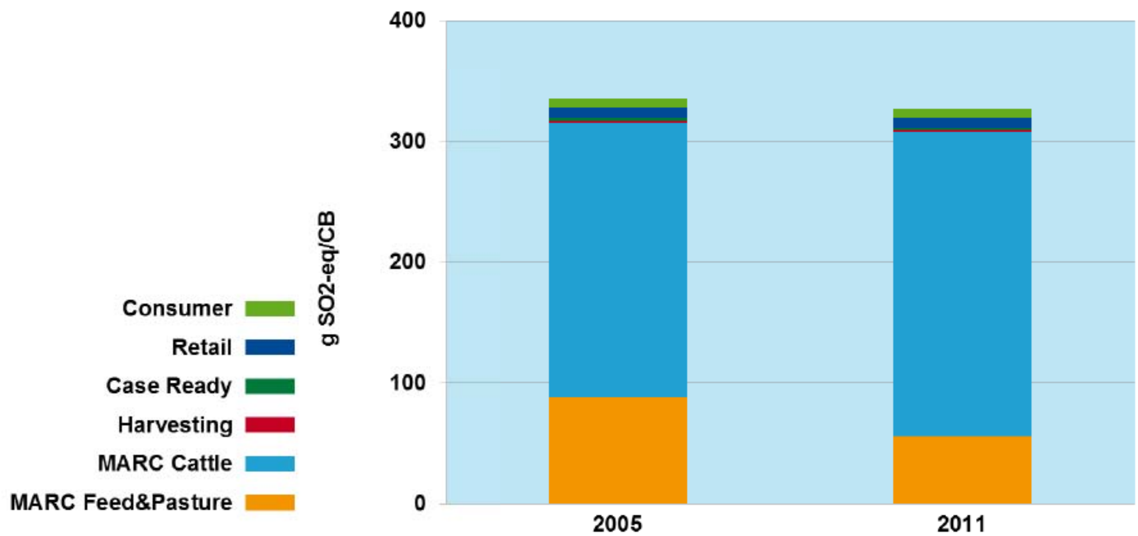

Figure 15: Acidification Potential (AP)

8.1.5 Water emissions

The main water emissions from the beef value chain were from the feed phase, which accounted for 78% of total water emissions in 2005 and 81% in 2011. Of the feed emissions, approximately 42% was a result of nitrogen runoff and leaching, 20% from phosphorous runoff, 35% from heavy metal runoff and leaching (associated with fertilizers), and 3% from Chemical Oxygen Demand

(COD). 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 16, there was a 10% reduction in water emissions from 4,981 to 4,487 L grey water-eq/CB from 2005 to 2011. This reduction is mainly a result of increased crop yields between the alternative periods that results in decreased fertilizer and pesticide use and associated runoff and leaching per unit of feed produced. Additional water emissions reductions were associated with the move to WDGS, packaging optimizations in the case-ready phase (reduction of pre-chain water emissions), reduced emissions from reduced packaging waste that went to landfill in the post-farm value chain due to those same packaging optimizations, and harvesting facility direct wastewater emission reductions.

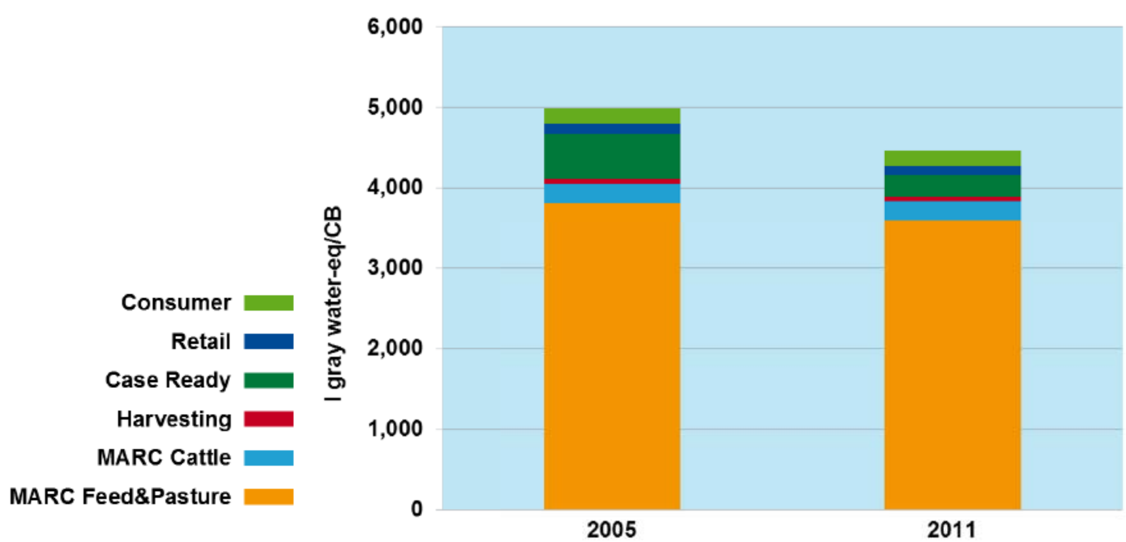

Figure 16: Water Emissions

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 17 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.

Solid waste generated from pre-chain production declined by 7% from 0.19 to 0.18 kg/CB between 2005 and 2011. This was due to greater use of biogas at the harvesting facilities and numerous other efficiency improvements throughout the value chain mentioned throughout this analysis. As a result of replacing more purchased diesel with biogas and the other value chain efficiency improvements, less materials were utilized overall, which had a direct relation to reducing all pre-chain environmental impacts including solid waste generation. The use of WDGS as feed had no noticeable impact on solid waste changes from 2005 to 2011.

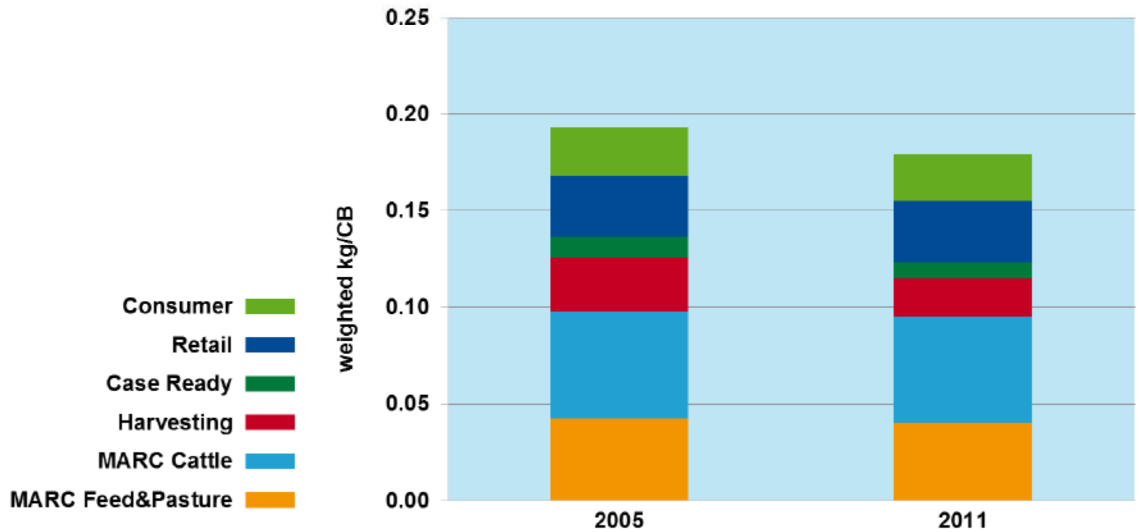

Figure 17: Solid Waste Generation

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 18, land use declined by 4% from 21.4 to 20.5 m^2-years/CB between 2005 and 2011. Most of this decline was associated with increased crop yields. Other notable declines were associated with the use of WDGS, packaging optimization (reduced pre-chain impacts, particularly associated with cardboard), increased use of recovered biogas that reduced pre-chain impacts associated with diesel, and other energy efficiency improvements across the value chain that reduced associated pre-chain impacts.

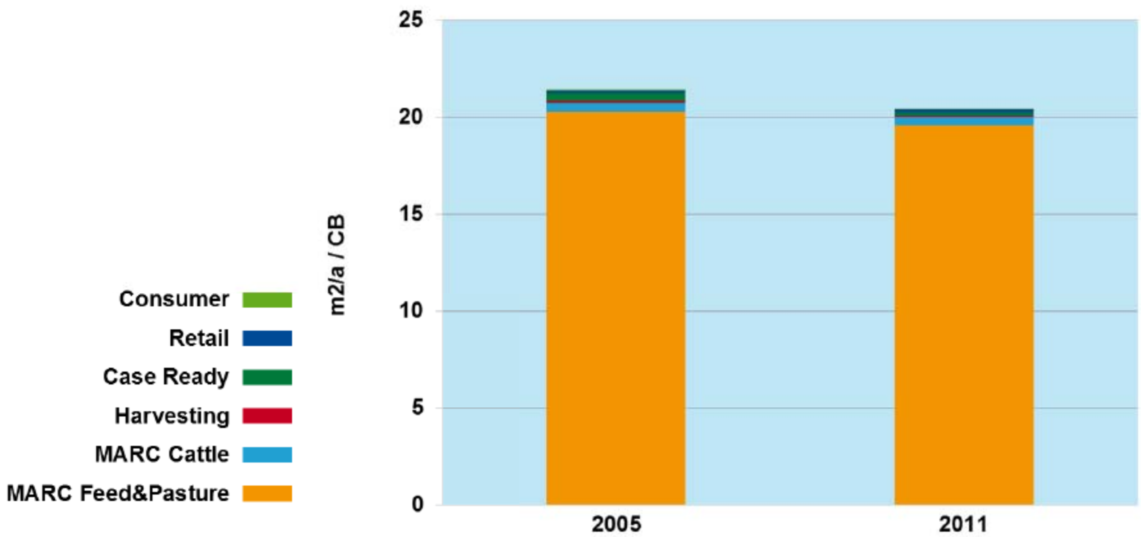

Figure 18: Land Use

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 19 shows how each module 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 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.

As shown below in Figure 19, the normalized and weighted toxicity potential remained essentially the same from 2005 to 2011. There were reductions in toxicity potential from increased use of recovered biogas from lagoons at harvesting facilities (requiring less purchased diesel), decreased LDPE (reducing pre-chain toxicity potential), and other energy efficiency improvements throughout the value chain that resulted in lower fossil energy use. However, these reductions were effectively neutralized due to the toxicity associated with increased ammonia releases from urine as a result of the use of WDGS in 2011 as well as some small toxicity contribution from the bioethanol distillation associated with the WDGS generation in the feed phase.

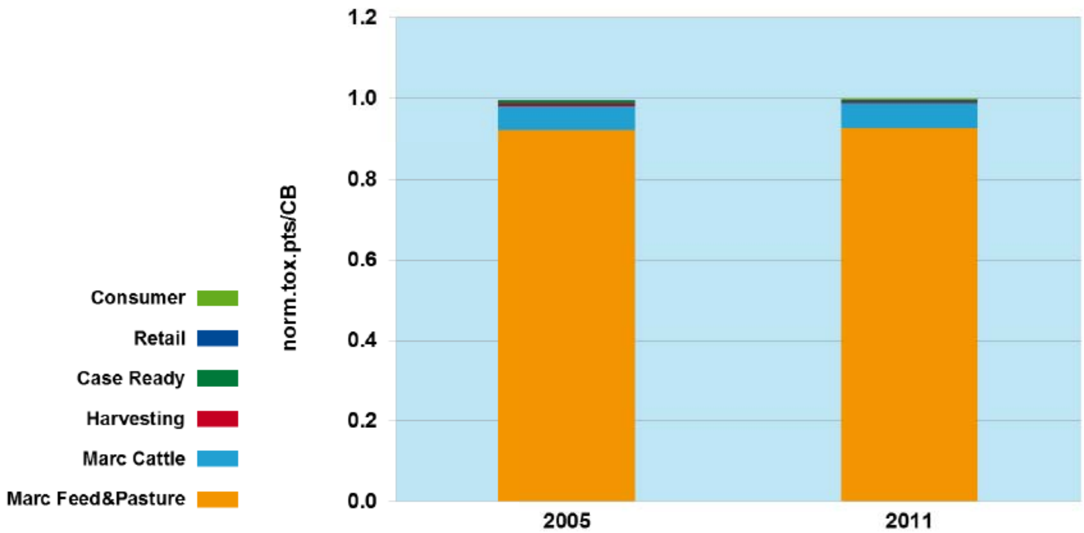

Figure 19: Toxicity Potential

8.1.9 Risk (Occupational Illnesses and Accidents potential)

All of the materials and activities in the various life cycle stages were assigned specific NACE codes[39]. 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 change over time in 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 at 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 48.4%, Fatal Accidents at 27.5%, and Non-fatal Accidents at 12.6% of total study risk.

As shown in Figure 20, total risk declined by 32% between 2005 and 2011. Outside of the additional risks analyzed according to expert analysis, the Occupational Illnesses and Accidents reductions are according to the BLS data for each alternative and are representative of the changes noted in each industry that was analyzed on a direct basis as well as a result of any pre-chain input reductions per CB that results in a corresponding decline in associated illnesses and accidents per CB. Some of these reductions can be attributed to the use of WDGS.

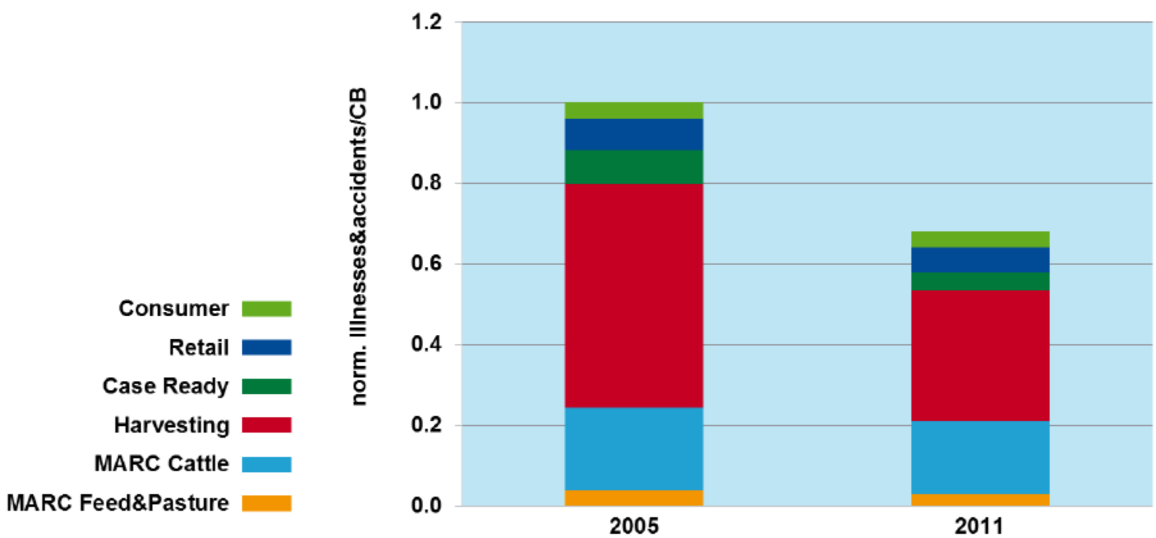

Figure 20: Risk Potential (Occupational Illnesses and Accidents)

8.1.10 Environmental Fingerprint

Following normalization or normalization and weighting according to the BASF EEA methodology, the relative impact for all seven of the main environmental categories for each alternative is shown in the environmental fingerprint in Figure 21. As discussed in each of the individual impact analyses above, there was at least a small decline in each of the seven main environmental impact categories and these are reflected in the environmental fingerprint. The largest category improvement is associated with Risk (Occupational Illnesses and Accidents) as shown below, which had a significant contribution to the overall environmental impact reduction of 7% for the beef value chain.

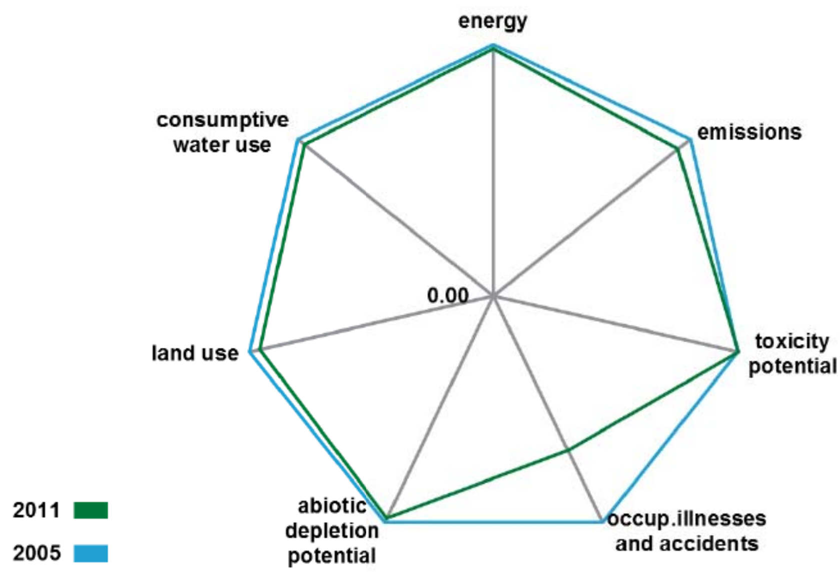

Figure 21: Environmental Fingerprint

8.2. Economic Cost Results

The life cycle cost data for the U.S. Beef EEA were generated as defined in Section 7 of the BASF EEA methodology and described in the overall study assumptions in Section 6 of this report. The results of the life cycle cost analysis based on a present value approach demonstrated an increase of 6% between 2005 and 2011 and are depicted in Figure 22. Again, the consumer prices used to reflect total cost/CB are not associated with USMARC operations but are intended to reflect general value chain cost/CB to the point of retail sale. To reflect current market conditions and pricing, 2005 pricing was adjusted to 2011 dollars.

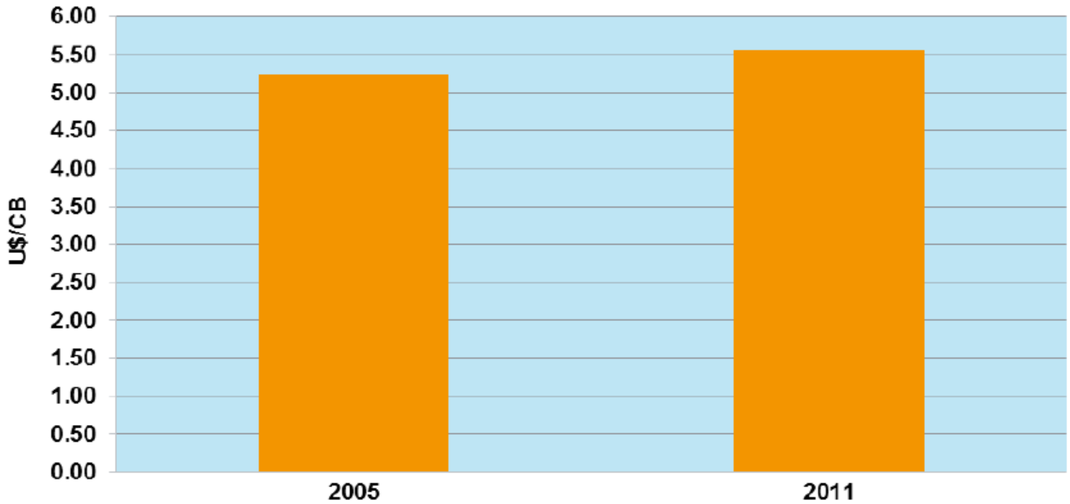

Figure 22: Life Cycle Costs

8.3 *Eco-efficiency Analysis Portfolio*

The eco-efficiency analysis portfolio for the U.S. Beef EEA was generated as defined in Section 9.5 of the BASF EEA methodology. Utilizing relevance and calculation factors, the relative importance of each of the individual environmental impact categories were used to determine and translate the fingerprint results to the position on the environmental axis for each alternative shown. For a clearer understanding of how weighting and normalization is determined and applied, please reference Section 8 of BASF's Part A submittal to P352. Specific to this study, the worksheets "Relevance" and "Evaluation" in the EEA model provided to NSF as part of this verification process should be consulted to see the specific values utilized and how they were applied to determine the appropriate calculation factors. Environmental relevance factors and social weighting factors for the USA (national average) were applied to this study. The environmental relevance values utilized were last reviewed in 2012 and the social weighting factors were recently updated in 2011 by an external, qualified third party organization[40].

Figure 23 displays the eco-efficiency portfolio for the base case analysis and shows the 2011 U.S. beef value chain to be more eco-efficient than that in 2005. While there was an increase in price of beef of 6% between 2005 and 2011, there was a simultaneous decrease in the overall environmental impacts from the U.S. beef value chain of approximately 7%. Following weighting and normalization per above, the EEA portfolio below results in a 5% improvement in overall eco-efficiency.

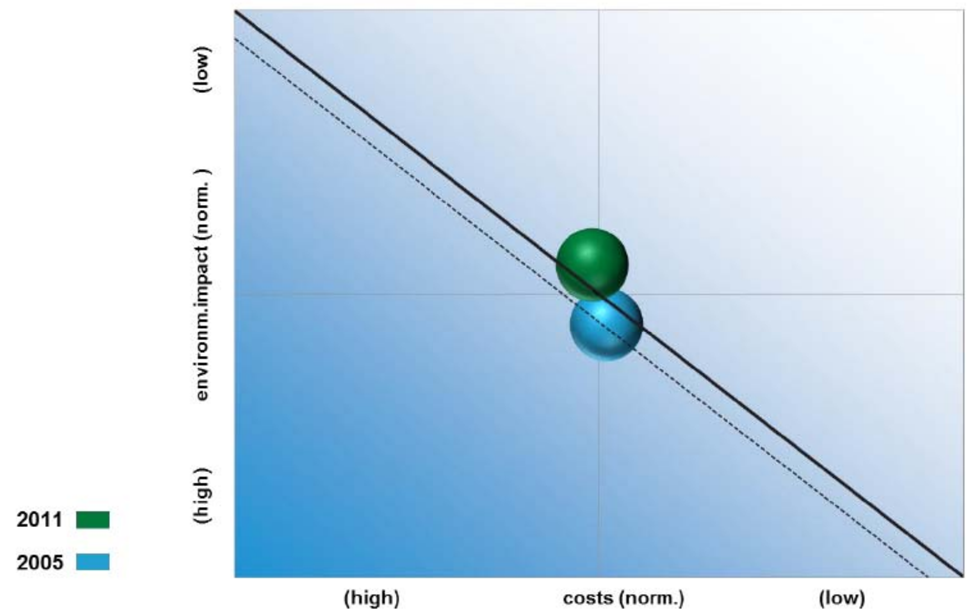

Figure 23: Eco-efficiency Portfolio: U.S. Beef – Phase 1

9. Scenario #1: 1970 On-Farm Scenario

9.1 General Discussion

As stated above, an assessment was performed for 1970 for the feed and cattle (or on-farm) phases of the study using the available IFSM data. While the original intent of this study was to perform an EEA analysis of three alternatives (1970, 2005, and 2011) for the entire beef value chain, due to the lack of available data for post-farm phases, this was not possible. However, the following discussion demonstrates some of the changes over time that have occurred between 1970 and the 2005 and 2011 alternatives for the on-farm phases as analyzed at USMARC. This detail provides the potential for assessing what changes have taken place on the feed and cattle phases since 1970 and demonstrates further opportunities for learning best practices that have taken place over a longer period of time in these areas.

This is particularly important since for six of the seven high-level impact categories (and correspondingly all six of the environmental impact categories), either the feed or cattle phase was the major contributor. The only impact category that did not have most of the impact from the feed or cattle phase was the Risk category. Additionally, all of the sub-environmental (emissions) categories except ODP had the majority of the impact from the feed or cattle phase. Therefore, while all phases play an integral role in improving the sustainability attributes of the U.S. beef value chain, the largest potential opportunities clearly lie within the feed and cattle phase.

Understanding what has changed since 1970 can provide great insight for future management improvement opportunities within these key phases of the beef value chain.

While as with the entire base case analysis, there are smaller trends or changes to understand in greater detail, the following are selected impacts that show a significant or important trend to highlight.

9.2 Cumulative Energy Demand

As shown below in Figure 24, there was a 9% increase in energy use from 408 MJ/CB in 1970 to 447 MJ/CB in 2005 (or 8% from 1970 to 2011 with a value of 444 MJ/CB). This increase demonstrates a classic water-energy (and GWP) nexus and is mainly due to increased irrigation of the pasture and the associated energy necessary to power the water pumps for the pivot irrigation systems. Irrigation was less frequently used in 1970 and it was used only for the corn produced at USMARC. As shown in the base case scenario, the majority of the energy used is associated with the gross energy of the feed. In this scenario here, feed gross energy is 93% of the CED in 1970 for the feed and cattle phases. The remaining CED is mainly associated with irrigation, transportation, and pre-chain energy consumption.

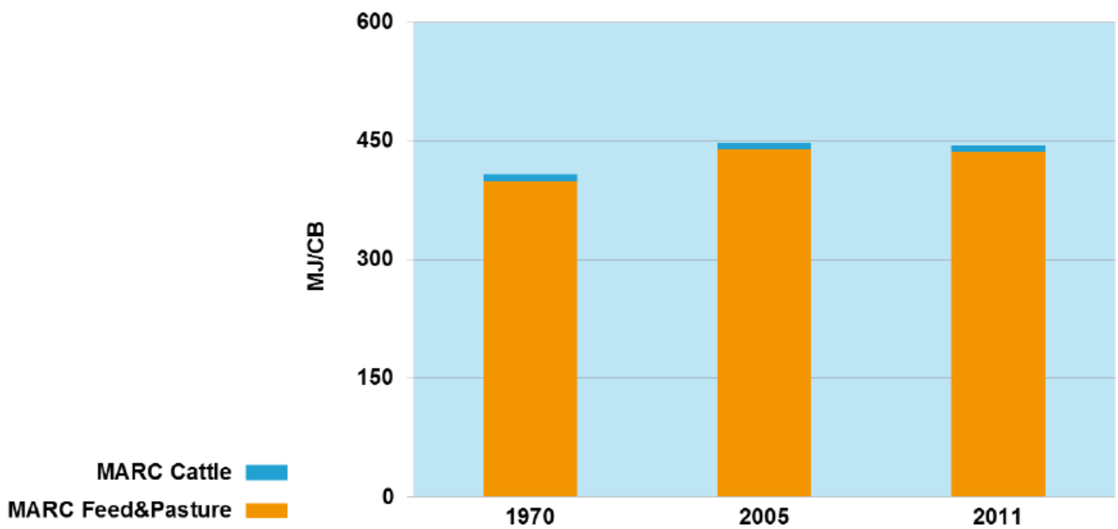

Figure 24: Cumulative Energy Demand for 1970 On-Farm Scenario

9.3 Consumptive Water Use

As can be seen below in Figure 25 (assessed consumptive water use) and Figure 26 (absolute consumptive water use), there was a 29% increase in consumptive water between 1970 with a value of 56,194 L-eq/CB or 1,681 L/CB absolute and 2005 with a value of 79,529 L-eq/CB or 2,380 L/CB absolute (or 27% from between 1970 and 2011 with a value of 76,917 L-eq/CB or 2,302 L/CB absolute). As mentioned above with the CED trend, there was a significant increase in irrigation water from 1970 to 2005 because some of the pasture is now irrigated at USMARC and more irrigated corn is produced. As with CED, the large increase in consumptive water negated some gains in efficiency that were noted on the cattle phase due to utility efficiency improvements.

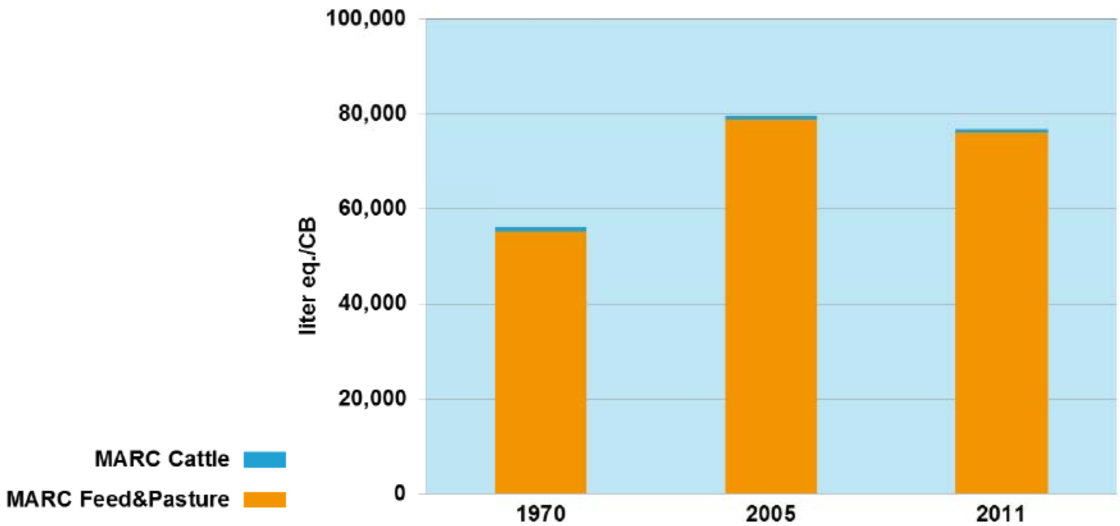

Figure 25: Assessed Consumptive Water Use for 1970 On-Farm Scenario

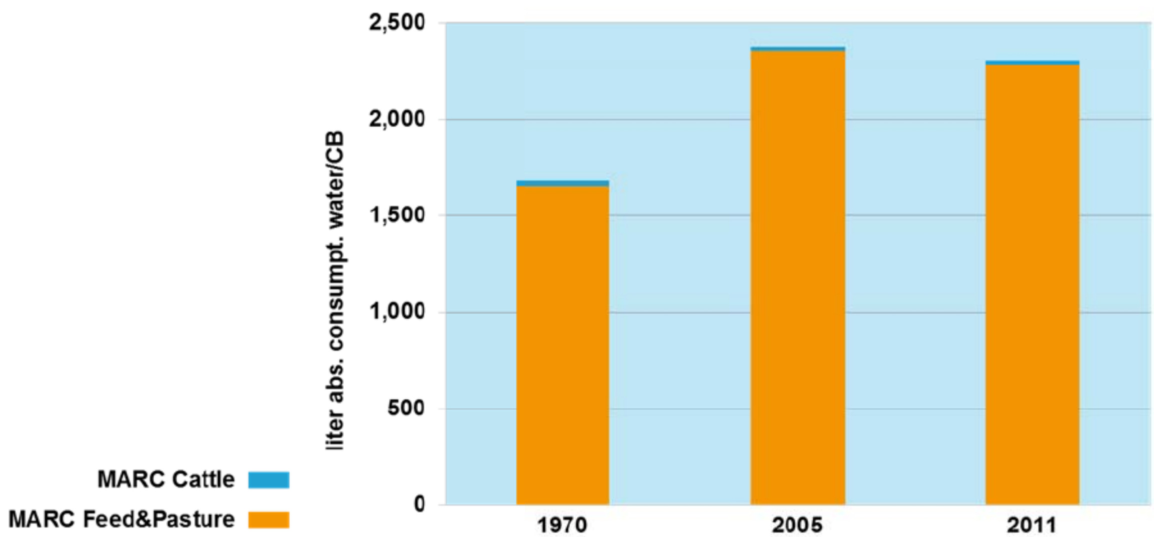

Figure 26: Absolute Consumptive Water Use for 1970 On-Farm Scenario

9.4 Global Warming Potential

As can be seen below in Figure 27, there was a 5% decrease in GWP from 19.6 to 18.6 kg CO_2-eq/CB between 1970 and 2005 (and essentially the same 5% from 1970 to 2011 with negligible change between 2005 and 2011 with a 2011 value of 18.7 kg CO_2-eq/CB). This decline was mainly attributed to the fact that the cattle were fed a higher forage diet in 1970 that produced higher enteric methane. Additionally, a small decline was also attributed to increased crop yields on the feed phase (less direct field N_2O emissions as well as reduced pre-chain emissions from reduced chemical input per unit of feed). At the same time, the increased use of irrigation added some GWP on the feed phase (corresponding with increased energy use in pumping). However, the increased crop yields still led to an overall reduction in GWP in the feed phase.

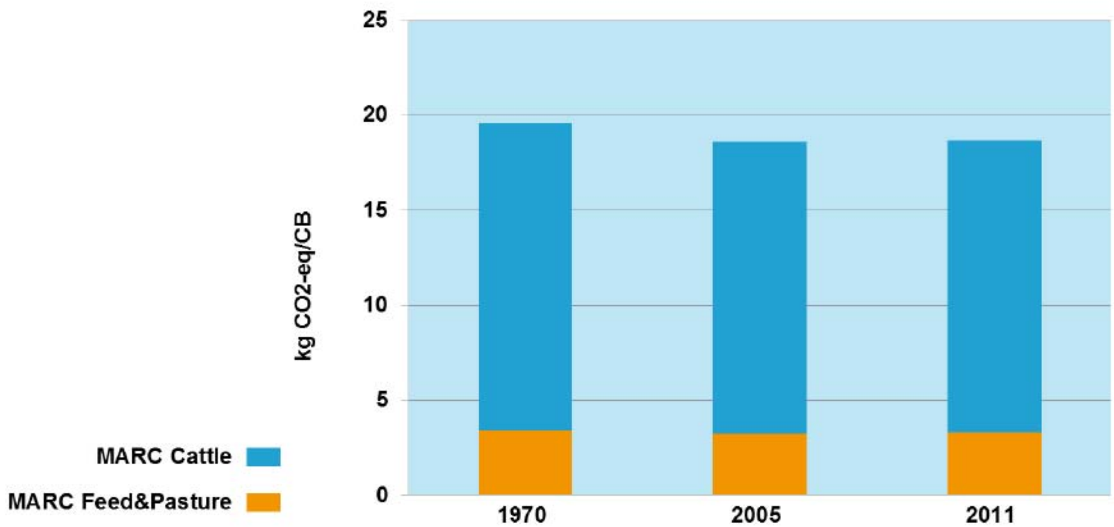

Figure 27: Global Warming Potential for 1970 On-Farm Scenario

9.5 Acidification Potential

As shown below in Figure 28, there was a 31% decline in AP from 458 to 315 g SO_2-eq/CB between 1970 and 2005 (and 33% from 1970 to 2011 with a value of 308 g SO_2-eq). This large decline was mainly a result of increased crop yields that allowed for reduced fertilizer inputs in the feed phase. Utilities and transportation efficiency improvements also led to some smaller reductions in AP on the farm system.

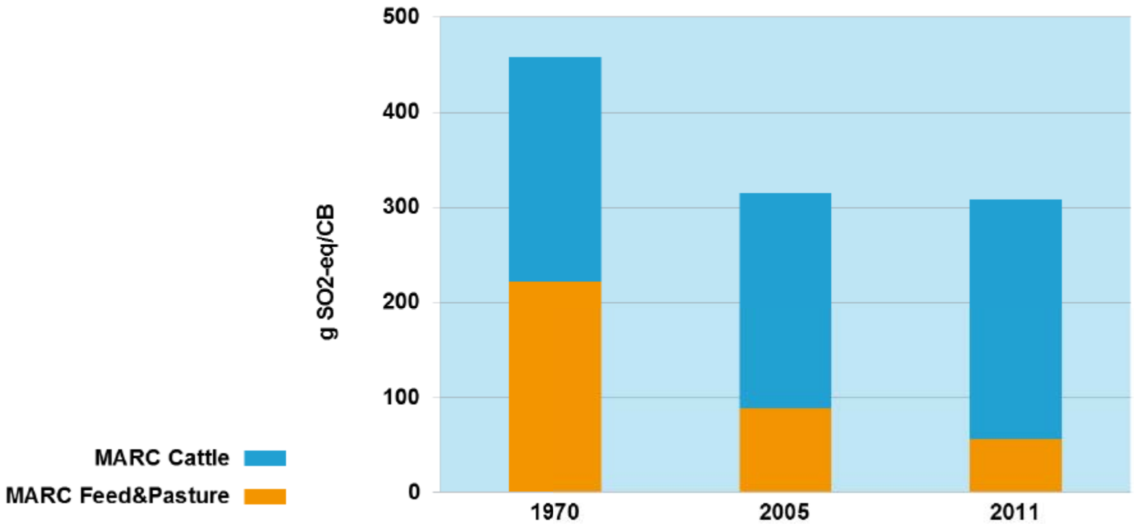

Figure 28: Acidification Potential for 1970 On-Farm Scenario

9.6 Water Emissions

As shown below in Figure 29, there was a 5% reduction in water emissions from 4,245 to 4,050 L grey water-eq/CB between 1970 and 2005 (9% from 1970 to 2011 with a value of 3,860 L grey water-eq/CB) and this was again mainly as a result of increased crop yields (less direct water emissions from crop inputs per unit of land).

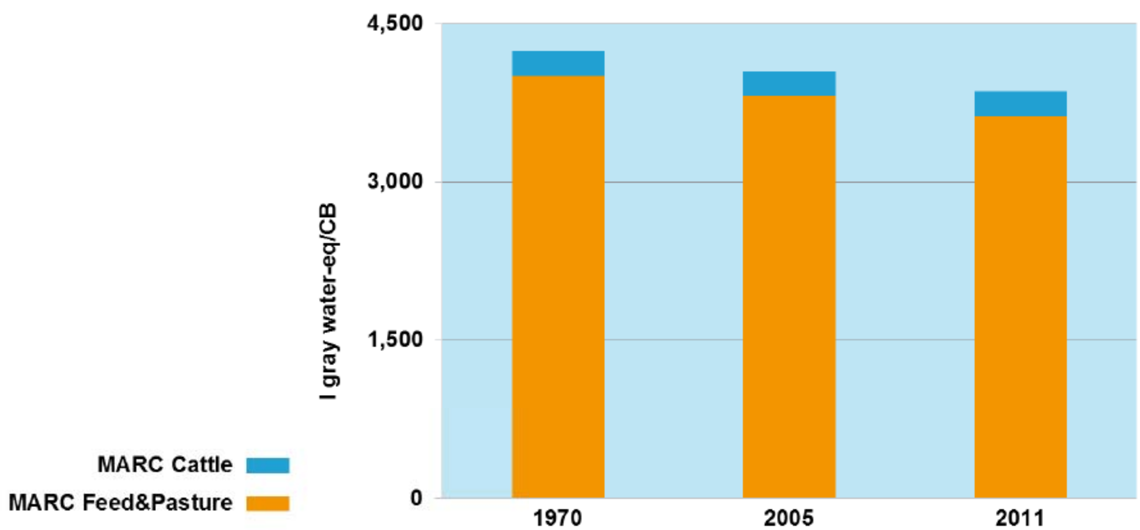

Figure 29: Water Emissions for 1970 On-Farm Scenario

9.7 Land Use

As shown below in Figure 30, there was a 7% reduction in land use from 22.3 to 20.7 m^2-years/CB between 1970 and 2005 (10% from 1970 to 2011 with a value of 20.0 m^2-years/CB). This was again mainly a result of increased crop yields on the feed phase.

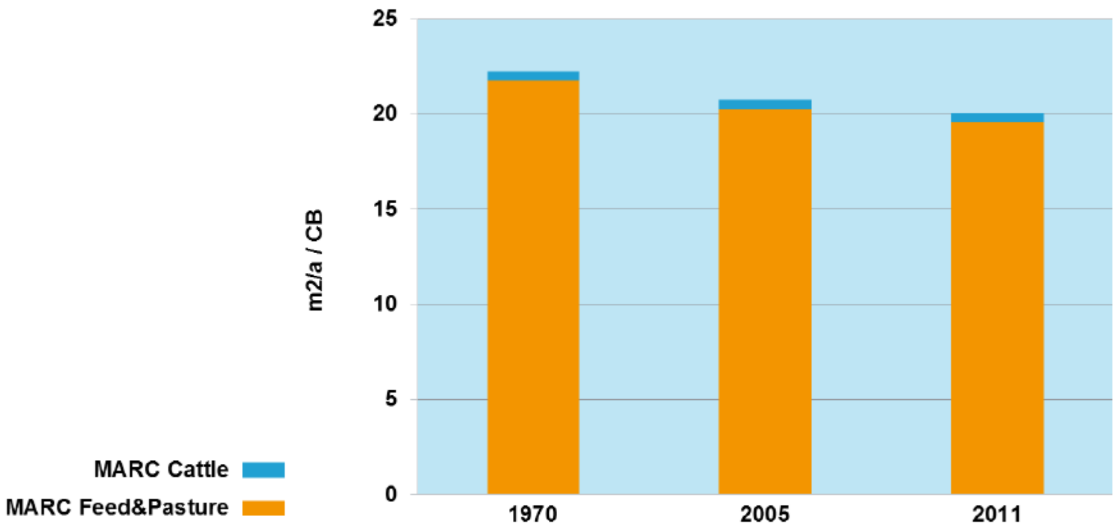

Figure 30: Land Use for 1970 On-Farm Scenario

9.8 Environmental Fingerprint

As can be seen below in Figure 31, the on-farm Environmental Fingerprint shows declines in all of the main impact categories since 1970 with the exceptions of energy and consumptive water use as discussed above. A 10% reduction in environmental impact is noted on this cradle to farm-gate scenario analysis from 1970 to 2005 and a 12% reduction from 1970 to 2011.

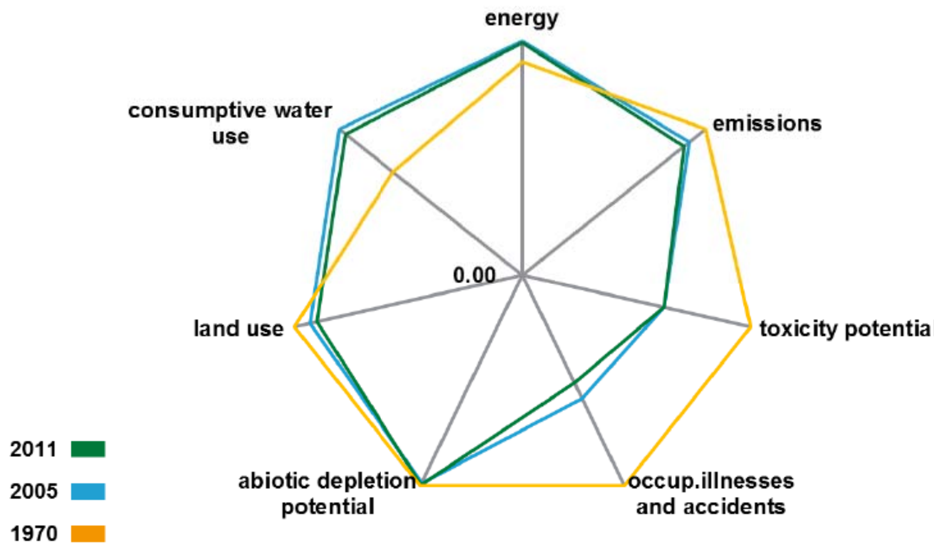

Figure 31: Environmental Fingerprint for 1970 On-Farm Scenario

9.9 Eco-Efficiency Analysis Portfolio

Figure 32 below shows the EEA Portfolio with the on-farm scenario, which shows a clear improvement in the environmental portfolio overall, while at the same time there has been a small reduction in operational costs.

Note that the costs considered to analyze the economic portion of the EEA portfolio were total operational costs related to the feed and cattle phases as opposed to consumer price of beef that was used for the base case analysis of the full beef value chain. There was a 5% decrease in operational costs from 1970 to 2005 and a 6% decrease from 1970 to 2011. At the same time, as noted above, there was a 10% reduction in environmental impact from 1970 to 2005 and a 12% reduction from 1970 to 2011. Following weighting and normalization, the EEA portfolio below shows approximately a 14% improvement in overall eco-efficiency from 1970 to 2011. The EEA portfolio for the periods of 2005 and 2011 show similar eco-efficiency attributes because the two alternative periods are within less than 5% of one another.

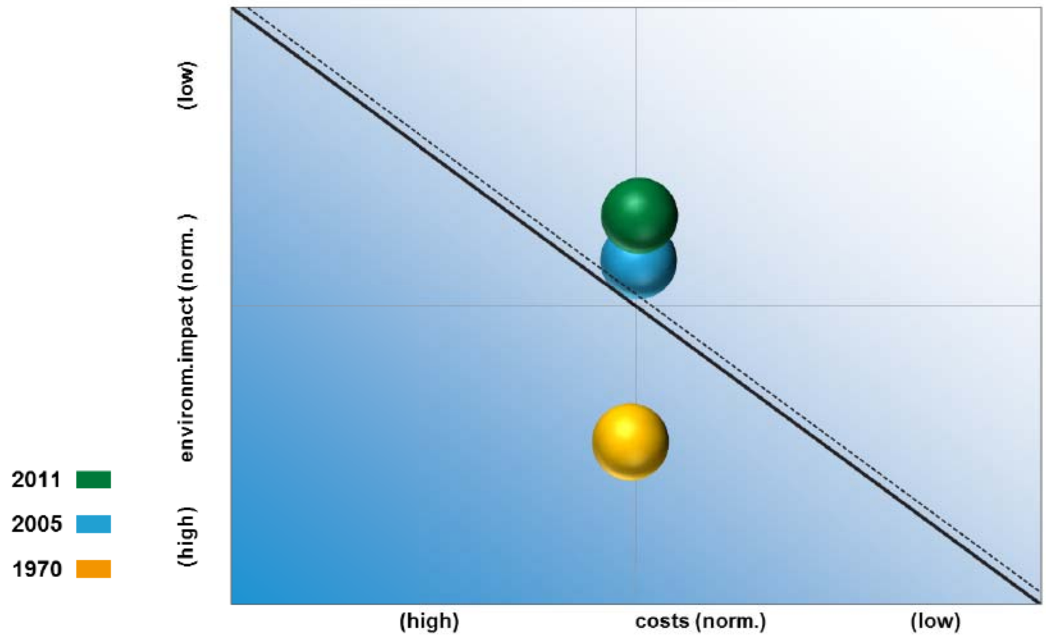

Figure 32: EEA Portfolio for 1970 On-Farm Scenario

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 8 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 quality for the EEA.

Phase	Quality Statement	Comments
Feed	High - Medium	Mainly IFSM data of high quality for 2005 and 2011. Data for 1970 contains more assumptions as all practices on farm have not been fully documented nor known.
Cattle	High-Medium	Mainly IFSM data of high quality for 2005 and 2011. Data for 1970 contains more assumptions as all practices on farm have not been fully documented nor known.
Harvesting	High	Primary data from harvesters whose facilities represent 60% of the industry.
Case-Ready	High-Medium	While the data was primary, the data source was only from one of the harvesting facilities that also had case-ready data.
Retail	Medium	None of the retail data was primary data but based off of industry averages from literature and industry reports.
Consumer	Medium	None of the consumer data was primary data but was based off of averages from literature and industry reports.

Table 9: Data Quality Evaluation for EEA Parameters

11. Sensitivity and Uncertainty Analysis

11.1 Sensitivity and Uncertainty Considerations

A sensitivity analysis of the final results indicates that the environmental impacts were more influential or relevant in determining the final relative eco-efficiency positions of the alternatives. This conclusion is supported by reviewing the BIP Relevance (or GDP-Relevance) factor calculated for the study. The BIP Relevance indicates for each individual study whether the environmental impacts or the economic impacts were more influential in determining the final results of the study. For this study, the BIP Relevance indicated that the environmental impacts were more influential in impacting the results than the economic impacts (reference the "Evaluation" worksheet in the Excel model for the BIP Relevance calculation).

As the data quality related to these main contributors of the environmental impacts was of at least moderate-high quality, this strengthened our confidence in the final conclusions indicated by the study. As expected from a study with large influence from agriculture, the impact categories with highest environmental relevance were water emissions, acidification potential, consumptive water use, and land use. The AP factor also had environmental relevance related to cattle emissions (manure and urine) as did GWP from enteric methane emissions.

The calculation factors shown in Figure 33, which considers both the social weighting factors and the environmental relevance factors, indicate which environmental impact categories had the largest effect on the final outcome. Calculation factors were utilized in converting the environmental fingerprint results (Figure 20) into the final, single environmental score as reflected in our portfolio (Figure 22). The input parameters that were related to these impact categories have sufficient data quality to support a conclusion that this study has a low uncertainty.

The social weighting factors did have an influence in shifting the relative weightings of a few impact categories represented in the emissions and air emissions sub-categories. While the environmental and societal impacts of consumptive water use, land use, and water emissions remained high along with toxicity potential and risk, lower societal relevance for AP and GWP caused a decrease in their respective weighting.

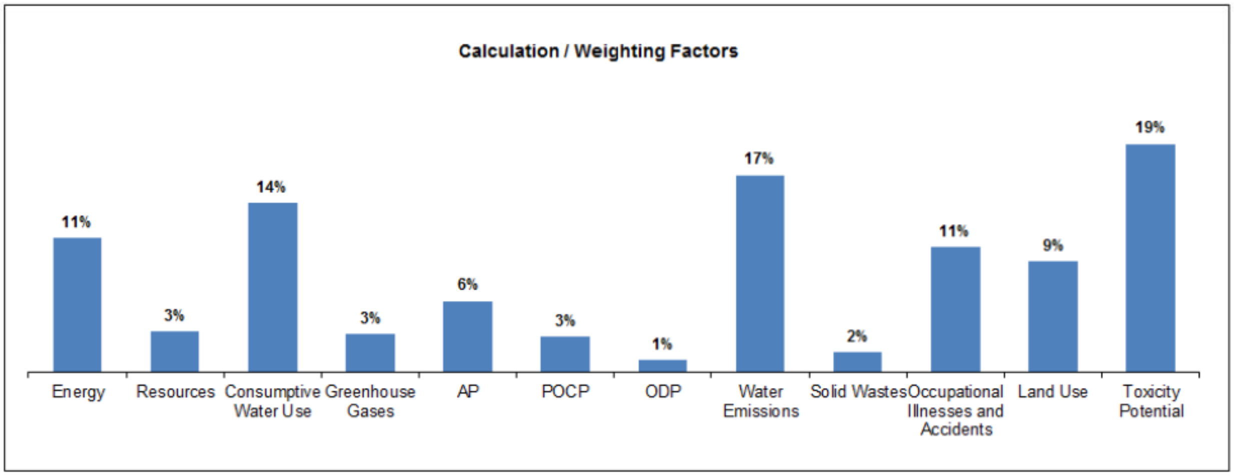

Figure 33: Calculation Factors Used in the Sensitivity and Uncertainty Analyses

11.2 Critical Uncertainties

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.

11.3 Sensitivity Analyses

11.3.1 Scenario #2: 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[41] (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 34 below demonstrates a near 3% increase in total value chain GWP as opposed to a 1% decrease on the economic allocation base case analysis. At the same time, Figure 35 shows a 25% increase in total value chain water emissions as opposed to an 11% decrease on the economic allocation base case analysis. Finally, the environmental fingerprint in Figure 36 shows significant movement in the opposite direction on total emissions, land use, toxicity potential, and resource consumption.

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.

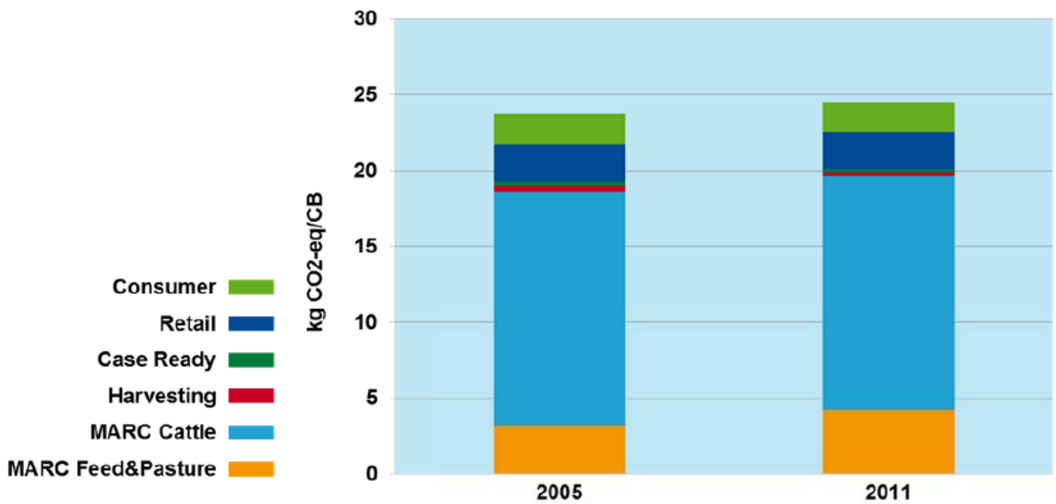

Figure 34: GWP for WDGS Mass Allocation Scenario

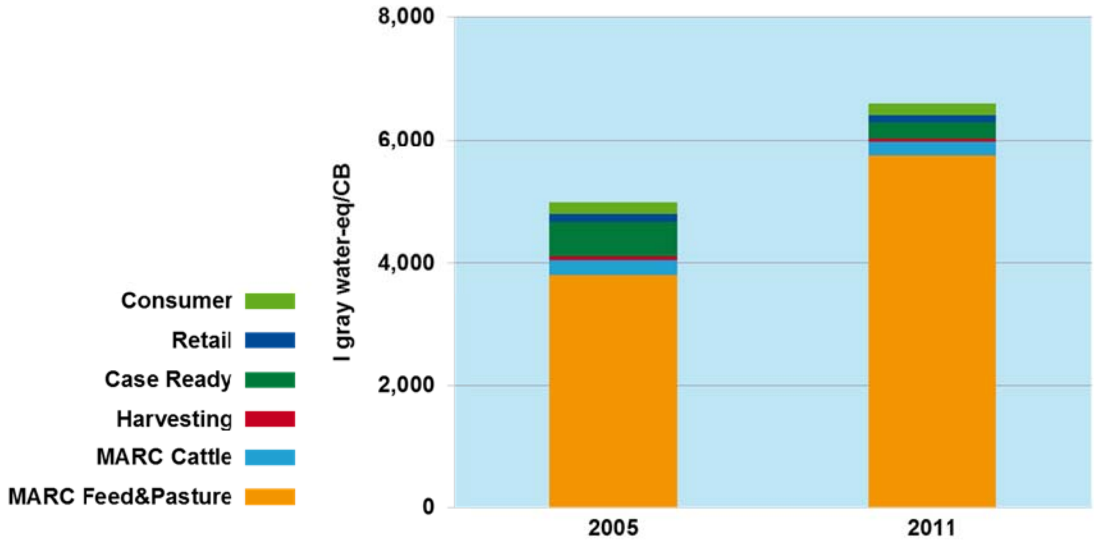

Figure 35: Water Emissions for WDGS Mass Allocation Scenario

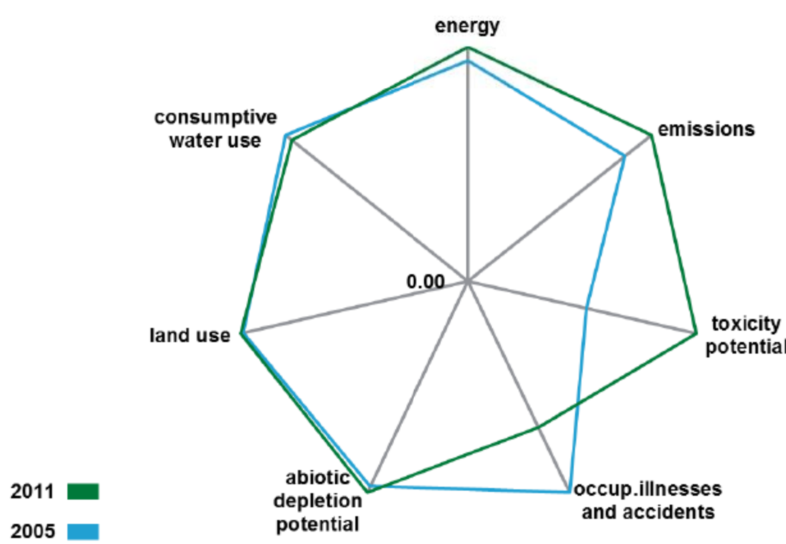

Figure 36: Environmental Fingerprint for WDGS Mass Allocation Scenario

11.3.2 Scenario #3: 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.[42] 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.

11.3.3 Scenario #4: Economic Allocation for Retail and Consumer Refrigeration and Retail Refrigerant Leakage

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

As expected, the results of using an economic allocation of the retail and consumer phase refrigeration and the retail refrigerant leakage resulted in noticeable changes in environmental impacts. For example, Figure 37 below demonstrates a near 6% increase in total value chain CED as compared to the volumetric allocation base case analysis. At the same time, Figure 38 shows a 20% increase in total value chain GWP compared to the volumetric allocation base case analysis (mainly as a result of the increased GWP of the refrigerant leakage). As can be seen in the environmental fingerprint in Figure 39 for the economic allocation scenario, there was little change in total environmental impact. The largest change with this alternate allocation method was on GWP. However, GWP is only weighted 3% of total beef value chain environmental impacts and this is the reason for little overall movement on the larger picture.

While there are significant differences between the economic and volumetric allocation for retail and 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 a physical allocation metric was not reasonably possible or logical for the other impacts analyzed for the retail and consumer phases, the economic allocation was used since this was the only alternative available.

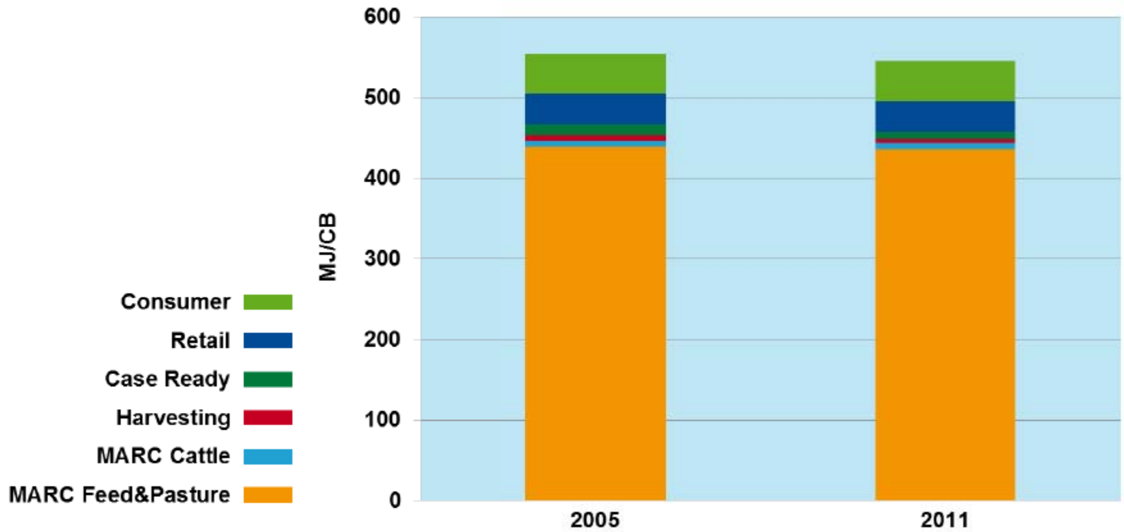

Figure 37: CED for Retail and Consumer Economic Allocation Scenario

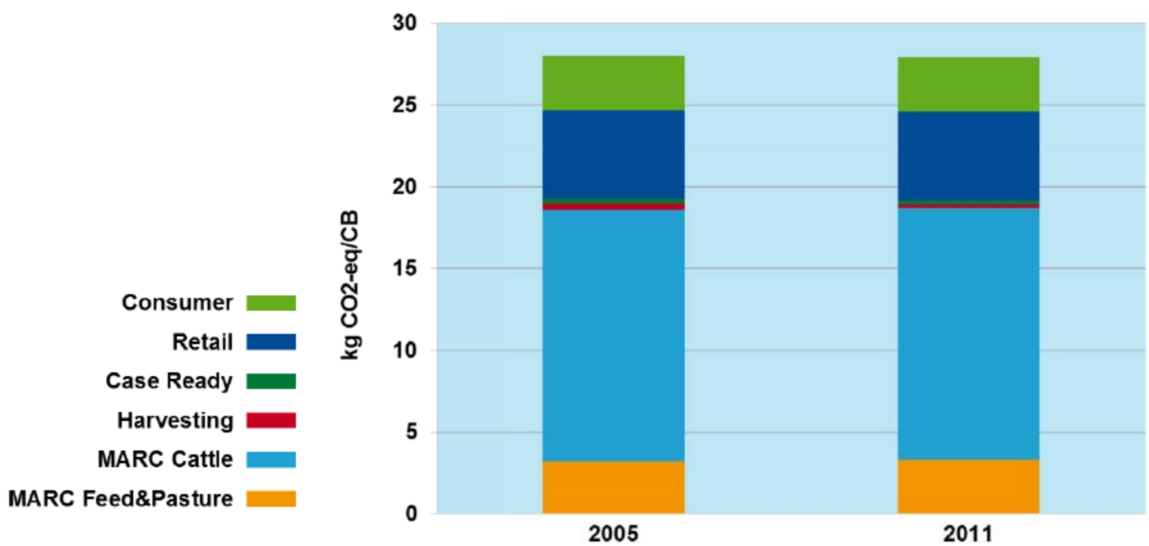

Figure 38: GWP for Retail and Consumer Economic Allocation Scenario

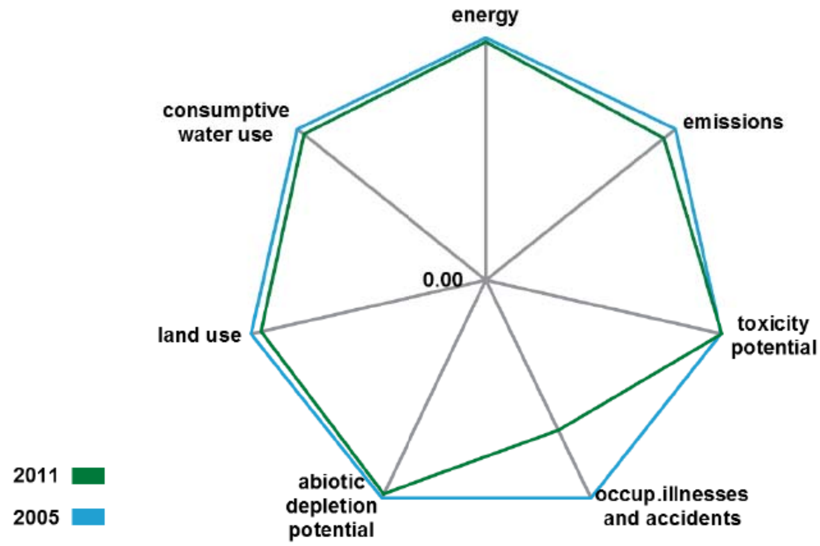

Figure 39: Environmental Fingerprint for Retail and Consumer Economic Allocation Scenario

12. Conclusions

As presented in the eco-efficiency portfolio analysis, there has been a 5% improvement in the eco-efficiency of the U.S. beef industry between 2005 and 2011 as represented by the system boundary of this study. This correlates to a 6% increase in cost (based on consumer retail price) and a 7% decrease in environmental impact (as represented by the environmental fingerprint analysis) over that same timeframe.

While environmental impacts stem from all phases of the beef value chain as represented throughout the study analysis, the majority of the impacts are attributed to on-farm processes in the feed and cattle phases. Many of the impact reductions that have been made through the feed and cattle phases relate directly to the improvement in yield of feed crops, leading to less system inputs being required per unit of land in order to achieve the same desired output of edible beef.

The main reason that 2005 was selected to be analyzed as an alternative period was because 2005 was the last year that WDGS was not widely used as a feed source. As a result of using WDGS (with associated allocation) in place of corn and urea in 2011, there were improvements from 2005 in consumptive water, water emissions, AP, land use, and risk (Occupational Illnesses and Accidents). WDGS is also a more cost effective feed, which has a contribution to reducing on-farm operational costs. At the same time, the use of WDGS in 2011 caused increases in impacts associated with energy, GWP, ADP, and ODP. However, in general, it appears that the overall eco-efficiency of the beef value chain is improved to at least a small extent with the use of the WDGS. Additionally, using WDGS as a feed source provides a beneficial use of a by-product of bioethanol processing, thus providing additional environmental benefit outside of the beef value chain.

The impacts associated with the post-farm phases of harvesting, case-ready, retail, and consumer, while generally contributing less overall value chain impacts, present significant opportunities for improvement. Additionally, these opportunities generally may be more straightforward in terms of implementation as seen in this study with examples such as biogas capture and recovery at the harvesting facilities, packaging optimizations, and energy efficiency opportunities throughout. These eco-efficiency analysis results provide the roadmap to identify and prioritize opportunities and to allow better understanding of the specific practices that can be used to further reduce the environmental impacts of the beef value chain, while maintaining the overall economic value proposition.

As made clear already, one must realize that there can be significant regional impact differences in the industry, especially related to the feed and cattle phases. Additionally, specific changes in eco-efficiency noted in this study may not be fully representative of the industry as a whole. For example, while the data used from the harvesting facilities comes from companies whose operations represent 60% of the industry, it is not known with a high level of certainty if some of the opportunities such as biogas recovery, which resulted in notable impact reductions throughout the harvesting phase, are fully indicative of the entire industry. Future research is already underway to better understand some of these 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 provide future communications as data refinement continues to be made.

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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