ISO-CONFORMANT REPORT

COMPARATIVE GHG EMISSIONS ASSESSMENT OF PERFECT DAY WHEY PROTEIN PRODUCTION TO DAIRY PROTEIN

PERFECT DAY, INC.

VERSION 1

WSP
851 SW 6TH STREET
SUITE 1600
PORTLAND, OR 97214 USA
PHONE: +1 503 478 2820
WSP

FEBRUARY 09, 2021

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EXECUTIVE SUMMARY

Perfect Day, Inc. is at the forefront of non-animal-based whey protein technology with a novel production pathway that is both efficient and scalable. The company commissioned this study to determine the total greenhouse gas (GHG) emissions from the life cycle of the company's specific production system and to compare these emissions to those of other dairy proteins. The total GHG emissions were compared; the differences between the Perfect Day product and two other products were also calculated and presented. The Life Cycle Assessment (LCA) method was used to aid Perfect Day in identifying GHG emissions impact hotspots in its whey protein production. This analysis evaluated the Global Warming Potential (GWP) of Perfect Day's non-animal-based whey protein as compared to the emissions from the following bovine dairy proteins and the total amount of protein found in cow's milk, hereafter referred to as "total lactated protein":

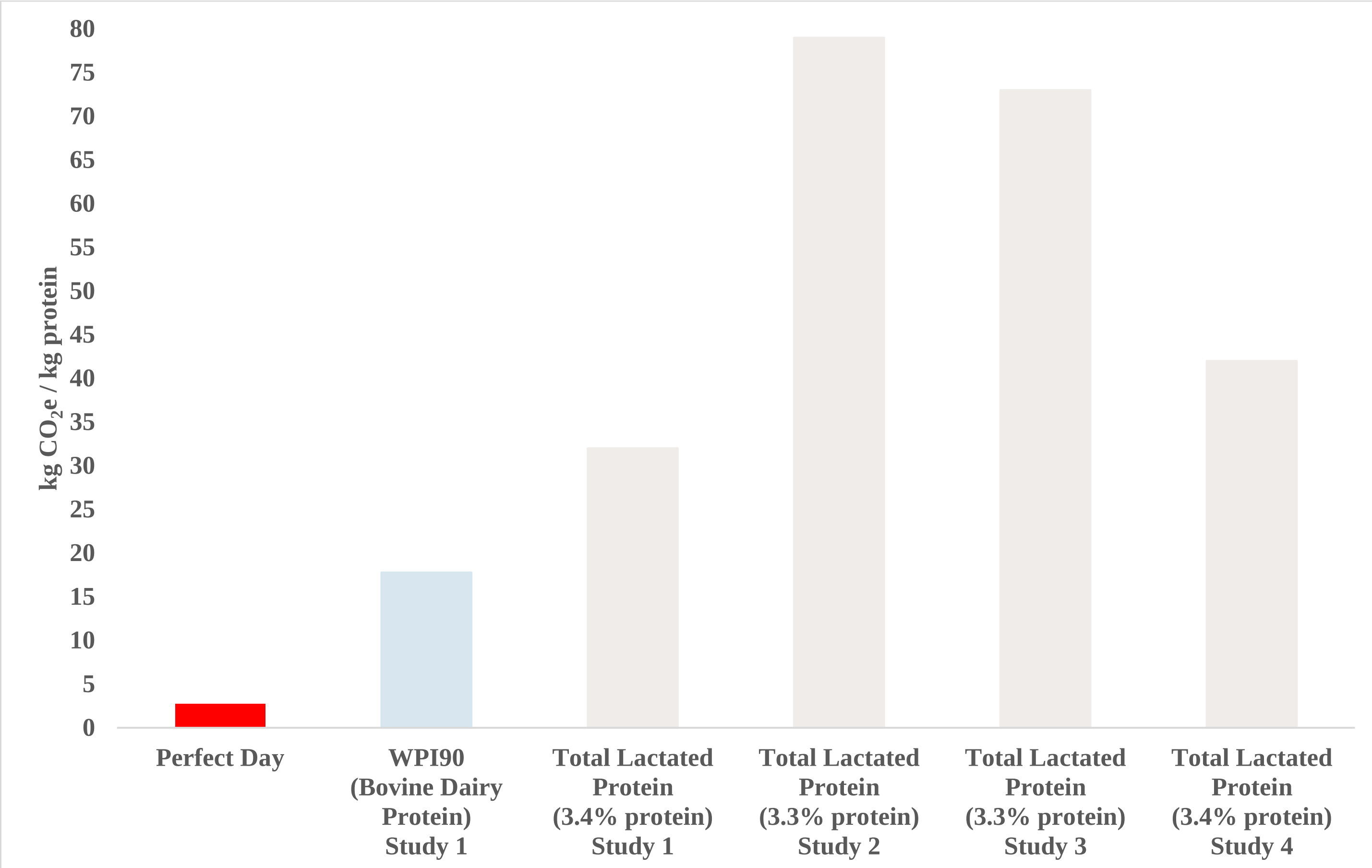
- Bovine dairy protein WPI90 with 90% protein concentration (WPC90/WPI)
- Two examples of total lactated proteins with 3.3% protein content and two lactated proteins with 3.4% protein content from four different studies. Four proteins from four studies were chosen to show the range of potential results based on these different studies.

The GWP category was evaluated to determine the potential GHG emissions impacts of all products considered in this study because this information will provide the most business value to Perfect Day in its discussions with existing and potential customers and stakeholders. Internal communication of the results of this study will aid in decision-making for product process improvement and provide information to the company's stakeholders who are interested in the GHG emissions impacts associated with producing Perfect Day whey protein. The function of the product is to be a provider of protein; therefore, the functional unit of the product is a measure of this nutritional aspect: one kilogram (kg) of protein in the product.

Since the company intends to communicate results externally, the study was critically reviewed by a three-person panel of independent experts in conformance with ISO Standard 14067 on GHG emissions. The reviewers' findings are summarized in the verification statement at the end of this report. The GWP was assessed using the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5) 100-year timescale excluding biogenic carbon method. Excluding biogenic carbon was chosen to quantify the GHG emissions from fossil sources. Whereas biogenic carbon is part of the natural cycle, fossil-derived carbon releases locked-up carbon to the atmosphere. Moreover, this study is from cradle to gate and will not quantify the fate of carbon contained in the products that originated from biological, rather than fossil, sources.

Perfect Day recognizes that the environmental impacts from different proteins depend greatly on the specifics of the material inputs, production method, location, and transportation of the inputs. Therefore, the analysis was conducted from cradle-to-gate to include the upstream production of the materials and materials used for the Perfect Day process, production of all other inputs to the process (e.g., natural gas and electricity), and transportation of materials to the Perfect Day production facility. Perfect Day whey protein production also yields a solid biomass co-product that can be sold as an ingredient in high-value domesticated animal pet food; therefore, mass allocation was applied to apportion GHG emissions between the primary and co-product.

The primary findings of this study are illustrated in ES-Figure 1 and show that Perfect Day whey protein reduces GHG emissions compared to all bovine dairy proteins considered. The Perfect Day whey protein is 85% to 97% lower in GHG emissions than the comparative proteins. The primary driver of GHG emissions for Perfect Day whey protein is the utilities which contribute 40% to total GHG emissions. Utilities include the US average natural gas and electricity used in the protein production process. Following utilities, the protein development phase contributes 25% to total GHG emissions.



ES-Figure 1: GHG emissions from Perfect Day whey protein compared to WPI90 and total lactated proteins. The Perfect Day whey protein impacts are modeled. The data for WPI90 and total lactated proteins were obtained from four different studies (details in Appendix C).

The application of the results, interpretation, and conclusions of this study are limited to the proteins considered in this study. Furthermore, the results calculated for Perfect Day whey protein are limited to its unique technology and cannot be extrapolated or applied to the production of non-animal-based dairy protein by other means.

Allocation by mass apportions GHG emissions between the Perfect Day whey protein and the co-product for high-quality pet food by a significant margin (between an 85% and 97% GHG emissions reduction compared to comparative bovine proteins). Mass allocation is preferred over economic allocation since the economic value of the co-product is unknown. It is not known what other protein sources in pet food the co-product would potentially displace, therefore, system expansion to avoid allocation cannot be conducted. Therefore, a sensitivity analysis evaluated whether the Perfect Day whey protein would still reduce GHG emissions compared to comparative bovine products without this allocation by using the conservative assumption that the co-product would become a waste product, eliminating the allocation of GHG emissions between the two products, but instead allocating all of the GHG emissions from production to the Perfect Day whey protein. The results of this sensitivity analysis demonstrated that there would still be at least a 31% reduction in GHG emissions from Perfect Day whey protein relative to the comparative bovine protein products, without any allocation by mass.

According to the Food and Agriculture Organization of the United Nations, the United States produces 97,787,000 tonnes of milk, excluding butter[1]. Assuming a 3.3% protein content, and depending on the animal protein compared, this results in 57 to 255 million tonnes of CO_2e emissions based on the GHG emissions resulting from the comparative bovine dairy proteins. If US consumers switched entirely to Perfect Day whey protein, this would result in avoiding 48 to 246 million tonnes of CO_2e emissions, which is equivalent to 5 to 28 million homes' energy use for one year or 10 to 53 million passenger vehicles driven for one year according to the US EPA Greenhouse Gas Equivalencies Calculator[2].

[1] http://www.fao.org/faostat/en/#data/FBS
[2] All values assume US average passenger vehicle and US homes. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

ASSESSMENT SUMMARY

Cradle-To-Grave Comparative GHG Assessment	
Comparative GHG assessment of Perfect Day whey protein to dairy proteins	
Parameter	**Description**
Company Name and Contact Information	Study Commissioner: Perfect Day, Inc. 813 Heinz Avenue Berkeley, CA 94710 Contacts: Ryan Pandya ryan@perfectdayfoods.com Perumal Gandhi perumal@perfectdayfoods.com Angela Braren angela.braren@perfectdayfoods.com Study Practitioners: WSP USA Julie Sinistore julie.sinistore@wsp.com Jessica Lab jessica.lab@wsp.com Mukunth Natarajan Mukunth.Natarajan@wsp.com Zoey Kriete Zoey.Kriete@wsp.com
Standard Used	ISO 14067: Greenhouse gases – Carbon footprint of products – Requirements and guidelines for communication and quantification
Product Names	The products under study are Perfect Day whey protein from non-bovine sources, and the comparative proteins WPI90 and total lactated milk protein from bovine sources.
Product Descriptions	The Perfect Day product is non-animal-based whey protein. The comparative proteins are bovine dairy proteins WPI90 with 90% protein concentration and 4 total lactated proteins (with 3.3% protein and 3.4% protein concentrations).
Functional Unit (Study Basis)	The function of the product is to be a provider of protein; therefore, the functional unit of the product is a measure of nutrition: the kg of protein in the product.
Temporal Boundary	Production yield and energy consumption data were collected from Perfect Day's operations based on daily data from 2020. Secondary data from GaBi® databases have a validity range between 2009 and 2021. The time period in which the results should be considered valid is five years from publication date of this study.
Country/Region of Product Consumption	Primary data from Perfect Day is based on a co-manufacturing site in the United States; this product will primarily be consumed in the United States. Therefore, the geographic boundary is the United States.
Version and Date of Issue	Version 1 2/9/2021

1 GOAL OF THE STUDY

Perfect Day, Inc. ("Perfect Day") commissioned WSP USA Inc. ("WSP") to develop a Life Cycle Assessment (LCA) using GaBi® ts[3] software to calculate the greenhouse gas (GHG) emissions of Perfect Day whey protein which is made without the use of animals. This LCA includes a comparison to bovine dairy whey and the total amount of protein found in cow's milk referred to hereafter as "total lactated protein." The goal of this study is twofold:

1. Determine the total GHG emissions of Perfect Day whey protein
2. Calculate the difference in GHG emissions between Perfect Day whey protein and conventional dairy whey and total lactated protein.

1.1 REASONS FOR CARRYING OUT THE STUDY

Perfect Day is dedicated to understanding and improving the life cycle GHG impacts of its products. Therefore, the company sought understanding of the relative environmental impacts of its protein product with the intention to communicate these insights internally and externally.

This study was conducted to inform internal decision-making and to provide information to the company's stakeholders who are interested in the GHG emissions associated with producing Perfect Day whey protein according to ISO standard 14067 on Greenhouse gases – Carbon footprint of products. This impact was considered because it will provide the most business value to Perfect Day in its discussions with customers and clients. Additionally, in the food systems space, GHG emissions are the primary ecological and economic issues by which Perfect Day's competitors are measured and with which clients are concerned.

Perfect Day recognizes that the environmental impacts from its protein depend greatly on the specifics of the inputs, production method, location and transportation. Perfect Day commissioned this study to determine the total GHG emissions impacts from the life cycle of the company's specific production system and to compare such values to those of other common proteins. Therefore, the results of this study include both total and comparative values that are intended to be communicated externally.

1.2 INTENDED APPLICATIONS

1. To provide useful environmental impact information about the GHG emissions impacts from all cradle-to-gate life cycle phases of the protein production
2. To compare the GHG emissions of Perfect Day whey protein to WPI90 and total lactated protein by conducting an ISO-conformant GHG emissions analysis

1.3 TARGET AUDIENCE

The study results are prepared for both Perfect Day's internal use and to be communicated externally in conformance with ISO standards.

1.4 TYPE OF CRITICAL REVIEW

Since the results of this study are comparative and intended for external communication, a critical review by a panel of three independent experts was conducted. Those experts are Corinne Scown, PhD; Pragnya Eranki, PhD; and Horacio Aguirre-Villegas, PhD.

[3] Modeling for all systems in this study were conducted in the LCA software GaBi, developed by thinkstep, now Sphera (http://www.gabi-software.com/america/index/).

2 SCOPE OF THE STUDY

2.1 FUNCTION

Perfect Day whey protein is made almost entirely of protein. This protein is created by the host organism (*Trichoderma reesei*, described below). All proteins are macromolecules made up of small subunits called amino acids. Specific amino acids in a specific sequence create a unique protein. Therefore, by instructing the organism to assemble the amino acid sequence, Perfect Day creates non-animal whey protein. The downstream process ensures there is virtually nothing else in the protein (besides a miniscule amount of residual carbohydrate, moisture, and minerals).

The function of the product is to deliver protein for human consumption. The primary use of a protein is to provide necessary nutrients to the human body.

2.2 FUNCTIONAL UNIT

Since the function of the product is to be a provider of protein, the functional unit of the product is a measure of nutrition: the kg of protein in the product.

2.3 SYSTEM BOUNDARY

2.3.1 *PERFECT DAY WHEY PROTEIN*

The study's system boundary is from cradle to gate for the life cycle inventory and impact assessment and includes the raw material extraction and processing, transportation, and protein production. The analysis does not include resource needs and environmental impacts embedded in infrastructure in either primary data or secondary data collection efforts.[4]

All product life cycle phases are included in the study's boundary. Figure 1: System Boundary illustrates all the phases of Perfect Day whey protein production. The Perfect Day process diagram from cradle to grave is illustrated in Figure 2: Perfect Day Process Diagram.

[4] Infrastructure processes comprise the production of capital equipment and machinery that are used to extract and process materials and produce products, and infrastructure for energy, water, waste, and transport processes.

Figure 1: System Boundary

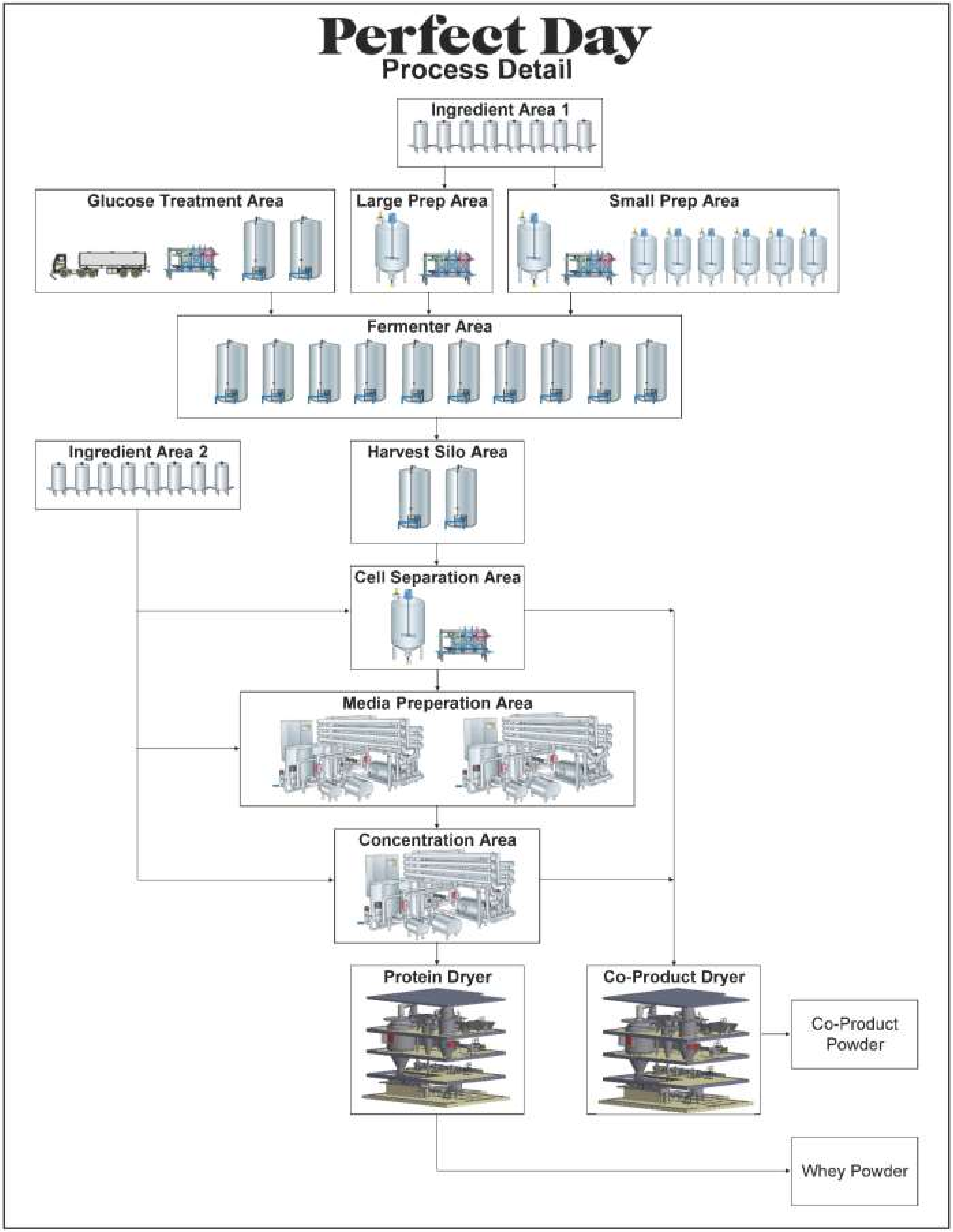


Figure 2: Perfect Day Process Diagram

2.4 ALLOCATION

There is one point in the analysis in which allocation must be applied, which is between the Perfect Day whey protein and one co-product produced. The Perfect Day whey protein process produces a solid biomass co-product stream from the fermentation ingredients as well as the final product stream. The solid biomass co-product accounts for 78.3% of total mass produced (on a dry mass basis). Of the final product stream, 21.7% (dry mass) is the Perfect Day whey protein product with its specific protein characteristics.

The co-product is high in proteins and other components (e.g., vitamins, minerals) that make it valuable for domesticated pet food and will be sold to this market. It is not known what other protein sources in pet food the co-product would potentially displace or if other proteins would be displaced at all, therefore, system expansion to avoid allocation cannot be conducted. The co-product is dried using a natural gas-powered dryer (82% efficiency) before it is sold. ISO standards require allocation by physical basis if allocation cannot be avoided; therefore, mass allocation was chosen. Energy allocation would apply if the function of the products were as energy carriers, but it is not. Mass allocation is also recommended over economic allocation in the ISO standards. Further, economic allocation is not possible because the economic value of the co-product is not known.

2.5 SENSITIVITY ANALYSIS

To be extremely conservative, we have also included a hypothetical sensitivity analysis where 100% of the burdens of production are attributed to Perfect Day whey protein. In this scenario, the co-product is no longer treated as a co-product, but as a waste product, and would not be dried. Therefore, the energy for drying the co-product is not included for this sensitivity analysis without allocation. Energy to dry the primary product is accounted for in both scenarios as this would occur regardless of the existence of a co-product. Therefore, in the sensitivity analysis, the drying of the co-product is subdivided from the system boundary.

3 LIFE CYCLE INVENTORY ANALYSIS

3.1 DATA COLLECTION PROCEDURES

The life cycle inventory analysis phase combines the collection of primary activity data with the application of secondary life cycle inventory data for similar and comparable material inputs used to produce Perfect Day whey protein. Data not collected directly from Perfect Day were sourced from the GaBi® databases, and the model used to calculate impacts from the life cycle of Perfect Day and comparative products were built in GaBi®. The Life Cycle Impact Assessment (LCIA) was conducted within GaBi®. The thinkstep dataset was used to model water, electricity and natural gas. The dataset used for the different ingredients is listed in Confidential Appendix A. This section describes how various sources of primary product activity data have been collected for each phase of the product life cycle described in Section 3. This section also describes the process for sourcing and evaluating literature sources for the comparative dairy proteins.

3.1.1 PERFECT DAY WHEY PROTEIN

RAW MATERIAL TRANSPORTATION

This study is based on projected production of Perfect Day whey protein at a co-manufacturing site in the United States; the exact production location has not been finalized. A co-manufacturing facility creates batches of product for different customers, brands, or labels. Therefore, there is not only one single product produced at the facility under one brand, but multiple. It is not known what other products are produced at this same facility. Primary data on transportation from the field to the Perfect Day facility and from suppliers to the co-manufacturing facility were collected from Perfect Day. Secondary data for modeling transport by truck and train were sourced from the GaBi® database. Distances for transportation of inputs to production were calculated assuming a transportation distance of 100 miles. Glucose was assumed to be transported via train, and the remaining ingredients were assumed to be transported via truck. A summary table of transportation distances and methods is provided in Confidential Appendix A Table 8 Empty truck backhauls were not included in this analysis for Perfect Day to align with the system boundaries of the other proteins. It was assumed that the datasets for the comparative proteins had no empty return trips.

PROTEIN PRODUCTION

Primary data on final product production were collected from Perfect Day. Secondary data for the impacts from the production of inputs to the Perfect Day process, such as glucose, were sourced from the GaBi® database. Note that glucose is obtained on a large scale by hydrolysis of starch from corn, by boiling starch from corn at 393º K with dilute sulfuric acid under pressure.

Once the glucose and other ingredients are delivered to the co-manufacturing site, the fermentation process begins. The glucose is the only thing that is fed, along with a source of nitrogen and minerals/vitamins along with gaseous oxygen, into the fermentation process. The goal of the fermentation process is to take a purified vial of Perfect Day's production micro-organism (microflora) and, through a series of successively larger fermentation vessels, put enough biomass of the production host in place in the main production fermenter that a highly efficient expression of the target protein is achieved. The biomass production host is a type of filamentous fungus called *Trichoderma reesei*, referred to as microflora, or 'flora' for short. *T. reesei*, a cousin of yeast, has a proven track record of safe use in the production of enzymes since 1976. The fermentation media is composed of a variety of salts, trace metals, and a carbon source (glucose) and is fermented in three 40,000-gallon silos. Amino acids consist of oxygen (bubbled into the fermentation tank), nitrogen (provided in the form of ammonium salts), and carbon (using dextrose, DE-95). The flora uptake these basic inputs and assemble them into amino acids, which they then put together according to the whey protein gene sequence Perfect Day provided, to produce the end product whey protein.

The second step in the process is cell separation, which removes all biomass solids from the fermentation broth. Product from the silos is strained to remove large particles; the broth is then diluted with process water, and the pH is adjusted. Micro-filtration and further filtering are then used to remove soluble impurities (antifoam, salts, and unbound proteins) from the remaining solids and result in a solution rich in protein.

The final step is polishing, concentration, and drying. At this point, the target protein has been isolated from most of the components of the final fermentation broth, with some trace impurities remaining. All final product is dried using an indirect tall-form spray dryer and packed in bags. The powder is agglomerated and has a final moisture content of less than 4%.

Some natural gas is used for process steam and dryer production. All water is drawn from a municipal water source.

The input and output amounts for the protein production process are provided in Confidential Appendix A Table 9.

WASTE PRODUCTS AND WASTEWATER TREATMENT

Primary data on wastewater treatment were collected from Perfect Day. Secondary data for modeling the production of inputs to waste treatment were sourced from the GaBi® database. Portions of the waste stream are allocated as co-products and do not go to wastewater treatment.

ELECTRICITY GRID MIX

It was assumed that the electricity grid mix used for process equipment is the US average since the final production facility has not been determined. Because the final production facility has not been determined, and all utilities are not attributed to Perfect Day, the natural gas and electricity amounts used in this study are somewhat uncertain. The production of electricity was modeled using the GaBi® US average electricity grid mix database (data valid from 2016 to 2022).

CLEANING

Most pieces of equipment are cleaned and sanitized by CIP (Clean in Place), an automatic system for distributing a 2% solution of hot caustic soda, and in cases where it is required, Deptal EL at 2% or Deptacid KCH 1.2%. The system cleans the equipment and lines with a pre-wash cycle using deionized water, followed by a wash with liquid detergent and a neutralizing rinse with deionized water. Special change over cleaning and sanitizing occurs in between different product type manufacturing.

Cleaning occurs at the beginning and at the end of each lot. CIP is also performed if the system or part of it is not used for more than seven days and when particular conditions require additional cleaning and after any maintenance work

The inputs and output amounts for the cleaning process are provided in Confidential Appendix A Table 9.

3.1.2 COMPARATIVE DAIRY PROTEIN

The GHG emissions per kg protein results from the Perfect Day whey protein are compared to that of WPI90 and total lactated protein from dairy cows. A high protein concentration was selected for comparison among different protein concentrations. This approach was taken to compare the Perfect Day whey protein's performance to that of other products with high protein concentration as well as total lactated protein products that are more extensively available in the commercial market. Therefore, published literature sources were used for the GHG emissions impacts of WPI90 with 90% protein concentration (WPC90/ WPI) and total lactated protein (with 3.3% protein and 3.4% protein). Four studies were identified that provided emissions results for WPC90/ WPI, total lactated protein (3.3% protein), and total lactated protein (3.4% protein). While WPI90 is directly represented in these studies, only milk with different protein contents are presented in other studies. Results are reported per unit protein in the final milk product. Milk has other nutrients and functions, but the goal of this study is to compare the performance of Perfect Day protein against protein in milk (total lactated protein). These four studies will be referred to as study 1, study 2, study 3 and study 4 in this report and documentation with references to the full published studies in the references. These studies were selected to represent the global production of protein from milk as Perfect Day's whey product may be sold globally in the future. They were also selected to reflect recent management practices as well as recent background data used in the assessments to align with the temporal boundary of this study. Multiple studies were also selected to help illustrate the range of potential results for global average production of milk as this can vary greatly based on region, climate, management practices and several other factors that influence GHG emissions from dairy. While these four studies include the impacts of emissions from enteric fermentation of CH_4 and N_2O, they exclude biogenic CO_2. Table 1 and Table 2 provide a preview of the data from the 4 studies.

Table 1 Comparative studies characteristics

Study #	Literature Title	Functional Unit	System Boundary	Allocation Method	GHG impact value choices
1	**Greenhouse gas emissions in milk and dairy product chains (2012)**	per kg of product	Cradle-to-gate	Weighted allocation based on price of fat and protein which are drivers of milk price	WPI90: 17.04 kg CO_2 per kg of 90% Whey Protein Concentrate Total lactated protein: 1.05 kg CO_2 per liter of Whole milk

Study #	Literature Title	Functional Unit	System Boundary	Allocation Method	GHG impact value choices
2	**Reducing food's environmental impacts through producers and consumers (2018)**	per liter of milk	Cradle-to-gate	Economic allocation	1.8 to 4.8 kg CO_2 per liter of milk, median value of 2.7 kg CO_2 per L of milk was chosen.
3	**Greenhouse gas emissions from the dairy sector: A life cycle assessment (2010)**	per kg of fat and protein corrected milk (FPCM)	Cradle-to-gate	Protein content allocation	1 to 7.5 kg CO_2 per kg FPCM, global average value of 2.4 kg CO_2 per kg FPCM was chosen.
4	**Life cycle assessment of ripple non-dairy milk (2017)**	per liter of milk	Cradle-to-cradle	Economic allocation	41.7 kg CO_2 per kg protein was used by considering only farming and processing values.

Table 2 Study steps included and steps excluded for comparison.

Literature Title	Steps included	Steps excluded
Greenhouse gas emissions in milk and dairy product chains **(2012)**	Raw milk production, fresh dairy production, butter production, cheese production, whey production, milk powder production, transportation, feed and fertilizer inputs.	Consumption, disposal.
Reducing food's environmental impacts through producers and consumers **(2018)**	Land use change, crop production, livestock management, food processing, packaging, transportation.	Retail and post retail stages.
Greenhouse gas emissions from the dairy sector: A life cycle assessment **(2010)**	Processes for producing grass, feed crops, crop residues, byproducts, and concentrates, including: Production of N fertilizer (CO2); Application of manure and chemical fertilizers to crops, accounting for both direct and indirect emissions (N2O); Deposition of manure and urine on pasture crops, accounting for both direct and indirect emissions (N2O); Energy used for fertilization, field operations, drying, processing of feed crops and fodder (CO2); Processing of crops into byproducts and concentrates; Transport of feed from the production site to the feeding site; Changes in carbon stocks as a result of land use change (mostly from deforestation) in the previous 20 years (IPCC, 2006); and Nitrogen (N) losses related to changes in carbon stocks (N2O), Enteric fermentation by ruminants (CH4); and Direct and indirect emissions from manure storage (CH4 and N2O).	Transport of milk and animals to dairies and slaughterhouses; Processing of raw milk into commodities such as cooled milk, yoghurt, cheese, butter, and milk powder; Production of packaging; Refrigeration (energy and leakage of refrigerants); and Transport of processed products to the retail point.
Life cycle assessment of ripple non-dairy milk **(2017)**	Feed farming, Cow farming, milk processing.	Use and disposal, package recycling.

Study 1 is a PhD thesis from Aarhus University that was funded by the Danish Agency for Science, Technology and Innovation at Copenhagen, Denmark. This project was initiated with Arla Foods in an effort to promote a more sustainable dairy sector. This study explored aspects of methodology that estimate milk and dairy emissions (Flysjo, 2012). It also estimates the carbon footprint for different types of dairy products. The emissions are estimated using a cradle-to-farm-gate system boundary; the post-production activities shown in Figure 3 are not included in the system boundary of analysis for this comparative study with Perfect Day whey protein but were considered in the published study. The dissertation is published as 5 peer reviewed journal articles that identifies and examines the most critical parameters affecting the GHG emissions of milk at farm gate and quantifies the uncertainties in the final CF due to variation in the biogenic CH4 and N2O emissions, analyses farm management practices and how they affect the GHG emissions of milk, shows how methodological choices of co-product handling affect the GHG emissions of milk at farm gate and the importance of analyzing milk and beef in an integrated approach, investigates two critical parameters − the link between milk and beef production and accounting for emissions from LUC − and how these affect the GHG emissions of milk, estimates the CF for butter and butter blends as well as how to reduce emissions in the value chain of the products, and presents a model for calculating the CF for dairy products or dairy product groups (fresh dairy products; butter and butter blends; cheese; milk powder and whey based products), which can be used to track improvements at product level.

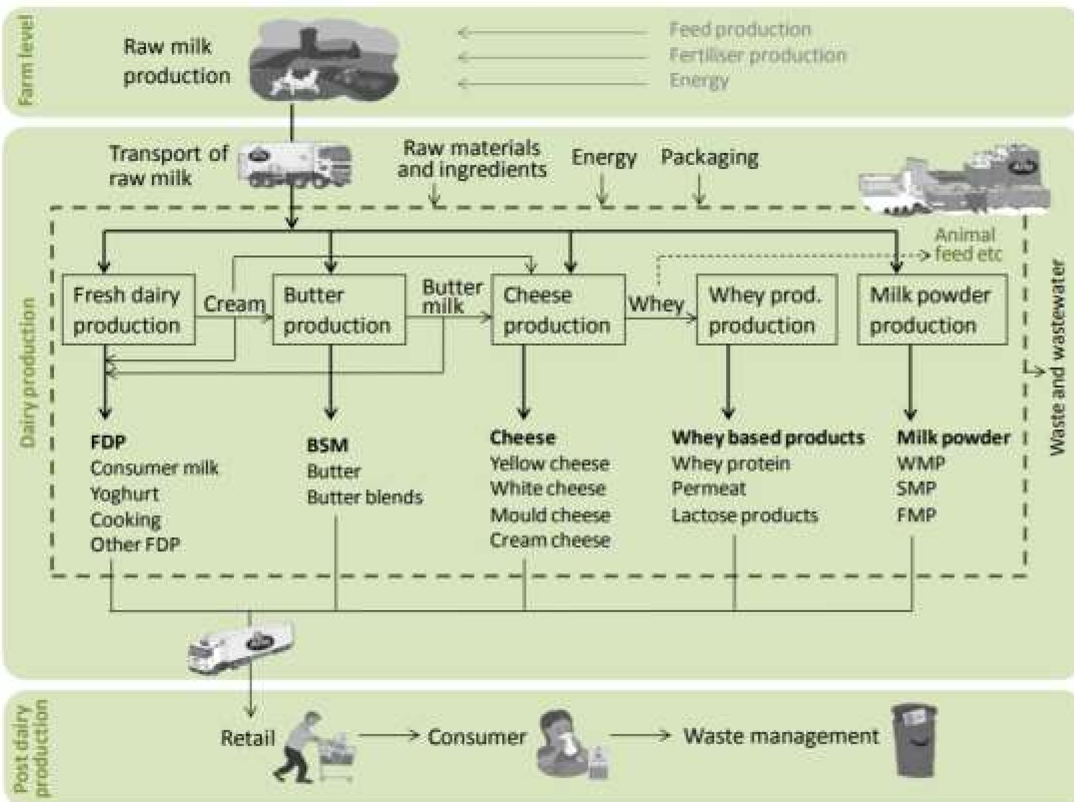


Figure 3: Flow chart of lifecycle of dairy products by group from study 1. Source: Greenhouse Gas Emissions in Milk and Dairy Product Chains by Anna Flysjö.

Study 1 examined both WPI90 as well as total lactated milk with a 3.4% protein concentration. The study provides the GHG impact per kg of product and the protein content was scaled to 100% to represent the impacts per kg of protein. A unique co-product allocation method was followed in this study. Milk solids are allocated based on the price the farmer is paid for the raw milk. Arla Foods, a key partner in this study, compensates farmers based on fat and protein content.

Study 2 is a meta-analysis of various food groups, including dairy, from different parts of the world conducted by authors at the University of Oxford. Approximately 600 studies were included in this analysis, but the system boundary was maintained at cradle-to-gate for all studies (Poore & Nemecek, 2018). Economic allocation was used between co-products. For allocation between beef and milk, and lamb and wool, economic allocation factors were calculated where required, using national price data and the yield of each product. There is no specific system boundary diagram available for this study, but it matched the cradle-to-gate analysis for comparison to Perfect Day whey protein.

Study 3 is global study that was carried out by the Food and Agriculture Organization (FAO) of the United Nations. The assessment encompasses the entire production chain of cow milk, from feed production through to the final processing of milk and meat, including transport to the retail sector (FAO Animal Production and Health Division, 2010), as shown in Figure 4.

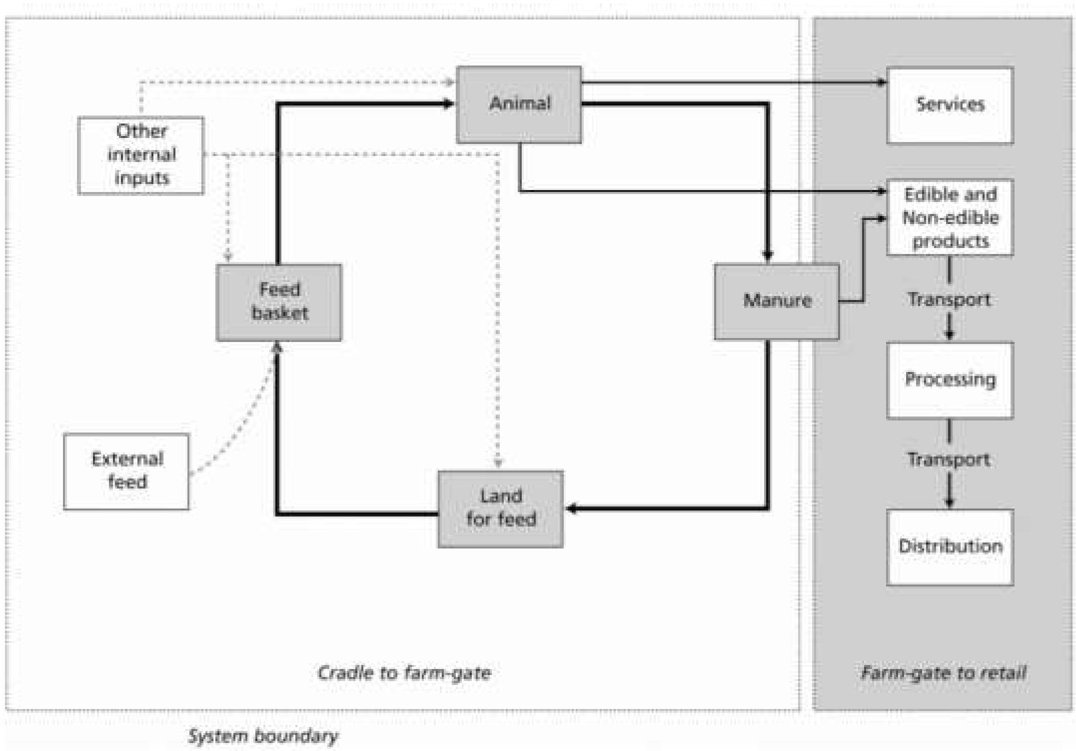


Figure 4: System boundary for the analysis in study 3. Source: Greenhouse Gas Emissions from the Dairy Sector by FAO.

The following sources of emissions were included and identified as pre- and post-gate emissions sources. While details are given for the post-gate emission sources, only the pre-gate emissions were used for comparative purposes. Hence only the cradle-to-gate results were considered while comparing against the Perfect Day product.

Cradle to farm-gate

- Processes for producing grass, feed crops, crop residues, byproducts, and concentrates, including:
  - Production of N fertilizer (CO_2);
  - Application of manure and chemical fertilizers to crops, accounting for both direct and indirect emissions (N_2O);
  - Deposition of manure and urine on pasture crops, accounting for both direct and indirect emissions (N_2O);
  - Energy used for fertilization, field operations, drying, processing of feed crops and fodder (CO_2);
  - Processing of crops into byproducts and concentrates;
  - Transport of feed from the production site to the feeding site;
  - Changes in carbon stocks as a result of land use change (mostly from deforestation) in the previous 20 years (IPCC, 2006); and
  - Nitrogen (N) losses related to changes in carbon stocks (N_2O).
- Enteric fermentation by ruminants (CH_4); and
- Direct and indirect emissions from manure storage (CH_4 and N_2O).

Farm-gate to retail

- Transport of milk and animals to dairies and slaughterhouses;
- Processing of raw milk into commodities such as cooled milk, yoghurt, cheese, butter, and milk powder;
- Production of packaging;
- Refrigeration (energy and leakage of refrigerants); and
- Transport of processed products to the retail point.

This study does not include land use under constant management practices, capital goods such as farm equipment, on-farm milking and cooling, production of cleaning agents, pharmaceuticals, and disposal of packaging. The GHG emissions from the dairy system are allocated based on milk protein content, as the dairy herd can produce both milk and meat. This method reflects the fact that a primary function of the dairy sector is to provide humans with edible protein. Advantages of using protein content are that it enables direct comparison with other food products, and that it is also relatively stable in time and it can be applied in situations where markets are absent or where they are highly localized and not comparable across regions. A disadvantage is that other nutritional properties, such as minerals, vitamins, energy, and essential fatty acids are not captured. While this study is highly aggregated, it provides useful information when disaggregated into the regional level as it accounts for feed production, animal feeding and manure management which facilitates comparison to the GHG performance of the Perfect Day whey protein given the potential for the product to be produced globally in the future.

Study 4 was initiated by Ripple Foods, Inc. (a producer of a dairy-milk alternative made from pea protein) to quantify the GHG emissions and water requirements of Ripple milk compared to dairy, almond and soy milks (Life Cycle Associates, LLC., 2017). The dairy results were extracted from this study, and this study assumes a total lactated protein content of 3.4%. The carbon intensity of dairy milk was taken from two 2013 studies (Thoma 2013a, 2013b) that examined the cradle-to-farm-gate and the farm-gate-to-end-of-life emissions of American produced dairy milk. The system boundary in Figure 5 shows the cradle-to-grave nature of the dairy milk system. For the sake of consistency, only the cradle-to-gate impacts were extracted since these results were presented separately.

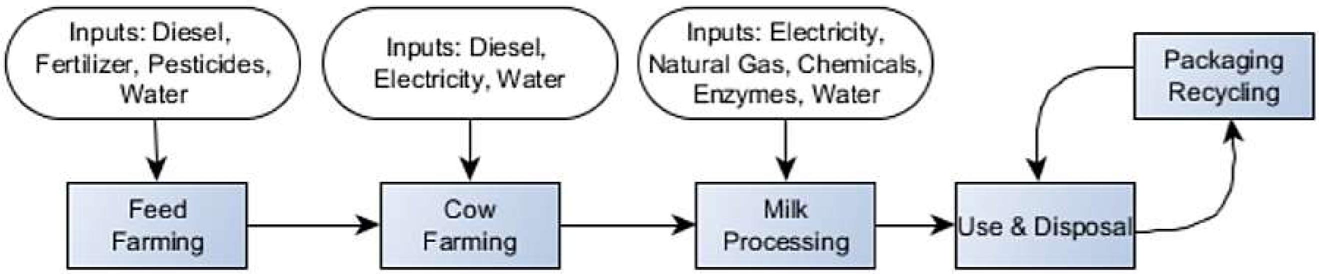


Figure 5: System boundary of dairy system studied in study 4. Source: Life Cycle Assessment of Ripple Non-Dairy Milk by Life Cycle Associates, LLC.

Allocation in this study follows a unique approach presented in another study from 2012 (Thoma, 2012) where an allocation ratio is used to distribute the impacts between beef and milk. This ratio is based on the ratio of feed consumed for the production of milk to the total feed consumed for both milk and meat. This study is chosen instead of the original study because Perfect Day wants to be competitive in the market and compare their product's performance against a very specific market product.

3.2 CALCULATION PROCEDURES

Life cycle activity inventory data were collected from primary (Perfect Day) and secondary (GaBi database) sources. A model was built in GaBi® to calculate the impacts of the Perfect Day process and compare them to those of other proteins. Results were exported from GaBi® to Microsoft Excel® for results presentation.

3.3 DATA VALIDATION

All primary activity data including inputs to the Perfect Day whey protein production process (e.g., glucose, materials for cleaning, water, electricity and outputs to wastewater treatment) were internally validated by Perfect Day and WSP. Secondary data from the GaBi databases undergo internal validation by thinkstep, as well as external review by DEKRA.[5]

3.4 SENSITIVITY ANALYSIS

The sensitivity analysis was conducted by increasing the burden of the Perfect Day whey protein from 21.7% to 100%. In this scenario, the co-product is no longer treated as a co-product, but as a waste product, and would not be dried. In the base case scenario, the co-product undergoes an additional drying process before it is sold to the market, hence this drying is included in the base case (21.7% allocation). Drying is carried out using a natural gas-powered dryer. When this co-product is instead treated as a waste in the sensitivity case, the additional energy needed to dry the co-product is excluded. Therefore, in the sensitivity case, all of the burdens of production are put on the Perfect Day whey protein and no allocation is performed.

[5] http://www.gabi-software.com/uploads/media/131211_GaBi_Review_Report_Verification_Statement_signed_DEKRA.pdf

3.5 ALLOCATION PROCEDURES

There is one point in the analysis in which allocation must be applied, which is between the Perfect Day whey protein and one co-product produced. The allocation methods are described in section 2.4.

Secondary Life Cycle Inventory (LCI) data used in this study also include allocation procedures to model the production of glucose. Allocation of burdens to co-products is embedded in the GaBi® datasets and are described in the GaBi® documentation of these datasets and in the literature sources.[6]

[6] http://www.gabi-software.com/support/gabi/gabi-6-lci-documentation/

4 LIFE CYCLE IMPACT ASSESSMENT (LCIA)

4.1 LCIA PROCEDURES AND CALCULATIONS

LCIA was carried out using characterization factors programmed into GaBi®. Global Warming Potential (GWP) was the impact category considered in this report. The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5) 100-year time-scale excluding biogenic carbon (IPCC AR5 GWP 100 excl. biogen) method was used for quantifying GWP, and it is measured in carbon dioxide equivalents (kg CO_2e). This metric is a midpoint assessment method. Biogenic carbon emissions are those that originate from natural carbon-cycle related biological sources such as plants, trees, and soil. Excluding biogenic carbon was chosen to quantify the GHG emissions from fossil sources. Whereas biogenic carbon is part of the natural cycle, fossil-derived carbon releases locked-up carbon to the atmosphere. Moreover, this study is from cradle to gate and will not quantify the fate of carbon contained in the products that originated from biological, rather than fossil, sources. At the gate end of the system boundary, the product still contains carbon from the growth of plants used to make the protein which will eventually be released to the atmosphere once the product is consumed.

4.2 LCIA RESULTS

The GaBi® software calculates LCIA results in its balance function and computes the environmental impact results according to predefined characterization methods in the selected LCIA methodology.

4.2.1 GLOBAL WARMING POTENTIAL

The GWP (excluding biogenic carbon) results of the product life cycle, as characterized by the IPCC AR5 characterization factors for GWP 100, per functional unit (kg of protein) for GHG emissions are given in Table 3**Table 3: GHG emissions results per project life cycle phase for** . Biogenic carbon is part of the natural cycle; fossil-derived carbon releases locked-up carbon to the atmosphere. The contribution to GHG emissions per kg of protein across all phases of Perfect Day whey protein production from cradle to gate are also presented in Table 3**Table 3: GHG emissions results per project life cycle phase for Table 3: GHG emissions results per project life cycle phase for** and Figure 6.

Table 3: GHG emissions results per project life cycle phase for Perfect Day whey protein

GHG kg CO_2e/ kg of protein	Perfect Day Total	Cleaning	Downstream Process	Protein Development	Transportation	Utilities	Wastewater Treatment
GWP 100, excluding biogenic carbon	**2.71**	0.497	0.317	0.604	0.0460	0.973	0.00322

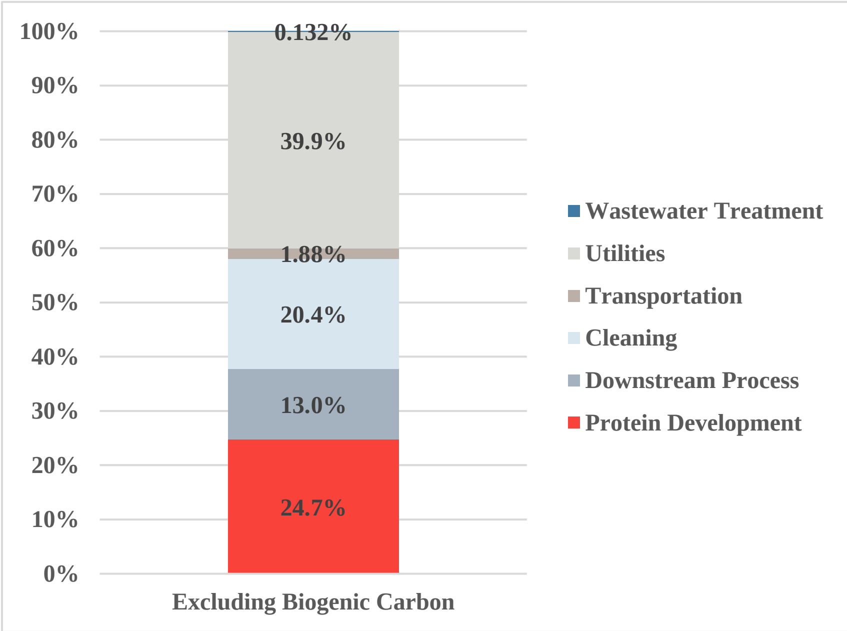


Figure 6: Relative contribution of life cycle inputs to Perfect Day whey protein GHG emissions excluding biogenic carbon

Figure 6 illustrates that the largest contributor to GHG emissions is utilities. Utilities contribute 40% of the GHG emissions followed by protein development which contributes 25%. Utilities are the largest contributor to GHG emissions due to the composition of the US electric grid. The electricity grid mix consists primarily of coal (31%), natural gas (33%), nuclear (20%), hydro (7%), wind (5%), biomass and photovoltaic (1% each). The largest contributors to GHG emissions within the utilities are electricity used for the protein processing (50%) and the electricity for the cooling equipment (31%), even though electricity makes up only 37% of total utility energy use. One kg of Perfect Day whey protein requires 13 kWh of electricity to produce. Protein development is the next highest contributor to GHG emissions due to the production of glucose via starch hydrolysis. Glucose production contributes 83% to the emissions from the protein development phase. Glucose is obtained on a large scale by hydrolysis of starch, by boiling starch from corn at 393°K with dilute sulfuric acid under pressure. The high temperature and pressure requirements in this hydrolysis process are energy intensive and require electricity and combustion of fuel which release significant GHG emissions. Within this LCI glucose dataset, different kinds of allocation are applied. For the combined heat and power production, allocation by exergetic content is applied. For the electricity generation and byproducts, e.g. gypsum, allocation by market value is applied due to no common physical properties. Within the refinery allocation by low heating value (net caloric value) and mass are used. For the combined crude oil, natural gas, and natural gas liquids, production allocation by net caloric value is applied.

Cleaning and downstream processes are critical phases that also contribute considerable amounts of GHG emissions as shown in Figure 6. In the cleaning phase, sodium hypochlorite contributes to 59% of emissions. Sodium hypochlorite is a chlorine compound often used as a disinfectant or a bleaching agent. Lactic acid is second to sodium hypochlorite and contributes 16% to GHG emissions. Lactic acid fermentation is a metabolic process by which glucose or other six-carbon sugars (also, disaccharides of six-carbon sugars, e.g., sucrose or lactose) are converted into cellular energy and the metabolite lactate, which is lactic acid in solution. Within the downstream processes phase, calcium acetate is the largest contributor to this phase. The use of calcium acetate contributes 61% of the cleaning GHG emissions. The contribution of carboxy methyl cellulose powder is the second highest contributor, at 19%, within the downstream process. Carboxymethyl cellulose powder is used as a proxy to another downstream agent that was not available in the database, based on similar emulsification performance and use in the food industry.

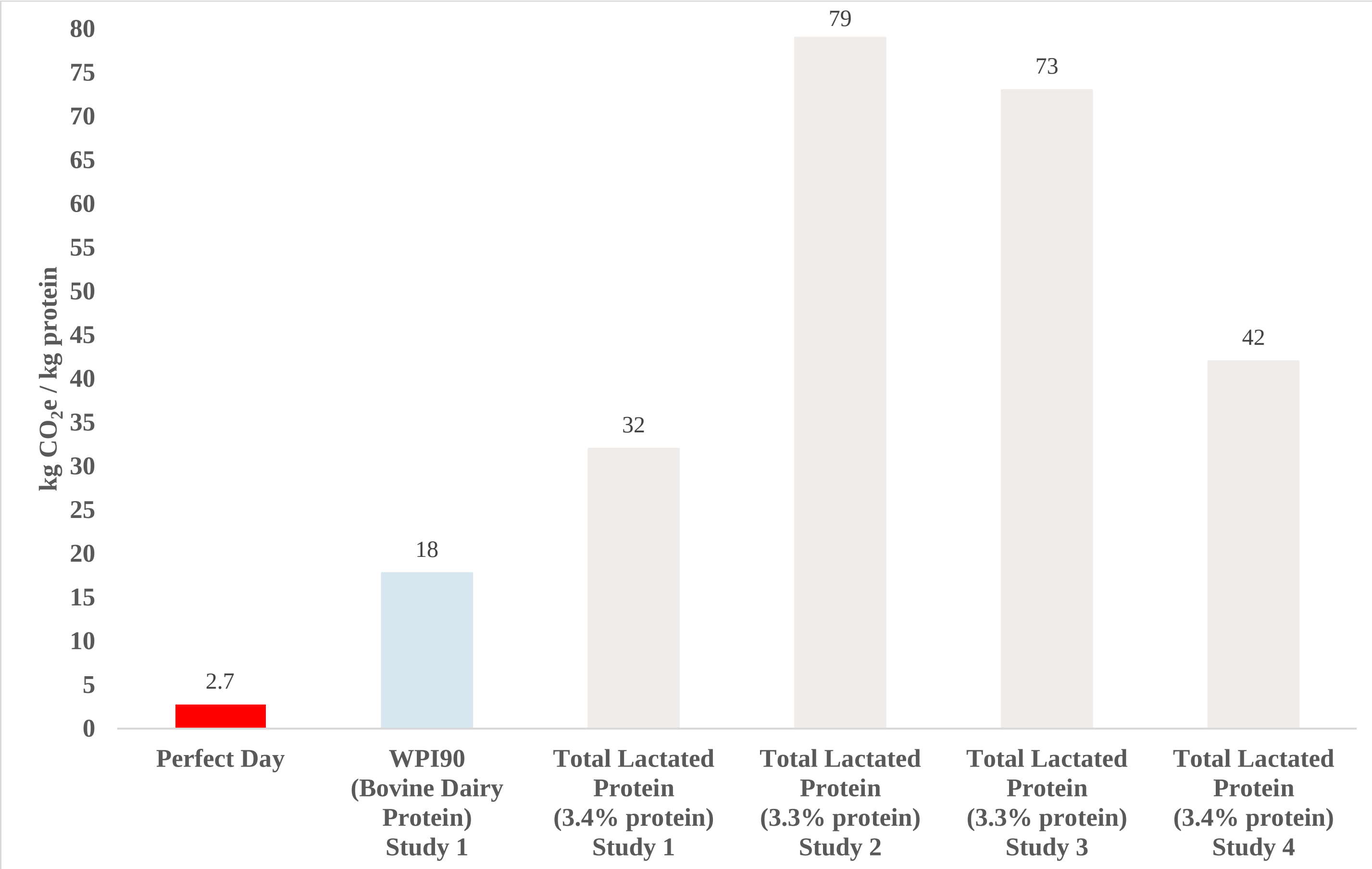


Figure 7: Emissions from Perfect Day whey protein compared to WPI90 and total lactated proteins. Results for WPI90 and total lactated protein were derived from studies 1-4 presented in Appendix C. Perfect Day whey protein results were modeled.

Table 4: Perfect Day whey protein emissions comparison with WPI90 and total lactated protein.

Product	Perfect Day Whey Protein GHG emissions kg CO_2e / kg protein	Comparative product GHG emissions kg CO_2e / kg protein	% difference of Perfect Day whey protein compared to comparative products
WPI90 (Bovine Dairy Protein) Study 1	2.7	18	-85%
Total Lactated Protein (3.4% protein) Study 1		32	-92%
Total Lactated Protein (3.3% protein) Study 2		79	-97%
Total Lactated Protein (3.3% protein) Study 3		73	-96%
Total Lactated Protein (3.4% protein) Study 4		42	-94%

Table 4 highlights the total emissions from the different protein products shown in Figure 7. The percentage reduction in emissions from Perfect Day whey protein compared to WPI90 and total lactated protein is greater than or equal to 85% across all products. The four studies also did not include biogenic carbon. The differences between the GHG emissions among the total lactated proteins are due to scale and location of the study. Manure management and other management strategies also have a major role in the differences in GHG impact since all four studies recognize and consider manure management within their system boundary. There are significant differences in manure management between the developed and the developing world. In North America and Europe, the majority of the manure is handled through slurry or solid storage while in Asia, Africa and Oceania the majority of the manure is left in the pasture. The difference in manure management leads to significant differences in the GHG value. Since Study 2 and Study 3 are global studies, they have higher GHG emissions due to greater emissions of methane from manure in pastures. All these studies also assume feed to be mostly corn. In Study 1, close to 75% of the emissions are from the production of raw milk. Methane emissions contribute to 50% of the total emissions, while CO_2 emissions from energy sources contribute to 15% of total emissions. The energy impacts are specific to Sweden. The methane emissions include emissions from manure, enteric fermentation and other sources. Enteric methane emissions are related to total feed intake needed to produce milk as well as the composition of the feed. While Study 2 is a meta-analysis, it reports that 25% of producers contribute, on average, to 53% of the products' environmental impact. The total emissions from 553 million tonnes of milk produced were estimated to be 1,328 million tonnes CO_2e in Study 3. The study estimates that milk production, processing and transport alone contribute 2.7 percent [±26%] to total anthropogenic GHG emissions. The study reports that the largest portion of dairy sector emissions occurs at the farm level, which, on average, is 93%. In North America, Western Europe and Oceania, 78 to 83% of emissions are generated by activities on the farm, and in all other parts of the world, these emissions are estimated to contribute to between 90 and 99% of the total emissions. Regional variations in emissions are predominantly driven by differences in farming systems. From the study referenced for milk in Study 4, it is clear that on-farm practices are the largest contributor to the GHG emissions sited in this study, followed by both enteric emissions and manure emissions, across all the regions that were considered. The on-farm emissions contribute twice as much to GHG emissions as enteric or manure emissions. This study identifies on-farm fuel efficiency, enteric emission and manure management, and farm size as the largest drivers of emissions across the different regions of their study.

Table 5 Data ranges extracted from studies

Study Title	GHG impact value choices
Study 1: Greenhouse gas emissions in milk and dairy product chains (2012)	WPI90: 17.04 kg CO_2 per kg of 90% Whey Protein Concentrate Total lactated protein: 1.05 kg CO_2 per liter of Whole milk
Study 2: Reducing food's environmental impacts through producers and consumers (2018)	1.8 to 4.8 kg CO_2 per liter of milk, median value of 2.7 kg CO_2 per L of milk was chosen.
Study 3: Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment (2010)	1 to 7.5 kg CO_2 per kg FPCM, global average value of 2.4 kg CO_2 per kg FPCM was chosen.
Study 4: Life Cycle Assessment of Ripple Non-Dairy Milk (2017)	41.7 kg CO_2 per kg protein was used by considering only farming and processing values.

The four studies chosen were ensured to have the same system boundary as the Perfect Day analysis, but some studies provided GHG impacts as a range, as shown in Table 6. There is value in using these studies from a market perspective. Perfect Day aspires to sell its product globally and hence it is important for Perfect Day to compare its product against a global average. Studies 2 and 3 are inherently different, though they are global studies. Study 2 is a meta-analysis that aggregates results to provide a range of values found in the results of different studies and provides a mean and a median. Study 3 is a global analysis that estimates impacts from datasets collected by region to estimate a global average. Comparing against both these studies enables Perfect Day to compare its product's performance against literature data as well as a global model. Study 1 represents the European market, which is one of the easier markets for Perfect Day to establish itself in given the recent food trends in Europe. Study 4 is a specific product in the US market and hence is a critical data point that measures the performance of the Perfect Day product to create a value proposition within the US market.

4.3 SENSITIVITY ANALYSIS RESULTS

In order to test the sensitivity of the GHG emissions to the effects of allocation, the results were adjusted to remove allocation and treat the co-product as a waste with no value. Therefore, the burdens from the Perfect Day whey protein were increased from 21.7% to 100%, resulting in a fourfold increase in GHG emissions, as shown in Figure 1Figure 8. The drivers of the GHG impact remained the same, even though the drying energy for the co-product was completely removed for the 100% allocation to the Perfect Day whey protein scenario. There were changes in the percentage contribution of these drivers, but these changes are within a 5% range.

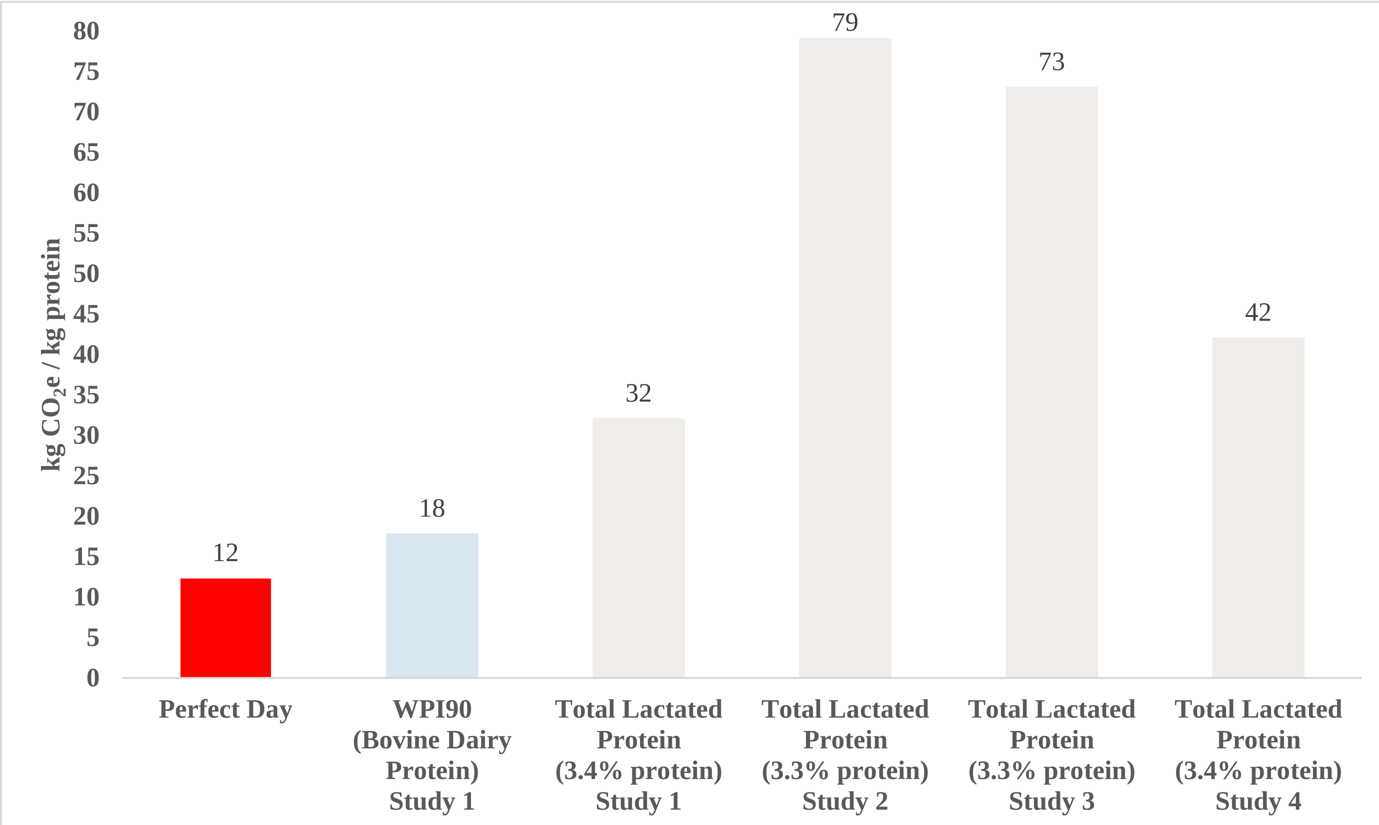


Figure 8: Emissions from Perfect Day whey protein compared to WPI90 and total lactated proteins, after allocation was increased to 100%. Results for WPI90 and total lactated protein were derived from studies 1-4.

The GHG emissions reductions for Perfect Day whey protein compared to other bovine proteins were at least 31% or more even when the allocation to the co-product was removed for this sensitivity analysis. Table 6 provides the total GHG emissions and the percent reduction in GHG emissions achieved by Perfect Day whey protein without allocation compared to other proteins.

Table 6: Perfect Day whey protein emissions comparison with WPI90 and total lactated protein after burden increased to 100%

Product	Perfect Day whey protein GHG emissions kg CO_2e / kg protein	Comparative product GHG emissions kg CO_2e / kg protein	% difference of Perfect Day whey protein compared to comparative products
WPI90 (Bovine Dairy Protein) Study 1	12	18	-31%
Total Lactated Protein (3.4% protein) Study 1		32	-62%
Total Lactated Protein (3.3% protein) Study 2		79	-84%
Total Lactated Protein (3.3% protein) Study 3		73	-83%
Total Lactated Protein (3.4% protein) Study 4		42	-71%

4.4 LCIA RESULTS LIMITATIONS RELATIVE TO DEFINED GOALS

Other impact categories were not quantified in the results of this study because they do not serve to answer the questions defined in the goal and scope of the study for the intended audience stated in Section 1. As such, the application of the results of this study are limited to interpretations based on the GWP impact category metric for quantifying GHG emissions and cannot be generalized or applied to other environmental impacts. Future studies are under consideration to include additional impact categories.

4.5 DESCRIPTION OF PRACTICIONER VALUE CHOICES

The practitioner value choices have been limited to the selected LCIA and the allocations procedures described in the relevant sections of this report. All results are presented on a midpoint basis, using the methods noted in Section 4.1; normalization and weighting are not used. Other impact categories have been excluded from the results because they do not answer the questions defined as the goal and scope for the intended audience in Section 1 of this report.

4.6 STATEMENT OF RELATIVITY

LCIA results are relative expressions and do not predict impacts on category endpoints, the exceeding of thresholds, safety margins, or risks. No grouping of impact categories has been performed; all impacts are presented at the midpoint level. LCIA impacts presented in this report are based on midpoint characterization factors (e.g., kg CO_2 equivalent for GWP), and this study does not refer to the ultimate damage to human health and the environment. For example, GWP may be a negative or a positive environmental impact depending on the conditions in locations where emissions occur. Since this study does not present end-point results, it does not draw any conclusions about the relative impact (positive or negative) for the categories considered by the study.

5 LIFE CYCLE INTERPRETATION

5.1 IDENTIFICATION OF RELEVANT FINDINGS

Based on the results presented in Section 4.2, Perfect Day whey protein reduces GHG emissions significantly when compared to WPI90 and all four comparative total lactated proteins. The Perfect Day whey protein is 85% to 97% lower than the comparative proteins. The primary driver of GHG emissions for Perfect Day whey protein are the utilities which contribute 40% to the total GHG emissions. Utilities include the US average natural gas and electricity used in the protein production process. After utilities, the protein development phase contributes 25% to total GHG emissions. Even with the removal of the allocation of GHG emissions to the co-product (treating it instead as a waste), the Perfect Day whey protein still reduces GHG emissions compared to other dairy proteins considered in this study by at least 30%.

5.2 DATA QUALITY ASSESSMENT

The life cycle data used in the analysis relies upon the secondary data sources from GaBi® to produce GHG emissions. Perfect Day provided primary activity data for the production of the Perfect Day whey protein product. Secondary sources and estimates were required for the life cycle inventory data on raw material extraction, preprocessing, use phase, and for the comparative products since Perfect Day does not directly control or influence these life cycle phases. The data quality evaluation in accordance with ISO Standards 14040 and 14044 are given in Table 7 .

Table 7 Data Quality Evaluation

Data Quality Requirement	Explanation
Temporal coverage	Process data are extrapolations of experimental and pilot-scale data collected during research and development activities in 2020 and reflect the most up-to-date results (within the past 12 months). Input data (e.g., electricity grid mix) are current within the past 12 months. Secondary data are representative of materials and processes in production over the 2010-2019 timeframe and the secondary data sources are temporally appropriate for characterizing the inputs to Perfect Day production activities. Temporal coverage is considered to be adequate for all inventory data.
Geographical coverage	The Perfect Day facility on which this study is focused is located at a co-manufacturing site in the United States and would primarily produce the protein for use in the United States. The primary data collected from Perfect Day on protein production and use is representative of the United States. Secondary data sources represent US averages in many cases, and some global or regional data sources were used; approximately 52% of datasets are from non-US sources. Secondary data sources for the comparative proteins represent the geographies in which those proteins are produced. Geographic coverage is considered adequate for all inventory data.
Technology coverage	The production methods employed by Perfect Day represent current and modern technology. Production technologies for the inputs to the Perfect Day process (e.g., electricity, natural gas, and materials used for cleaning) as well as for the comparative products evolve over time. These changes over time are captured in the annual update of the GaBi® databases used to source secondary data. Therefore, technology coverage is considered to be adequate for the inventory data used in this study.
Precision	Because primary data for modeling are based on primary information from Perfect Day, no better precision is available within this study. Variability in primary activity data has not been assessed as no direct measurement data are available. In all cases where primary data have been collected, only theoretical commercial-scale annual totals have been obtained and assessing process-level variability is not possible with theoretical commercial-scale data. All background data are from GaBi® and are well documented for precision. Therefore, precision is considered to be adequate for this study.

Data Quality Requirement	Explanation
Completeness	All flows were modeled with either primary or secondary data and checked for mass and energy balance. No process steps or data were knowingly omitted; therefore, completeness is considered high for this study.
Representativeness	All process inputs were modeled using secondary data sources. In this way, the data largely reflects North American averages for the materials and processes modeled. For some inputs, exact matches to secondary datasets were not available, therefore, suitable proxy datasets were identified in the GaBi® databases. Only 6.7% (by count) of the materials required for protein production, including cleaning, were modeled with proxy data and this represented 3.1% of the total mass of inputs. Confidential Table 8 shows the proxy information. Therefore, representativeness is considered adequate for this study.
Consistency	All secondary data are considered to be internally consistent as they have been modeled according to the GaBi modeling principles and guidelines. According to these principles, cut-off rules for each unit process require coverage of at least 95% of mass and energy of the input and output flows, and 98% of their environmental relevance (according to expert judgment). Therefore, consistency is considered adequate for this study.
Reproducibility	Because Perfect Day primary data are confidential, an independent practitioner would not be able to reproduce the results reported in this study. However, if a hypothetical study team was granted access to the Perfect Day whey protein production data, production volumes, and transportation information, the methodology description in this report would be a sufficient guideline to reproduce the results presented herein. Therefore, reproducibility is considered adequate for this study.
Sources	Primary data, including material inputs, production data, production volumes, and transportation information, were provided by Perfect Day. Secondary data for all material and energy inputs as well as comparative proteins were sourced from GaBi® databases.
Uncertainty	Input uncertainty and data variability were assessed to be low for non-agricultural system inputs and model precision assessed to be high. Further, the impact categories assessed in this study are not associated with high degrees of uncertainty, as is the case with GHG metrics. Therefore, uncertainty analysis was not performed on the inventory data or impact assessments. It is acknowledged that spatial and temporal variability in input data and results introduces uncertainty into any LCA, but they can only be assessed if some measure of this uncertainty is available for testing. Three of the four dairy studies reported an uncertainty of 26% to 35%. Given the inherent uncertainty and variability associated with agricultural systems, the uncertainty in this study related to underlying agricultural data is considered high. A sensitivity analysis was done by adjusting the allocation from 21.7% to 100% allocation to the Perfect Day whey protein.

5.3 CONCLUSIONS AND RECOMMENDATIONS

Perfect Day whey protein reduces GHG emissions compared to WPI90 and all four comparative total lactated proteins by between 85% and 97%. The primary driver of GHG emissions for Perfect Day whey protein are the utilities which contribute 40% to total GHG emissions. Utilities include the US average natural gas and electricity used in the protein production process. After utilities, the protein development phase contributes 25% to total GHG emissions.

Utilities have a significant impact on total GHG emissions from Perfect Day whey protein (40% of total GHG impact). Therefore, it is recommended that additional data collection be leveraged to refine modeling of utilities. This could be accomplished by using a dedicated Perfect Day production facility instead of a shared co-manufacturing facility, where other products are also manufactured. Electricity contributes 84% to the GHG emissions impact of utilities. Thus, producing the Perfect Day whey protein in an electricity grid with a high percentage of renewable energy could also decrease the utilities impact of electricity.

Mass allocation apportions GHG emissions to Perfect Day whey protein and the co-product high-quality pet food ingredient by 21.7% and 78.3%, respectively (based on the dry mass allocation). Therefore, a sensitivity analysis evaluated if the Perfect Day whey protein would still reduce GHG emissions compared to comparative products without this allocation by using the conservative assumption that the co-product would instead be a waste. In this way, all of the GHG burdens of the production were allocated to the Perfect Day whey protein. The results of this sensitivity analysis demonstrated that there would still be at least a 31% reduction in GHG emissions from Perfect Day whey protein relative to the comparative protein products, without any allocation by mass.

According to the Food and Agriculture Organization of the United Nations, the United States produces 97,787,000 tonnes of milk, excluding butter[7]. Assuming a 3.3% protein content, and depending on the animal protein compared, this results in 57 to 255 million tonnes of CO_2e emissions based on the GHG emissions resulting from the comparative bovine dairy proteins. If US consumers switched entirely to Perfect Day whey protein, this would result in avoiding 48 to 246 million tonnes of CO_2e emissions, which is equivalent to 5 to 28 million homes' energy use for one year or 10 to 53 million passenger vehicles driven for one year according to the US EPA Greenhouse Gas Equivalencies Calculator[8].

5.4 LIMITATIONS AND ASSUMPTIONS

The application of the results, interpretation, and conclusions of this study are limited to the proteins considered in this study. Furthermore, the results calculated for Perfect Day whey protein cannot be extrapolated or applied to the production of dairy protein by other means. Milk has other functions and provides many other nutrients such as calcium and vitamins. This study is designed to compare only environmental performance of the protein and not of other nutrients. This study was based on calculations for a co-manufacturing facility; therefore, the results may change if operational conditions for a built Perfect Day production facility may differ from the primary data used in this study. The selection of the comparative studies in itself presents a limitation since there are many dairy and whey studies with distinct methodological approaches. These methodological differences are not fully understood and are impossible to fully capture, even though this study has tried to present possible ranges of impact. There are a few recent studies published based on dairy systems in California and Pennsylvania, but these studies are limited in geographic scope have not been considered due to global aspirations of Perfect Day. While current Perfect Day production is in the US, future production and sale of the product is intended to be global, therefore comparisons were made to global production. Future global production should be modeled to account for country and regional differences in background data such as energy grid mix and ingredients sourcing.

Assumptions in this study were made to proxy certain inputs for which secondary datasets were not available, but, as previously mentioned, these inputs represented only 3.1% of the total mass of inputs. Additionally, return empty backhaul transportation was not included in the Perfect Day system boundary (nor the system boundaries of the comparative products). Given that transportation has a small impact on the overall GHG emissions of Perfect Day whey protein, the impact of this assumption is likely negligible. The application of results of this study is also limited to only the consideration of the GHG emissions environmental impact as no other impacts were considered. Future study is under consideration to include additional impacts. If, in the future, there is a clear method to apply system expansion to the co-product, this could be considered to avoid allocation by mass. Finally, the final form of this product at sale is as a powder that could be used in a variety of consumer-ready products. If, in the future, a primary final product such as fluid milk, pastry, or other product is identified, Perfect Day could consider a cradle-to-grave analysis on this full product life cycle as compared to that of a product not containing Perfect Day whey protein.

[7] http://www.fao.org/faostat/en/#data/FBS

[8] All values assume US average passenger vehicle and US homes. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

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APPENDIX C: WHEY & TOTAL LACTATED PROTEIN STUDIES

Study #	Title	System Boundary	Co-products and allocation method	Sponsor/ Funder	Notes
1	Greenhouse gas emissions in milk and dairy product chains (2012)	Cradle to gate	Special WPC, permeate, lactose, whole milk powder, skimmed milk powder, full milk powder, semi-skimmed milk, skimmed milk, yoghurt, cream, cottage cheese, butter. Weighted allocation based on price of fat and protein which are drivers of farmers milk price	Danish Agency for Science, Technology and Innovation	The data used largely represents Aria Foods. Protein content of 80% and 90% are assumed to be WPC80 and WPC 90. Whole Total lactated protein content is 3.4%. Study region: Europe.
2	Reducing food's environmental impacts through producers and consumers (2018)	Cradle to gate	No co-products. Economic allocation	University of Oxford, Agroscope (The institution of the authors. There were no funding agencies identified in the study)	Study compares multiple food groups. 1 liter of pasteurized milk is the functional unit, with a protein content of 3.3%. A liter of milk is converted to kg using a density of 1.03 kg/l. Global study.
3	Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment (2010)	Cradle to gate	Whey, cheese, milk powder, cream, fermented milk, fresh milk Protein Content allocation	International Dairy Federation (IDF), the Food and Agriculture Organization of the United Nations (The institution of the authors. There were no funding agencies identified in the study)	Study compares milk emissions across different regions. Protein content in milk is 3.3%. Global Study.
4	Life Cycle Assessment of Ripple Non-Dairy Milk (2017)	Cradle to Cradle	No co-products Economic Allocation	Ripple Foods	Study conducted across ripple milk, almond milk, soy milk, dairy milk. 1 liter of pasteurized milk is the functional unit, with a protein content of 3.4%. A liter of milk is converted to kg using a density of 1.03 kg/l. Study region: mostly USA.

APPENDIX D: CRITICAL REVIEW STATEMENT

Review of the Report "ISO-Conformant Report: Comparative GHG Emissions Assessment of Perfect Day Whey Protein Production to Dairy Protein" (Dated February 9, 2021), Conducted for Perfect Day, Inc. by WSP USA Inc.

Review Statement Prepared by the Critical Review Panel:
Corinne Scown (Chair), Pragnya Eranki, Horacio Aguirre-Villegas

February 9, 2021

The review of this report has found that:

- the approach used to carry out the LCA is consistent with the ISO 14040:2006 principles and framework and the ISO 14044:2006 requirements and guidelines,
- the methods used in the LCA appear to be scientifically and technically valid,
- the interpretations of the results reflect the limitations identified in the goals and methods of the study,
- the report is transparent concerning the study steps and consistent for the purposes of the stated goals of the study.

This review statement only applies to the report named in the title, made available to the Critical Review Panel on February 9, 2021, but not to any other report versions, excerpts, press releases, and similar derivative texts.

Corinne D. Scown
Emeryville, California

Horacio Aguirre-Villegas
Madison, Wisconsin

Pragnya Eranki
Houston, Texas