ISO-CONFORMANT REPORT

COMPARATIVE LIFE CYCLE ASSESSMENT OF PERFECT DAY WHEY PROTEIN PRODUCTION TO DAIRY PROTEIN

PERFECT DAY, INC.

VERSION 1

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EXECUTIVE SUMMARY

Perfect Day, Inc. is at the forefront of non-animal whey protein technology with their novel production pathway that is both efficient and scalable. The company commissioned this study to determine total greenhouse gas (GHG) emissions, primary energy demand (non-renewable)[1], and blue water consumption from the life cycle of the company's specific production system, and to compare these environmental impacts to those of bovine dairy protein. In this study, the total environmental impacts and the differences between the Perfect Day product and one other product (using seven literature sources for the environmental impacts of that product's production) were calculated using the Life Cycle Assessment (LCA) method. The results of this LCA will aid Perfect Day in understanding hotspots and drivers of GHG emissions, primary energy demand (non-renewable), and blue water consumption from its whey protein production as well as how those impacts compare to those of the total amount of protein found in cow's milk, hereafter referred to as "total protein in milk." The Perfect Day product is non-animal whey protein, which on a dry basis is 90% protein. The comparative protein is the total protein found in bovine milk. To show the range of potential results, seven different studies of bovine milk were chosen. Two examples of total protein in milk came from milk with 3.3% protein, four came from milk with 3.4% protein, one came from milk with 2.8% protein.

The environmental impacts selected for this study were evaluated for all products considered in order to provide the most business value to Perfect Day in its discussions with existing and potential customers and stakeholders. Internal communication of this study's results will aid in decision-making for product process improvement and provide information to the company's stakeholders who are interested in understanding the GHG emissions, primary energy demand (non-renewable), and blue water consumption 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 standards 14040 and 14044. The reviewers' findings are summarized in the verification statement at the end of this report. GHG emissions were assessed using the Global Warming Potential (GWP) based on the 100-year time scale method, excluding biogenic carbon, of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5). Biogenic carbon dioxide emissions were excluded as they are part of the carbon cycle as opposed to fossil-derived carbon emissions which release locked-up carbon into the atmosphere. The lower heating value (LHV or net calorific value), reported in megajoules (MJ), was used to determine the primary energy from non-renewable resources as a measurement of energy use from fossil resources that cannot be replenished. Blue water consumption (BWC) was quantified to capture the amount of water consumed by the system, not just the total withdrawals. This metric is measured in liters (L) of water by determining the total amount of water withdrawn from and not returned to surface and ground water 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 system boundary of analysis is from cradle to gate, including the upstream production of the materials used for the Perfect Day process (e.g., corn grain for sugar production; production of all other inputs to the process including 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 for many applications from an ingredient in high-value domesticated animal pet food or as fertilizer, to applications in the pharmaceuticals industry or as an alternative to leather; therefore, mass allocation was applied to apportion the environmental impacts between the primary product and co-product.

The primary findings of this study are illustrated in Figure ES. 1 and Table ES. 1. The GHG emissions, primary energy demand, and BWC for Perfect Day whey protein are 2.71 kg CO_2e, 56.3 MJ, and 73.9 L water per kg of protein, respectively. Perfect Day whey protein is between 91.2% and 96.6% lower in GHG emissions than that of total protein in milk. 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, which consists primarily of coal (31%), and natural gas (33%).[2] 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. The primary energy demand for Perfect Day whey protein is 28.9% and 59.7% lower than that of total protein in milk from study 2 and study 4, respectively. The primary driver of energy is utilities, which include the US average natural gas and electricity used in the protein production process. Perfect Day whey protein has a lower BWC when compared to that of total protein in milk from studies 1 and 3 by 98.7% and 96.3%, respectively. For BWC, the starch hydrolysis to produce glucose is the primary driver, with corn production being a major contributor. It is important to note that there is no single study that explores all of these different environmental impacts on a global scale.[3] Hence, a combination of studies is used to compare the Perfect Day results to total protein in milk. Seven different studies were used to cover all the impact of total protein in milk from a

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[1] This category refers to fossil energy.

[2] The US electric grid used to model represents the national average grid from the year 2016. According to the GaBi documentation for the dataset, this data set is valid between 2016 and 2022.

[3] A study was released in June of 2021 which included these impacts categories for US milk, but was not included in this study.

global perspective and European perspective. Note that studies that did not cover a specific impact category are omitted from the table in that category.

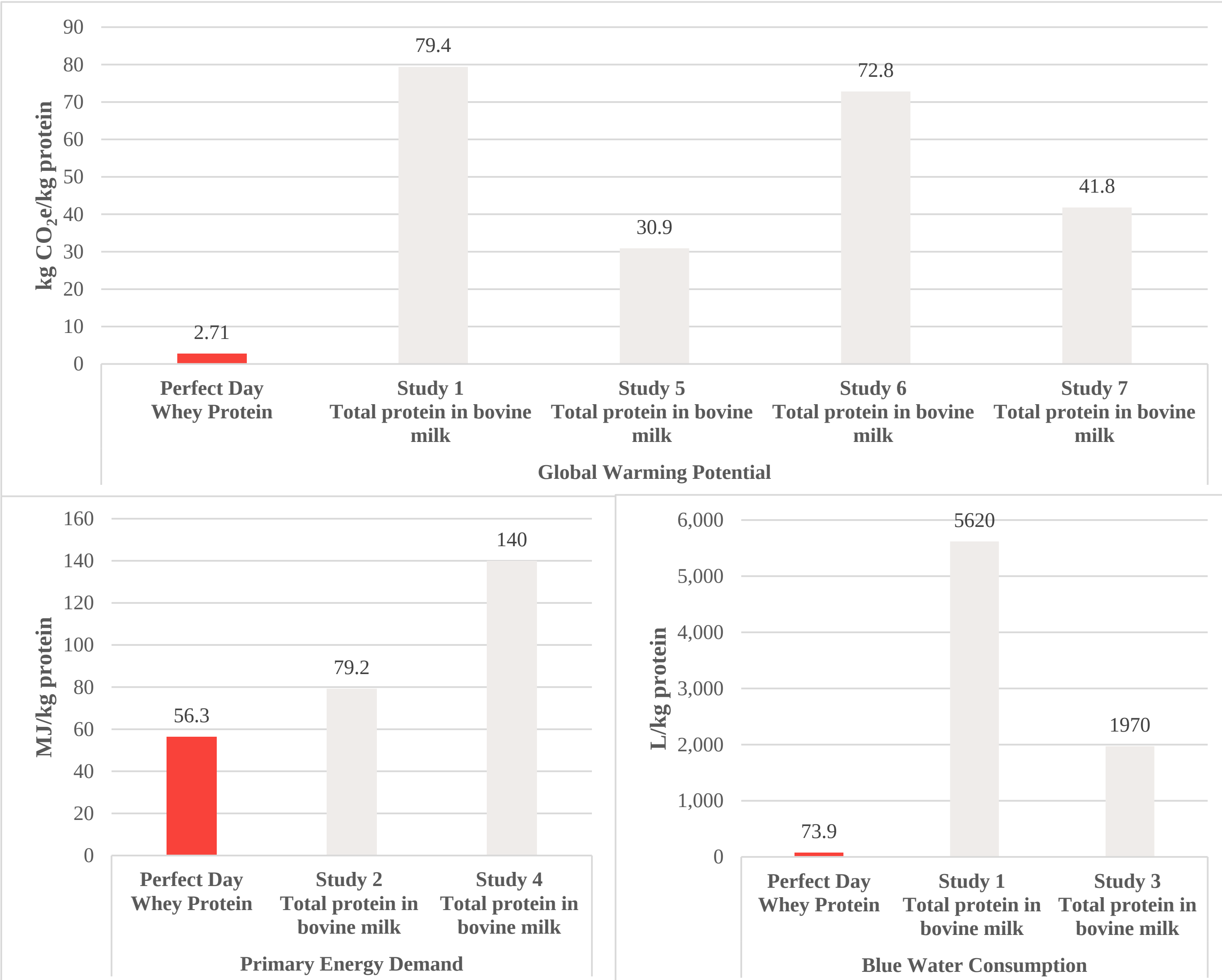

Figure ES. 1 Environmental impacts of Perfect Day whey protein compared to total protein in bovine milk per kg protein.

The application of the results, interpretations, 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.

Table ES. 1 Environmental impacts of Perfect Day whey protein compared to total protein in milk per kg protein

Impact Category	Perfect Day Whey Protein	Source and Product	Impact from Study	% Change
Global Warming Potential (kg CO_2e/kg protein)	2.71	Study 1 - Total protein in bovine milk 3.3%	79.4	-96.6%

Impact Category	Perfect Day Whey Protein	Source and Product	Impact from Study	% Change
		Study 5 - Total protein in bovine milk 3.4%	30.9	-91.2%
		Study 6 -Total protein in bovine milk 3.3%	72.8	-96.3%
		Study 7 -Total protein in bovine milk 3.4%	41.8	-93.5%
Primary Energy Demand (MJ/kg protein)	56.3	Study 2 - Total protein in bovine milk 3.4%	79.2	-28.9%
		Study 4 - Total protein in bovine milk 3.4%	140	-59.7%
Blue Water Consumption (L/kg protein)	73.9	Study 1 - Total protein in bovine milk 3.3%	5,620	-98.7%
		Study 3 - Total protein in bovine milk 2.8%	1,970	-96.3%

Allocation by mass apportions the GHG emissions, primary energy demand (non-renewable), and BWC impacts between the Perfect Day whey protein and the co-product for high-value applications. Mass allocation was used instead of economic allocation since the economic value of the co-product is unknown. For example, it is not known what other protein sources in pet food the co-product would potentially displace or what other inputs would be replaced by this coproduct in pharmaceutical applications; therefore, system expansion to avoid allocation cannot be conducted. A sensitivity analysis evaluated whether the Perfect Day whey protein would still reduce GHG emissions, primary energy demand (non-renewable), and BWC impacts compared to total protein in milk without this allocation by using the conservative assumption that the co-product would become a waste product. In this scenario, all of the environmental impacts from production would be allocated to the Perfect Day whey protein rather than between the two products. Under this assumption, the GHG emissions reduction would be between 61.8% from study 5 (study 5 has the highest GWP impact for total protein in milk) and 85.1% from study 1 (study 1 has the lowest GWP impact for total protein in milk). The primary energy demand of Perfect Day whey protein became 177% higher than that of total protein in milk in study 2 and 56.9% higher than that of total protein in milk in study 4. For BWC, the sensitivity analysis still showed that the Perfect Day whey protein decreased this impact by 94.5% compared to study 1 and 84.4% compared to study 3.

According to the United Nations Food and Agriculture Organization, the US produces 97,787,000 tonnes of milk annually, excluding butter.[4] If US consumers switched entirely to Perfect Day whey protein as a protein source from milk (assuming a 3.3% protein

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

content of milk), this would result in avoiding 246 million tonnes of CO_2e emissions, which is equivalent to 28 million homes' energy use for one year or 53 million passenger vehicles driven for one year according to the US EPA Greenhouse Gas Equivalencies Calculator.[2] According to studies 1 and 2, the same amount of milk would require 32% of the total lighting energy consumed by US residential and commercial sectors[5] and the amount of water needed by 187 billion people for daily indoor home use.[6] Therefore, deriving non-animal whey protein from Perfect Day rather than bovine dairy would lead to a reduction of approximately 18,600 billion gallons of water and 75 billion MJ energy use.

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5 https://www.eia.gov/tools/faqs/faq.php?id=99&t=3#:~:text=The%20U.S.%20Energy%20Information%20Administration,kWh)%20of%20electricity%20for%20lighting

6 https://www.usgs.gov/special-topic/water-science-school/science/water-qa-how-much-water-do-i-use-home-each-day?qt-science_center_objects=0#qt-science_center_objects

ASSESSMENT SUMMARY

Cradle-To-Gate Comparative Life Cycle Assessment	
Comparative Life Cycle Assessment of Perfect Day whey protein to total protein in milk	
Parameter	**Description**
Company Name and Contact Information	Study Commissioner: Perfect Day, Inc. 740 Heinz Avenue Berkeley, CA 94710 Contacts: Nicki Briggs nicki.briggs@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 14040 - Environmental management - Life cycle assessment - Principles and framework, ISO 14044 - Environmental management - Life cycle assessment - Requirements and guidelines
Product Names	The products under study are Perfect Day whey protein from non-animal sources, and total milk protein from bovine sources.
Product Descriptions	The Perfect Day product is non-animal whey protein. The comparative protein is 3 types of total protein in milk (with 2.8% protein, 3.3% protein, and 3.4% protein concentrations).
Functional Unit (Study Basis)	The function of the product is to provide 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 US; this product will primarily be consumed in the US, but could be consumed globally in the future. Therefore, the geographic boundary is the US.
Version and Date of Issue	Version 1 8/20/2021

1 GOAL OF THE STUDY

Perfect Day, Inc. ("Perfect Day") commissioned WSP USA Inc. ("WSP") to develop a Life Cycle Assessment (LCA) using GaBi®[7] software to calculate the GHG emissions, primary energy demand (non-renewable), and blue water consumption of Perfect Day whey protein, which is made without the use of animals. This LCA includes a comparison to the total amount of protein found in cow's milk, referred to hereafter as "total protein in milk." The goal of this study is twofold:

1. Determine the GHG emissions, total primary energy demand (non-renewable), and blue water consumption impacts of Perfect Day whey protein; and
2. Calculate the difference in the GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts between Perfect Day whey protein and total protein in milk.

1.1 REASONS FOR CARRYING OUT THE STUDY

Perfect Day is dedicated to understanding and improving the life cycle environmental 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, primary energy demand (non-renewable), and blue water consumption impacts associated with producing Perfect Day whey protein according to ISO standards 14040 and 14044 on Life Cycle Assessment. The GHG emissions, primary energy demand, and blue water consumption impacts were considered because information regarding these impacts were specifically requested by their stakeholders. Analysing these impacts will provide the most business value to Perfect Day in its discussions with customers and clients. Additionally, in the food systems space, GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts 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 GHG emissions, total primary energy demand (non-renewable), and blue water consumption impacts impacts from the life cycle of the company's specific production system and to compare such values to those of total protein in milk. 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, primary energy demand (non-renewable), and blue water consumption impacts from all cradle-to-gate life cycle phases of the protein production; and
2. To compare the GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts of Perfect Day whey protein to total protein in milk by conducting an ISO-conformant life cycle assessment with critical review.

1.3 TARGET AUDIENCE

The study results are prepared both for 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.

[7] Modeling for all systems in this study was 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 Separations & Purification process ensures there is virtually nothing else in the protein (besides a miniscule amount of residual carbohydrate, moisture, and minerals).

The product's function 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 provide 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 raw material extraction and processing, transportation, and protein production. The analysis does not include resource needs and environmental impacts embedded in infrastructure in either the primary data or secondary data collection efforts.[8]

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 gate is illustrated in Figure 2: Perfect Day Process Diagram.

[8] 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.

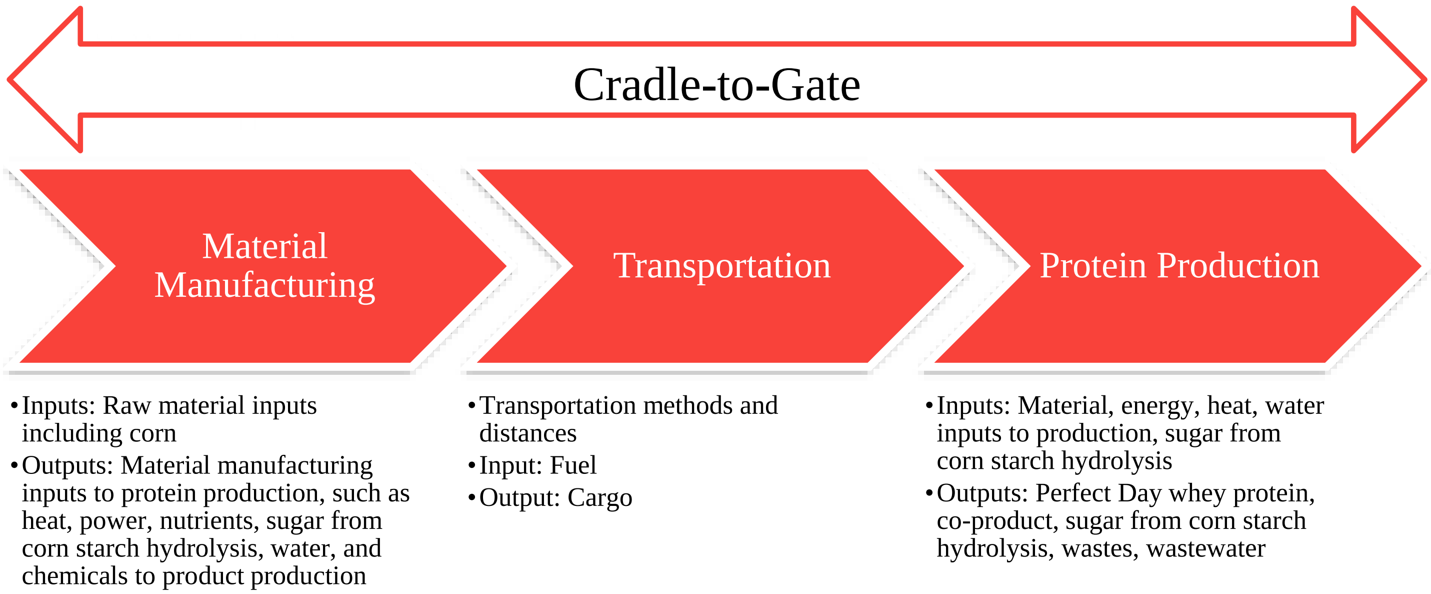

Figure 1: System Boundary

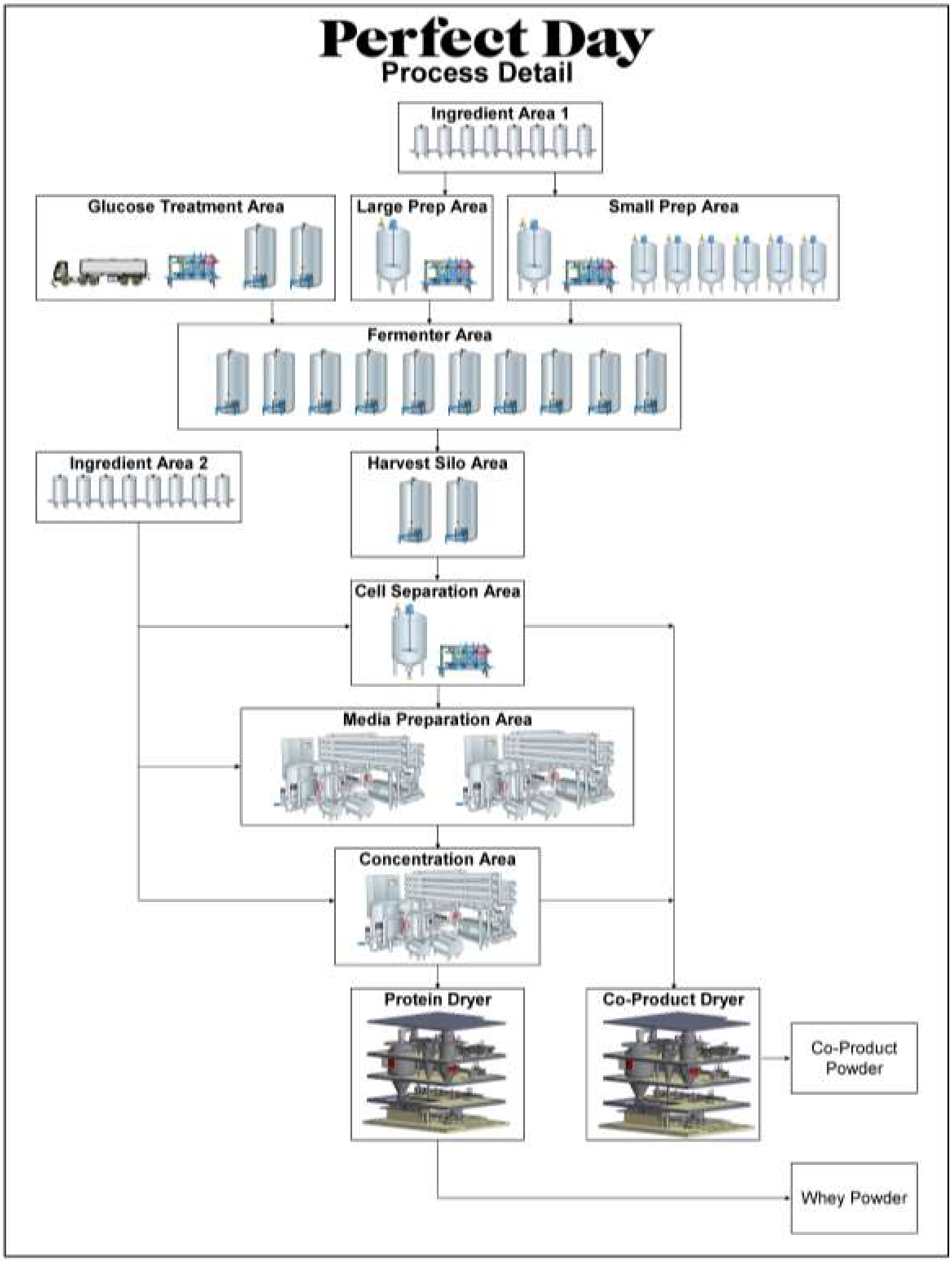

Figure 2: Perfect Day Process Diagram

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. 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., fat, carbohydrate, soluable fiber, vitamins, minerals) that make it valuable for several applications including: domesticated pet food, fertilizer, pharmaceuticals and to make a leather alternative. It is not known what other protein sources in pet food the co-product would potentially displace, nor is it known what other inputs to fertilizers, pharmaceuticals or leather alternatives or if other ingredients 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 unknown.

2.5 SENSITIVITY ANALYSIS

To be extremely conservative, we have also included a hypothetical sensitivity analysis where 100% of the production burden is 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 that would not be dried. Therefore, the energy for drying the co-product is subdivided from the system boundary and not included for this sensitivity analysis. Energy to dry the primary product is accounted for in both scenarios as this would occur regardless of the existence of a co-product.

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 Sphera dataset was used to model water, electricity, and natural gas. The dataset used for the different ingredients is listed in a confidential appendix. This section describes how various sources of primary product activity data have been collected for each phase of the product life cycle. This section also describes the process for sourcing and evaluating literature sources for the comparative bovine 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 US; 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 unknown 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 assumed to average 100 miles[9]. 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 a confidential appendix. Empty truck backhauls were not included in this analysis for Perfect Day to align with the system boundaries of the bovine dairy proteins. It was assumed that the datasets for the comparative bovine dairy 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, minerals and vitamins, and 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 the main production fermenter to achieve a highly efficient expression of the target protein. 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[10] (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, producing 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. Microfiltration and further filtering are then used to remove soluble impurities (antifoam, salts, and unbound proteins) from the remaining solids, resulting 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, withtrace impurities remaining. All final product is dried using an indirect tall-form spray dryer and

[9] 100 miles is a conservative transportation radius from a future plant location. Proximity to ingredient suppliers is a consideration in site selection.
[10] The gaseous oxygen in the fermenter is air, there is not a purchase of oxygen.

packed in bags. The powder is agglomerated and has a final moisture content of less than 4%, and the protein content of the powder is at 90%.

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 a confidential appendix.

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 a co-product and do not go to wastewater treatment.

ELECTRICITY GRID MIX

It was assumed that the electricity grid mix and the natural gas used for process equipment is the US average since the final production facility has not been determined. The production of electricity was modeled using the GaBi® US average electricity grid mix database (data valid from 2016 to 2022). The US electricity grid mix from this dataset consists primarily of coal (31%), natural gas (33%), nuclear (20%), hydro (7%), wind (5%), and biomass and photovoltaic (1% each). According to the US Energy Information Administration, the US electricity grid mix in 2020 consists of coal (20%), natural gas (39%), nuclear (21%), hydro (8%), wind (9%), and photovoltaic (2%) and biomass (1%).[11] The shift in production of energy is mostly from coal to natural gas. Fossil energy is still the primary source of electricity.The environmental impact from natural gas and electricity will be different based on the location where the product is being produced.

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 where 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. All cleaning products are approved for use in food production.

The inputs and output amounts for the cleaning process are provided in a confidential appendix.

3.1.2 COMPARATIVE DAIRY PROTEIN

GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts per kg of protein from the Perfect Day whey protein are compared to that of total protein in milk from dairy cows. This approach was taken to compare the Perfect Day whey protein's performance to that of total protein in milk products that are more extensively available in the commercial market. Therefore, data from published literature sources on GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts were extracted for milk and then scaled to represent impacts of total protein in milk (with 2.8% protein, 3.3% protein, and 3.4% protein). Studies 1, 5, 6, and 7 estimated GHG emissions for total protein in milk. Study 1 and study 3 provided blue water consumption impact results for use in this study. Study 2 and study 4 provided primary energy demand impact results for use in this report. Milk with different protein contents are presented in studies 1 through 4. 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 protein in milk). Studies 2, 3, and 4 present the results in terms of fat- and protein-corrected milk (FPCM). There is a set relationship between 1 kg of milk and 1 kg FPCM (1 kg FPCM = 1 kg milk*(0.337 + 0.116 * fat % + 0.06 * protein %)). The scaling of results for comparison from studies using FPCM as a functional unit is direct scaling. It is essential to use the fat and protein percentages from the studies to estimate total protein in milk.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. When global studies were not available, European studies were selected based on input from Perfect Day. 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

[11] https://www.eia.gov/outlooks/steo/data/browser/#/?v=22

on region, climate, management practices, and several other factors that influence GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts from dairy. Also, no single study contained all of the relevant information for comparison of all environmental impacts over a range of global means of production; therefore, comparing results from multiple studies is meant to ensure accurate comparison to the wide range of potential impacts of protein from bovine dairy milk. and the results from the seven studies.

Table 1 and Table 2 provide some key characteristics and the results from the seven studies.

Table 1: Comparative studies characteristics

Study #	Literature Title	Functional Unit	System Boundary	Allocation Method	Region
1	**Reducing food's environmental impacts through producers and consumers (Poore & Nemeck, 2018)**	1 L of milk	Cradle to gate	Economic allocation	Global
2	**An operational method for the evaluation of resource use and environmental impacts of dairy farms by life cycle assessment (van der Werf et al, 2009)**	1000 kg FPCM sold	Cradle to farm gate	System division and economic allocation	France
3	**Assessing environmental impacts associated with freshwater consumption along the life cycle of animal products: the case of Dutch milk production in Noord-Brabant. (De Boer et al, 2012)**	1 kg FPCM	Cradle to farm gate	Economic allocation	Netherlands
4	**Life cycle assessment of conventional and organic milk production in the Netherlands (Thomassen et al, 2008)**	1 kg FPCM	Cradle to farm gate	Economic allocation	Netherlands
5	**Greenhouse gas emissions in milk and dairy product chains (Flusjo, 2012)**	1 L of milk	Cradle to gate	Weighted allocation based on price of fat and protein which are drivers of milk price	Denmark
6	**Greenhouse gas emissions from the dairy sector: A life cycle assessment (FAO Animal Production and Health Division, 2010)**	1 kg of FPCM	Cradle to gate	Protein content allocation	Global
7	**Life cycle assessment of Ripple non-dairy milk (Life Cycle Associates LLC, 2017)**	1 kg of protein	Cradle to grave	Economic allocation	United States

Table 2: Data ranges from literature

Study # and Title	Product (Protein %)	Functional Unit	Greenhouse Gas Emission	Blue Water Consumption	Energy
1. Reducing food's environmental impacts through producers and consumers	Milk (3.3%)	1 L of milk	Range: 1.8 to 4.8 kg CO_2e Value used: Median, 2.7 kg CO_2e	Range: 19 L to 2664 L Value used: Median, 191 L	Not quantified in study
2. An operational method for the evaluation of resource use and	Milk (3.4%)	1000 kg FPCM sold	Value from study: 1037 kg CO_2e (not included in this report)	Not quantified in study	Range: 2.5 GJ to 3.2 GJ Value used: Mean, 2.8 GJ

Study # and Title	Product (Protein %)	Functional Unit	Greenhouse Gas Emission	Blue Water Consumption	Energy
environmental impacts of dairy farms by life cycle assessment					
3. Assessing environmental impacts associated with freshwater consumption along the life cycle of animal products: the case of Dutch milk production in Noord-Brabant	Milk (2.8%)	1 kg FPCM	Not quantified in study	66.4 L	Not quantified in study
4. Life cycle assessment of conventional and organic milk production in the Netherlands	Milk (3.4%)	1 kg FPCM	Value from Study: 1.5 kg CO_2e (not included in this report)	Not quantified in study	Range: 4.4 MJ to 5.6 MJ Value used: Mean, 5 MJ
5. Greenhouse gas emissions in milk and dairy product chains	Milk (3.4%)	1 L of milk	1.05 kg CO_2e	Not quantified in study	Not quantified in study
6. Greenhouse gas emissions from the dairy sector: A life cycle assessment	Milk (3.3%)	1 kg of FPCM	Range: 1 to 7.5 kg CO_2e Value used: Mean, 2.4 kg CO_2e	Not quantified in study	Not quantified in study
7. Life cycle assessment of Ripple non-dairy milk	Milk (3.4%)	1 kg of protein	41.8 kg CO_2e	Not quantified in study	Not quantified in study

STUDIES USED TO COMPARE TO MILK PROTEIN GHG IMPACTS

Study 1 is a meta-analysis of various food groups, including dairy, from different parts of the world and was 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. According to the supplementary material provided, the freshwater withdrawals results are not based on any specific LCA methodology. Freshwater withdrawals were characterized by irrigation, drinking, pond, and processing water.

Study 5 is a PhD thesis from Aarhus University and was funded by the Danish Agency for Science, Technology and Innovation at Copenhagen, Denmark and was initiated with Arla Foods in an effort to promote a more sustainable dairy sector. Arla Foods, a key partner in this study and compensates farmers based on fat and protein content. This study explored aspects of methodology that estimate milk and dairy emissions (Flysjö, 2012), including the carbon footprint (CF) for different types of dairy products. The emissions are estimated using a cradle-to-farm-gate system boundary such that 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 even though they were considered in the published study. The dissertation was published as five peer reviewed journal articles that explore the effects of key parameters (such as management practices and co-product allocation) on the carbon footprint. Among the products examined in this study was total bovine milk with a 3.4% protein concentration including the results for the GHG impact per kg of product, where the protein content was scaled to 100% to represent the impacts per kg of protein. A unique co-product allocation method was followed in which milk solids are allocated based on the price the farmer is paid for the raw milk.

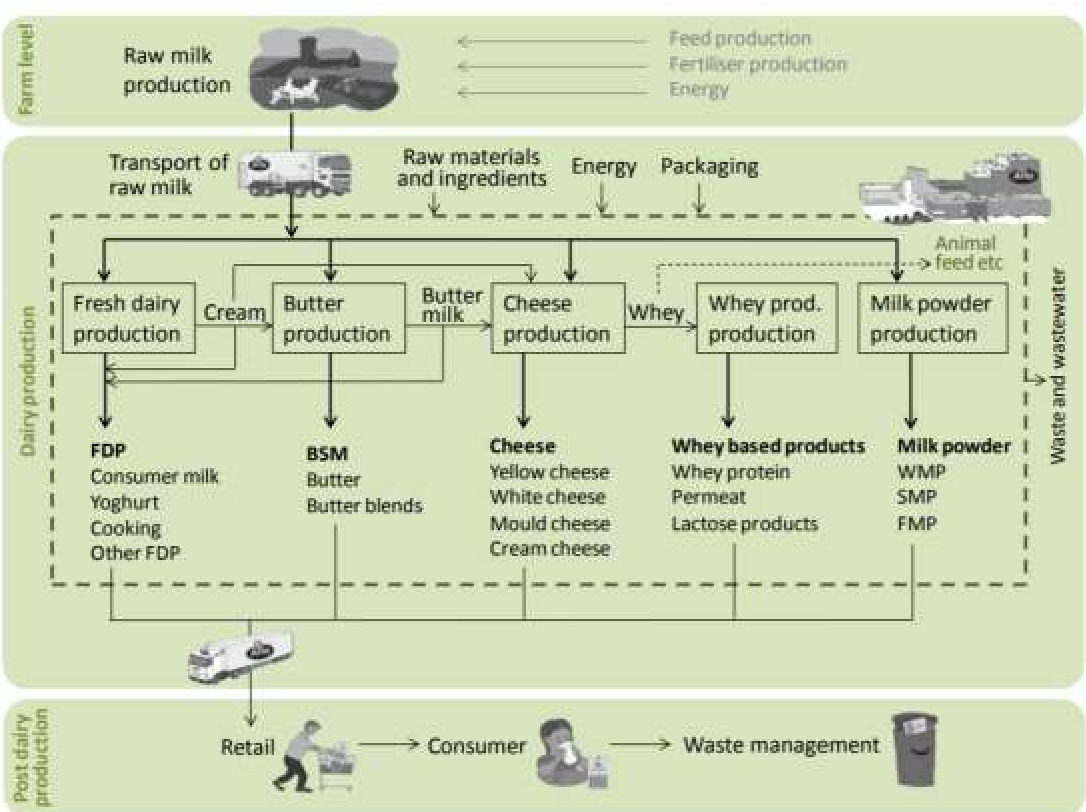

Figure 3: Flow chart of lifecycle of dairy products by group from study 5. Source: Greenhouse Gas Emissions in Milk and Dairy Product Chains by Anna Flysjö.

Study 6 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.

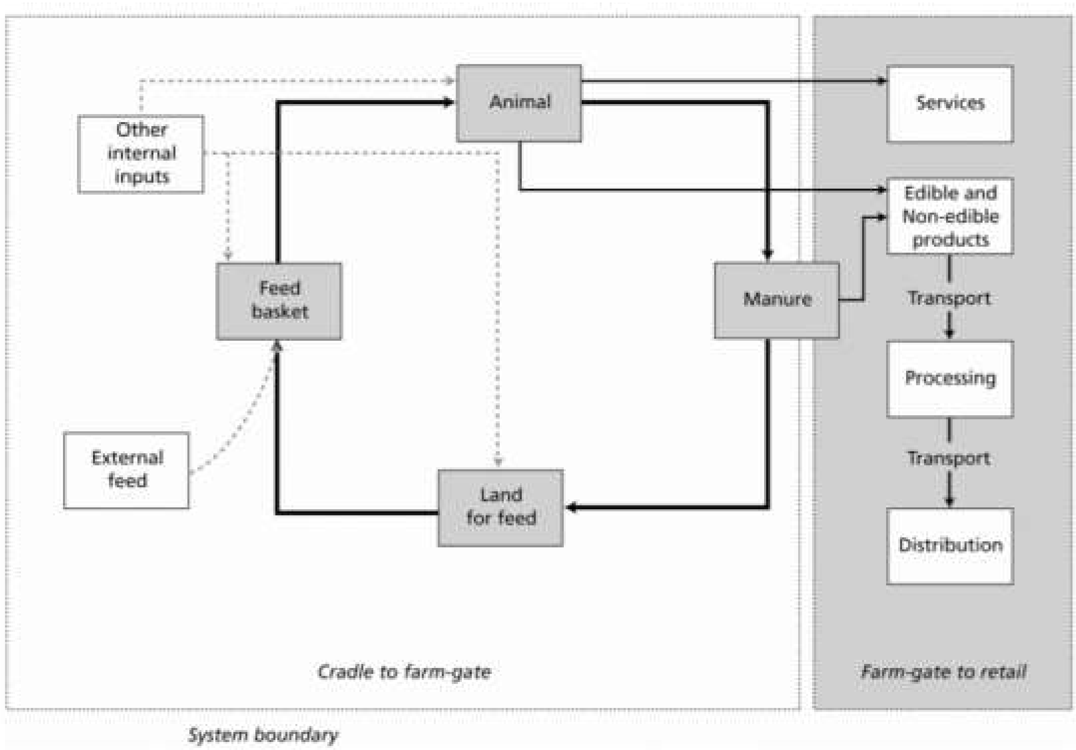

Figure 4: System boundary for the analysis in study 6. Source: Greenhouse Gas Emissions from the Dairy Sector by FAO.

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);
    - e
    - 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 bovine 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 7 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, which assumes a 3.4% total protein content in bovine milk. The carbon intensity of dairy milk was taken from two 2013 studies (Thoma, et al., 2013a; Thoma, et al., 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.

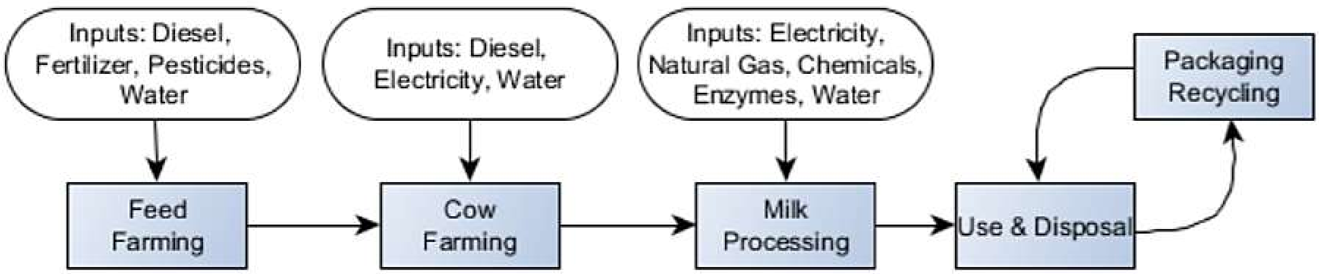

Figure 5: System boundary of dairy system studied in study 7. Source: Life Cycle Assessment of Ripple Non-Dairy Milk by Life Cycle Associates, LLC.

Allocation in this study follows a unique approach presented in another study from 2013 (Thoma, Jolliet, & Wang, 2013) in which 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. Study 7 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.

The GHG emissions data from studies 2 and 4 are not included in this comparison. The GHG comparison focuses on the global production of protein from milk that is not influenced by specific geographical features and regional dairy practices that are not common globally. The values reported in study 2 and study 4 are 29.3 and 42.0 kg CO_2e per kg of protein. The range of global emissions from studies 1, 5, 6, and 7 vary between 30.9 and 79.4 kg CO_2e per kg protein. It is clear that the emissions from study 2 and study 4 are already represented within the range of impact. Moreover, studies 2 and 4 are specific to France and Netherlands. Study 3, a study from Netherlands, is preferred as a representative of the GHG emissions impact from milk production in Europe because of its allocation method. Both studies 2 and 4 apply economic allocation, while study 5 applies a fat and protein based allocation. Fat and protein content determine quality of milk and therefore the price of milk (Flysjö, 2012). When data are available, this is considered a more consistent allocation method with the methodology in the Perfect Day study, and also, by using this study, the comparison accounts for all possible variations in GHG emissions. Management practices also vary from country to country, in fact they vary from region to region within the same country. These management practices, including feeding patterns, can change the GHG emissions from different regions (Kleppel, 2020). European systems are typically industrialized systems that employ concentrated animal feeding operations (CAFOs) to feed and manage 700 or more cattle (Kleppel, 2020) to drive milk production efficiency. On the other hand, Asian systems are small holder systems that typically follow a low input low output model (Moran & Chamberlain, 2017). Using study 2 and study 4 would disproportionately represent European cattle management systems in the results. One key consideration is that Studies 1, 5, 6, and 7 set out to estimate the GHG of dairy systems but studies 2 and 4 set out to compare the differences in GHG emissions from conventional dairy production and organic dairy production. Study 2 and study 4 are still used to compare energy impacts, due to the lack of data and present the best option for comparison.

STUDIES USED TO COMPARE TO MILK PROTEIN ENERGY IMPACTS

Study 2 is a study that uses Evaluation de la Durabilite´ des ExploitatioNs (EDEN), an operational method, based on the life cycle assessment conceptual framework, for the environmental as well as social cost evaluation of dairy farms (van der Werf, Kanyarushoki, & Corson, 2009). This study compared the impacts created from organic farms and conventional dairy farms. The EDEN-E method specifically estimates environmental performance using the following inputs: energy carriers (e.g., diesel, natural gas, electricity, lubricants), pesticides, plastic sheeting, agricultural machines, operations carried out by agricultural contractors (e.g., ploughing, ensiling a crop), mineral fertilizers (e.g., nitrogen (N), phosphorus (P), potassium (K), lime), concentrated feed (including cereals, pulses, seed cake, dried lucerne), fodder and stable bedding (e.g., hay, silage, straw), and animals. The input amounts used for this study were taken directly from the farm's records, except for agricultural machines, which have a lifetime exceeding one year. For machines, allocation was performed according to the hours (or hectares) of use within the year under consideration compared to the total hours (or hectares) of use over the life of the machine. Most on-farm emissions of pollutants are not linearly related to the amounts of farm inputs used. This study used an approach that estimates emissions as much as possible directly at the farm scale, based largely on farm-gate balances. The study avoided allocation between animal and crop products by separating the farms into two parts: production of crop products not used for animal production and all other farm processes, which included only the farm inputs and outputs that feed for animals. After processing, remaining environmental interventions were due only to milk and animal production. Economic allocation was then used to allocate remaining environmental impacts between milk and animal production. This method employs the LCA thinking and the broader LCA conceptual framework but does not use any of the existing LCA impact category metrics to calculate and present impacts and hence cannot be considered to be traditional LCA.

Study 4 compares the environmental impact assessment of conventional and organic milk production systems and identifies hotspots in the conventional and organic milk production chains. The LCA of conventional and organic milk production systems was based on data of 21 commercial dairy farms: ten conventional commercial dairy farms and eleven organic commercial dairy farms. For each dairy farm, a detailed cradle-to-farm-gate LCA was performed (Thomassen, van Calker, Smits, Iepema, & de Boer, 2008). The system under study included the whole life cycle required for the production of raw milk from the production and transport of fertilizer, pesticide, concentrates, roughage, and bedding; transport of animals and animal manure; and supply and use of fuels and electricity. It excluded the transport and processing of raw milk. Several multifunctional processes were present: the production of roughage, bedding material, and ingredients for concentrates, and the joint production of milk, meat, roughage, and manure leaving the farm gate. Economic allocation based on shares in proceeds of the products was performed for multifunctional processes. This study references the Handbook on Lifecycle Assessment in its design and hence uses the ReCiPe impact category method to evaluate the impacts.

STUDIES USED TO COMPARE TO MILK PROTEIN BLUE WATER CONSUMPTION IMPACTS

The water consumption impacts from study 1 is again used to compare to the blue water consumption of Perfect Day whey protein. It is also important to note that these studies do not explicitly state all their irrigation assumptions for the corn into the feedstock.

Study 3 focuses on the environmental impact of consumptive water use in the dairy life cycle. This cradle-to-farm-gate LCA included freshwater use related to cultivation of crops used to produce purchased feed (i.e., concentrates and roughage), the processing of concentrates at the feed mill, production of energy and artificial fertilizer purchased by the dairy farm, on-farm cultivation of grass or maize, and water required for dairy cattle husbandry (e.g., drinking and cleaning water). Freshwater use related to transport of feed ingredients to the feed mill and from the feed mill to the farm was also included (de Boer, et al., 2012). The study used economic allocation for production of feed ingredients because this allocation method is mostly used in LCAs of milk products and is recommended by the International Dairy Federation's guide for LCA. Water use required for cultivation of citrus pulp and palm kernel expeller was excluded from the analysis due to their low economic allocation factor. This work studied in detail the various sources and sinks of water within the system and developed a net water consumption based on the available data.

The seven studies discussed above establish the GHG emissions, primary energy use, and blue water consumption of bovine milk. The bovine milk across these studies have varying protein content as shown in Table 2. Additionally, studies 2–4 represent the impacts in terms of fat- and protein-corrected milk. These values are converted back to kg of milk using the fat and protein contents of milk presented in these studies. Moreover, study 3 assumes the milk protein concentration to be similar to that of broccoli and presents a fat content range from 1% to 6%. Broccoli's protein content of 2.8% and 6% of fat is conservatively assumed (Bhattacharjee & Singhal, 2018). The density of bovine milk, 1.03 kg/L, is used to convert the volume of milk from liters to kg. To assess the environmental impacts per kg of protein, the different impact category results are scaled linearly by increasing the protein content in milk from the current protein content to 100% across these individual studies. By doing so, the Perfect Day whey protein product can be compared to total protein in bovine milk.

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 whey protein production process and compare these impacts to that of literature data on GHG emissions, primary energy use, and bluewater consumption for total protein in bovine milk. Results were exported from GaBi® to Microsoft Excel® for 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 Sphera as well as external review by DEKRA.[12]

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 it would not be dried. The base case scenario includes an additional drying process the co-product undergoes before it is sold to the market, resulting in a 21.7% allocation to Perfect Day whey protein. 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. Since the co-product is now treated as a waste in this sensitivity analysis, the waste treatment was modeled using the US solid waste to landfill dataset. The mass of waste to landfill is calculated as the remaining 78.3% of the total production. Therefore, in the sensitivity case, all of the production burdens are put on the Perfect Day whey protein and no allocation is performed.

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. 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.[13]

[12] http://www.gabi-software.com/uploads/media/131211_GaBi_Review_Report_Verification_Statement_signed_DEKRA.pdf
[13] 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 reported in carbon dioxide equivalents (kg CO_2e). The low heating value (LHV or net calorific value) approach was used to determine the primary energy from non-renewable resources and is measured in megajoules (MJ). Blue water consumption is measured in kilograms of water (kg of water) by determining the total amount of water withdrawn from surface and ground water sources. The blue water consumption results from GaBi® are given in kilograms (kg), but in the metric system, one kilogram of water is equal to one liter of water, hence the results are presented in terms of liters (L) of water. This metric is a midpoint assessment method.

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 dioxide is part of the natural cycle; fossil-derived carbon use releases locked-up carbon to the atmosphere. Biogenic carbon emissions were excluded as they are part of the carbon cycle as oposted to fossil-derived carbon emissions which release locked-up carbon into 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

Impact per kg protein	Perfect Day Total	Protein Development	Separations & Purification	Cleaning	Transportation	Utilities	Wastewater Treatment
IPCC AR5 GWP100, excl biogenic carbon kg CO_2e	**2.71**	0.670	0.352	0.552	0.0510	1.08	0.00358

Figure 6 illustrates that the largest contributor to GHG emissions is utilities, which 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. Electricity from the US electric grid contribuges to 81% of the utility GHG emissions, while natural gas contributes 19% of the Utility GHG emissions. The electricity grid mix consists primarily of coal (31%), natural gas (33%), nuclear (20%), hydro (7%), wind (5%), and biomass and photovoltaic (1% each). The US electric grid dataset used in the model represents the national average grid from the year 2016. According to the GaBi documentation for the dataset, this data set is valid between 2016 and 2022. The largest contributors to GHG emissions within the utilities category are electricity used for the protein processing (50%) and 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, both of which release significant GHG emissions. Within this glucose LCI dataset, four different types of allocation are applied. Allocation by exergetic content (exergy is the energy that is available to be used) is applied to the combined heat and power production. Impacts from electricity generation and co-products are allocated by economic value due to the lack of common physical properties. Low heating value (net caloric value) and mass based allocation are utilized for the refinery impacts. For the production of combined crude oil, natural gas, and natural gas liquids, allocation by net caloric value is applied.

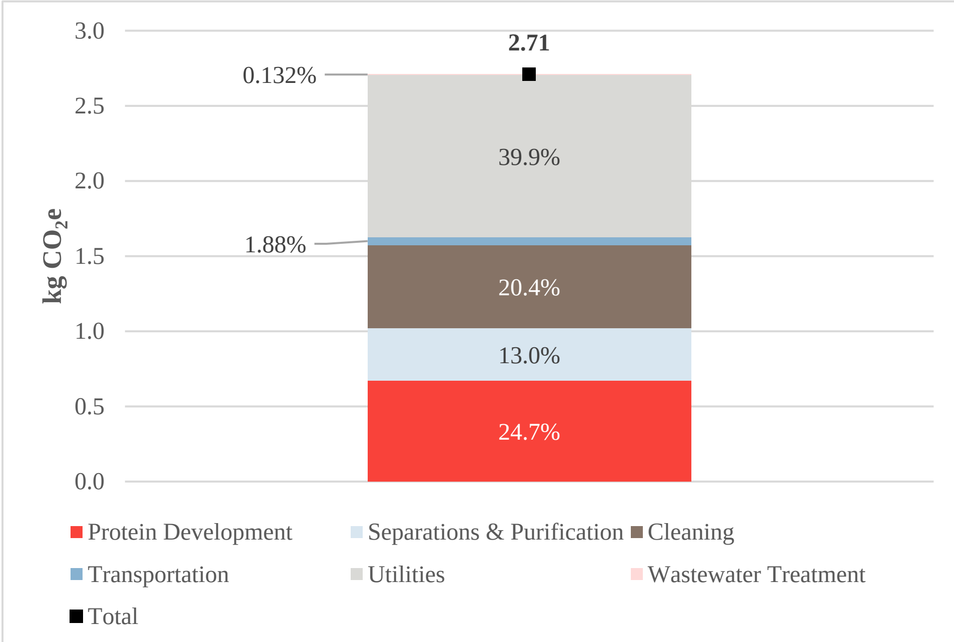

Figure 6: Relative contribution of life cycle inputs to Perfect Day whey protein GHG emissions excluding biogenic carbon

Cleaning and Separations & Purification processes are important phases that also contribute considerably to the GHG emissions of Perfect Day whey protein 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, contributing 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 Separations & Purification processes phase, calcium acetate is the largest contributor to GHG emissions during cleaning, contributing 61% of the cleaning GHG emissions during that phase. The contribution of carboxymethyl cellulose powder is the second highest, at 19%, within the Separations & Purification 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.

The GHG savings in Perfect Day whey protein compared to total protein in milk is 96.6%, 91.0%, 96.3%, and 93.5% across studies 1, 5, 6, and 7 respectively. According to studies 1, 5, 6, and 7 the GHG emissions for milk, and hence total protein in milk, is driven by the farming stage which involves the production of milk. Feed production and cattle eructation are key activities that add to GHG emissions from milk. The fossil fuel based energy embedded in water as well as fertilizers are also identified as contributors to GHG emissions within feed production.

Table 4: Perfect Day whey protein emissions comparison with total protein in bovine milk

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
Total protein in bovine milk (3.3% protein) - Study 1	2.71	79.4	-96.6%
Total protein in bovine milk (3.4% protein) - Study 5		30.9	-91.2%
Total protein in bovine milk (3.3% protein) - Study 6		72.8	-96.3%
Total protein in bovine milk (3.4% protein) - Study 7		41.8	-93.5%

4.2.2 PRIMARY ENERGY DEMAND (NON-RENEWABLE RESOURCES)

Embodied primary energy includes all energy, direct and indirect, used to transform or transport raw materials into products, including inherent energy contained in raw or feedstock materials that are also used as common energy sources. The primary energy demand from non-renewable sources impact category represents the amount of energy demanded from the ecosystem. This category specifically refers to energy from fossil fuels. The utilities and the protein development stages are the top two contributors to Perfect Day whey protein, as shown in Table 5 and Figure 7. Electricity and natural gas are the top drivers of impact within the utilities stage, while glucose and ammonia sulfate production drive impacts within the protein development stage.

Table 5 Energy demand results per project life cycle phase for Perfect Day whey protein

Impact per kg protein	Perfect Day Total	Protein Development	Separations & Purification process	Cleaning	Transportation	Utilities	Wastewater Treatment
Primary energy from non-renewable resources **MJ**	**56.3**	10.5	6.58	8.92	0.734	29.6	0.0167

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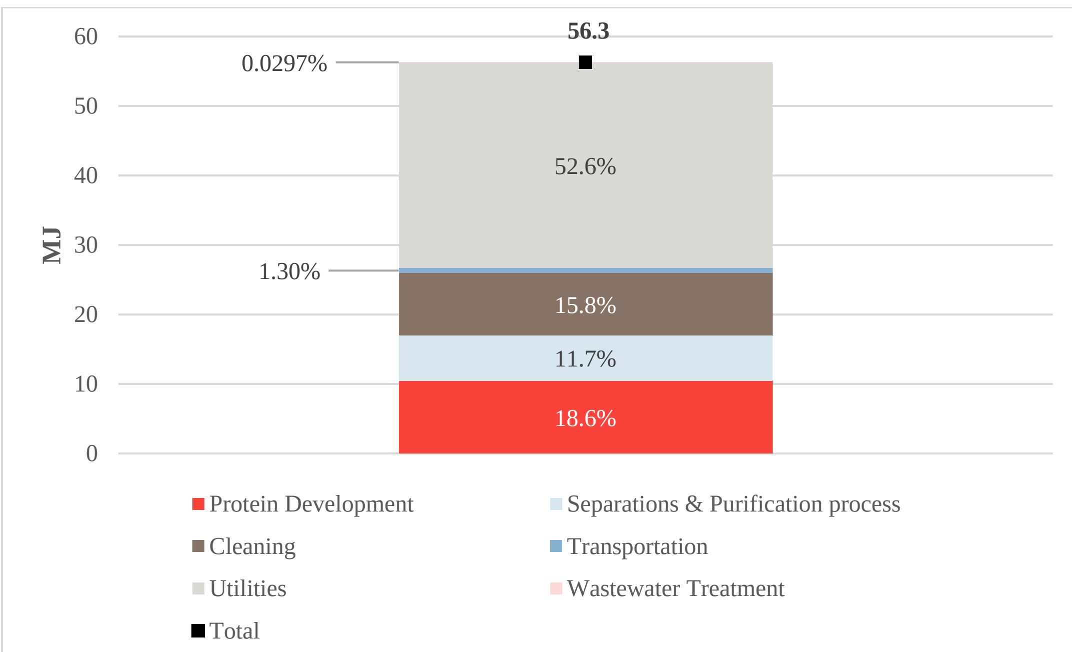

Figure 7: Relative contribution of life cycle inputs to Perfect Day whey protein primary energy demand

As shown in Table 6, the primary energy demand for Perfect Day whey protein is 28.9% to 59.7% lower than that of total protein in milk. According to studies 2 and 4, indirect energy use is the main contributor to energy demand contributing 70% and 88% respectively. The range of values in energy impacts arises from the different system boundaries around fossil fuel energy in each study. Study 2 accounts only for the direct energy content of fossil fuel use (the energy in the fuel), while study 4 accounts for both the direct and indirect (the energy for fuel production) fossil fuel energy. In both studies, indirect energy demand also included the energy needed to produce and transport feed and other concentrates.

Table 6: Perfect Day whey protein primary energy impacts comparison with total protein in bovine milk

Product	Perfect Day whey protein primary energy (non-renewable) impacts MJ / kg protein	Comparative product primary energy (non-renewable), impacts kg CO_2e / kg protein	% difference of Perfect Day whey protein compared to comparative products
Total protein in bovine milk (3.4% protein) – Study 2	56.3	79.2	-28.9%
Total protein in bovine milk (3.4% protein) – Study 4		140	-59.7%

4.2.3 BLUE WATER CONSUMPTION

Blue water consumption is the volume of surface and groundwater consumed (or otherwise made unavailable by evaporation or fouling) as a result of the production of a good or service.[14] The top two drivers of water consumption for the Perfect Day whey protein are protein development (68%) and cleaning (19%), as shown in Table 7 and Figure 8. Glucose and vegetable oil drive the impacts within the protein development stage due to the large water consumption associated with corn and other agricultural produce used for starch hydrolysis and vegetable oil production. This corn dataset is a US average corn dataset which includes and average of water consumtion from irrigation and rain.Agricultural water input through irrigation and other sources for the data set used is derived from the feedgrains database with the USDA (USDA Economic Research Service, 2010) Soap production and citric acid drive impacts within the cleaning stage. Wastewater treatment results in a negative value because water is treated and returned to the blue water system from which water was withdrawn in a usable form.

Table 7 Blue water consumption results per project life cycle phase for Perfect Day whey protein

Impact per kg protein	Perfect Day Total	Protein Development	Separations & Purification process	Cleaning	Transportation	Utilities	Wastewater Treatment
Blue water consumption L	**73.9**	50.1	4.47	14.0	0.137	12.6	-7.37

[14] https://waterfootprint.org/en/water-footprint/glossary/#:~:text=year%20to%20year.-,Blue%20water%20footprint,or%20incorporated%20into%20a%20product

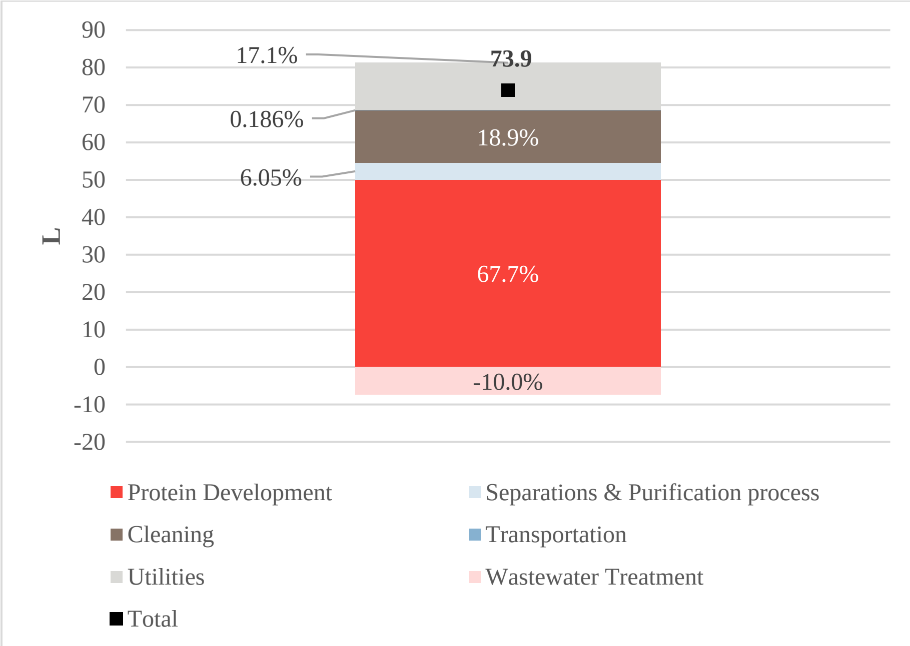

Figure 8: Relative contribution of life cycle inputs to Perfect Day whey protein blue water consumption

As shown in Table 8, Perfect Day whey protein has a lower blue water consumption compared to total protein in bovine milk from study 1 by 98.7% and from study 2 by 96.3%. The primary driver of water consumption in both studies 1 and 3 is water for feed production. Study 1 is a global study which accumulated data from a variety of countries with varying climates and water management practices and which were then averaged to create a globally representative value that can vary widely. Study 3 is a European study that reflects more effective water management and conservation efforts in agriculture. This helps explain the wide difference in values between the two studies. Nevertheless, Perfect Day whey protein has significantly lower BWC impacts compared to global or EU average total protein in bovine milk.

Table 8: Perfect Day whey protein blue water consumption impacts comparison with total protein in bovine milk

Study Title	Perfect Day whey protein blue water consumption impacts L / kg protein	Comparative product blue water consumption impacts L / kg protein	% difference of Perfect Day whey protein compared to comparative products
Total protein in bovine milk (3.3% protein) – Study 1	73.9	5,620	-98.7%
Total protein in bovine milk (2.8% protein) – Study 3		1,970	-96.3%

4.3 SENSITIVITY ANALYSIS RESULTS

To test the sensitivity of the environmental impact results to the effects of allocation, the results were adjusted to remove allocation and treat the co-product as a waste with no value. In this sensitivity analysis, the allocation of environmental impacts from Perfect Day whey protein production was increased from 21.7% to 100%. The results of this sensitivity analysis for Perfect Day whey protein and the resulting percent differences in impacts between Perfect Day whey protein and total protein in bovine milk are given in Table 9. This resulted in a 335% increase in GHG emissions, a 290% increase in primary energy demand, and a 316% increase in blue water consumption compared to the base case for Perfect Day whey protein. The drivers of each 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. This highlights that the drying of the co-product has minimal effect on all the impacts considered in this study.

The GHG emissions reductions for Perfect Day whey protein compared to total protein in bovine milk were still at least 61.7% even when the allocation to the co-product was removed. The primary energy demand of Perfect Day whey protein became 177% higher than that of total protein in bovine milk in study 2; 56.9% higher than that of total protein in bovine milk in study 4 as a result of the sensitivity analysis. For blue water consumption, the sensitivity analysis still showed that the Perfect Day whey protein decreased this impact by 94.5% compared to study 1 and 84.4% compared to study 3.

Table 9: Impacts of Perfect Day protein after the burden of impacts is allocated 100% to the whey product. Table also compares the sensitivity analysis results to environmental impacts of total protein in bovine milk from the seven studies.

Impact Category	Perfect Day whey protein impacts per kg protein	Study and Protein %	Comparative product impact per kg protein	% difference
IPCC AR5 GWP100, excl biogenic carbon ($kg\ CO_2e$)	11.8	Study 1 - Total protein in bovine milk 3.3%	79.4	-85.1%
		Study 5 - Total protein in bovine milk 3.4%	30.9	-61.7%
		Study 6 - Total protein in bovine milk 3.3%	72,8	-83.8%
		Study 7 - Total protein in bovine milk 3.4%	41.8	-71.7%
Primary Energy Demand (MJ)	219	Study 2 - Total protein in bovine milk 3.4%	79.2	177%
		Study 4 - Total protein in milk 3.4%	140	56.9%
Blue Water Consumption (L)	307	Study 1 - Total protein in bovine milk 3.3%	5,620	-94.5%
		Study 3 - Total protein in bovine milk 2.8%	1,970	-84.4%

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 environmental impact category metric for quantifying GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts and cannot be generalized or applied to other environmental impacts.

4.5 DESCRIPTION OF PRACTICIONER VALUE CHOICES

The practitioner value choices have been limited to the selected LCIA and the allocation 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 and water consumption may be a negative or a positive environmental impact depending on the conditions in locations where emissions or resource consumption 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

The GWP, primary energy use, and blue water consumption for Perfect Day whey protein are 2.71 kg CO_2e, 56.3 MJ, and 73.9 L water per kg of protein, respectively. Based on the results presented in Section 4.2 for the base case scenario, Perfect Day whey protein reduces GHG emissions significantly when compared to all four comparison studies of GHG emissions for total protein in bovine milk. The GHG emissions from Perfect Day whey protein are between 91.2% and 96.6% lower than the comparative total protein in bovine milk. The primary driver of GHG emissions for Perfect Day whey protein are the utilities, which contribute 40% to the total GHG emissions. The protein development phase is the second largest contributor (25%) to total GHG emissions.

The primary energy demand for Perfect Day whey protein is 28.9% and 59.7% lower than that of total protein in bovine milk from studies 2 and 4, respectively. The driver of primary energy demand (non-renewable) for Perfect Day whey protein are the utilities, which contribute 53%. Utilities include the US average natural gas and electricity used in the protein production process. The electricity grid mix consists primarily of coal (31%) and natural gas (33%).

Perfect Day whey protein has a lower blue water consumption compared to total protein in bovine milk from studies 1 and 3 by 98.7% and 96.3%, respectively. The protein development drives blue water consumption impacts by contributing 68%, within which glucose drives 98% of the water consumption.

The GHG emissions reductions for Perfect Day whey protein compared to total protein in bovine milk were still at least 61.7% even when the allocation to the co-product was removed. The primary energy demand of Perfect Day whey protein became 177% higher than that of total protein in bovine milk in study 2; 56.9% higher than that of total protein in bovine milk in study 4 as a result of the sensitivity analysis. For blue water consumption, the sensitivity analysis still showed that the Perfect Day whey protein decreased this impact by 94.5% compared to study 1 and 84.4% compared to study 3. Therefore, when environmental impacts are allocated between the Perfect Day whey protein and the co-product, Perfect Day whey reduces GHG emissions, energy use, and blue water consumption compared to total protein in bovine milk. Even when the co-product is treated as a waste, the Perfect Day whey protein still reduces GHG emissions and blue water consumption compared to total protein in bovine milk.

5.2 DATA QUALITY ASSESSMENT

The life cycle data used in the analysis relies upon secondary data sources from GaBi® to produce GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts. 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, and use phases, and for the comparative products since Perfect Day does not directly control or influence these life cycle phases or products. The data quality evaluation in accordance with ISO standards 14040 and 14044 is given in Table 10.

Table 10: 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 US and would primarily produce the protein for use in the US. The primary data collected from Perfect Day on protein production and use is representative of the US. Secondary data sources represent US averages in many cases, and some global or regional data sources were used; approximately 50% of datasets are from non-US sources. Secondary data sources for the comparative proteins represent the geographies in which those proteins are produced. Initially, the goal was to look for a more global perspective on data, but the need for data on energy and water limited the availability of well-

Data Quality Requirement	Explanation
	documented studies to draw comparative data from. Some studies still present a global perspective across water impacts, while others are more country-specific, but were used to model impacts with more geographically broad background data. 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	Since 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; 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.
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. A confidential appendix 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	Since 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. 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 seven 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

Data Quality Requirement	Explanation
	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

The GWP, primary energy use, and blue water consumption for Perfect Day whey protein are 2.71 kg CO_2e, 56.3 MJ, and 73.9 L water per kg of protein, respectively. Perfect Day whey protein reduces GHG emissions, primary energy demand (non-renewable), and blue water consumption impacts compared to the total protein in bovine milk in all seven comparative studies (in the cases where those studies calculated the relevant impact categories). . The GHG emissions from Perfect Day whey protein are between 91.2% and 96.6% lower than the comparative total protein in bovine milk. The primary energy demand for Perfect Day whey protein is 28.9% and 59.7% lower than that of total protein in bovine milk from studies 2 and 4, respectively. Perfect Day whey protein has a lower blue water consumption compared to total protein in bovine milk from studies 1 and 3 by 98.7% and 96.3%, respectively. The primary driver of GHG emissions for Perfect Day whey protein are the utilities which contribute 40% to total GHG emissions. Electricity drives the utility impacts and the study uses the average U.S. electricity mix, but emissions from electricity (and fossil primary energy use) would depend on where the plant is located. After utilities, the protein development phase contributes 25% to total GHG emissions. The primary driver of blue water consumption impacts for Perfect Day whey protein is the protein development stage while the primary energy demand is driven by the utilities. Utilities include the US average natural gas and electricity used in the protein production process. Utilities have a significant impact on total GHG emissions (40% of total GHG impact) and primary energy demand (53% of total energy impact) from Perfect Day whey protein. 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. Producing the Perfect Day whey protein with electricity sourced from renewables could decrease the utilities impact of electricity on non-renewable energy demand and blue water consumption. While corn is the current source of dextrose for fermentation feed in the production system under analysis, the sugar input could come from a variety of sources (e.g., sugar beet, sugarcane, or cellulosic feedstocks).

Mass allocation apportions impacts to Perfect Day whey protein and the co-product (for multiple potential applications)by 21.7% and 78.3%, respectively (based on the dry mass allocation). A sensitivity analysis evaluated if the Perfect Day whey protein would still reduce GHG emissions and blue water consumption impacts compared to total protein in bovine milk without this allocation by using the conservative assumption that the co-product would instead be a waste. In this way, all of the impact 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 61.7% reduction in GHG emissions from Perfect Day whey protein, without any allocation by mass. As a result of the sensitivity analysis, the primary energy demand of Perfect Day whey protein became 177% higher than that of total protein in bovine milk in study 2 and 56.9% higher than that of total protein in bovine milk in study 4. For blue water consumption, the sensitivity analysis still showed that the Perfect Day whey protein decreased this impact by 94.5% compared to study 1 and by 84.4% compared to study 3. Therefore, it is recommended that the co-product be utilized and not discarded as a waste to the greatest extent possible. Should more information become available about the use of the co-product, additional analysis should be done to determine a more precise allocation of environmental burdens to the co-product than the mass allocation.

According to the United Nations Food and Agriculture Organization, the US produces 97,787,000 tonnes of milk annually, excluding butter.[15] If US consumers switched entirely to Perfect Day whey protein as a protein source from milk (assuming a 3.3% protein content of bovine milk), this would result in avoiding 246 million tonnes of CO_2e emissions, which is equivalent to 28 million homes' energy use for one year or 53 million passenger vehicles driven for one year according to the US EPA Greenhouse Gas Equivalencies Calculator.[2] According to studies 1 and 2, the same amount of milk would require 32% of the total lighting energy consumed by US residential and commercial sectors,[16] and water needed by 187 billion people for daily indoor home use.[17] Therefore, deriving non-animal whey protein from Perfect Day rather than bovine dairy would lead to a reduction of approximately 18,600 billion gallons of water and 75 billion MJ energy use.

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

[16] https://www.eia.gov/tools/faqs/faq.php?id=99&t=3#:~:text=The%20U.S.%20Energy%20Information%20Administration,kWh)%20of%20electricity%20for%20lighting

[17] https://www.usgs.gov/special-topic/water-science-school/science/water-qa-how-much-water-do-i-use-home-each-day?qt-science_center_objects=0#qt-science_center_objects

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 whey 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 differ from the primary data used in this study. As Perfect Day scales in production, the transportation distances and modes will likely changes and should be considered for future evaluation once a facility is sited. The selection of the comparative studies in itself presents a limitation since there are many dairy studies with distinct methodological approaches and no single study on milk production calculated impacts for GHG emissions, energy and water impacts from global milk production. Each comparative study has methodological differences that make it difficult to ensure exact comparability, but this study has endeavored to take this into account and the use of multiple studies as reference is intended to present possible ranges of impact. Close to the finalization of this report, an study was published that evaluated the GHG emissions, water and energy associated with US dairy production. While it was not able to be incorporated into this study, it is recommended that it be considered for future study and evaluation for the US dairy production context (Rotz, et al., 2021). 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, primary energy demand (non-renewable), and blue water consumption impacts 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, primary energy demand (non-renewable), and blue water consumption environmental impacts as no other impacts were considered. 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. Lastly, 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.

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APPENDIX A: TOTAL PROTEIN IN MILK STUDIES

#	Title	System Boundary	Co-products and allocation method	Sponsor/ Funder	Notes
1	Reducing food's environmental impacts through producers and consumers (2018)	Cradle to gate	• No co-products • Economic allocation	University of Oxford, Agroscope*	• Study compares multiple food groups • Median value is chosen • 1 liter of pasteurized milk is the functional unit, with a protein content of 3.3% • Global study
2	An operational method for the evaluation of resource use and environmental impacts of dairy farms by life cycle assessment (2009)	Cradle to farm gate	• Milk, Animal production • Economic Allocation	INRA UMR 1069 Sol Agro et hydrosyste`me Spatialisation, Agrocampus Rennes, UMR 1069 Sol Agro et hydrosyste`me Spatialisation, Chambre Re´gionale d'Agriculture de Bretagne	• Describes and applies EDEN-E, an operational method for the environmental evaluation of dairy farms based on the life cycle assessment (LCA) conceptual framework. • Protein content is 3.4% • Functional Units: 1000 kg fat- and protein-corrected milk (FPCM) sold and per ha of land occupied • Study region: France
3	Assessing environmental impacts associated with freshwater consumption along the life cycle of animal products: the case of Dutch milk production in Noord-Brabant. (2013)	Cradle to farm gate	• Milk • Feed allocation conducted by economic allocation	Wageningen University, Wageningen UR Livestock Research, Food and Agricultural Organization	• Functional unit: 1 kg of fat- and protein-corrected milk (FPCM) • Mentions protein content similar to broccoli – 2.8% • Study Region: Netherlands

4	Life cycle assessment of conventional and organic milk production in the Netherlands (2008)	Cradle to farm gate	• Milk, Animals, Crops • Economic Allocation	Wageningen University and Research Centre	• Functional unit: 1 kg of fat- and protein-corrected milk (FPCM) • Study Region: Netherlands
5	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	• Whole total protein in milk content is 3.4% • Study region: Europe
6	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
7	Life Cycle Assessment of Ripple Non-Dairy Milk (2017)	Crade to grave	• 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 B: CRITICAL REVIEW STATEMENT

Review of the Report "ISO-Conformant Report: Comparative Life Cycle Assessment of Perfect Day Whey Protein Production to Dairy Protein" (Dated August 20, 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

August 20, 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 August 20, 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
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