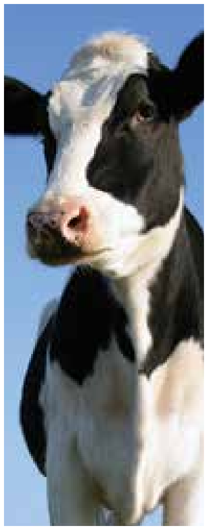
INNOVATION CENTER FOR U.S. DAIRY®
HEALTHY PEOPLE • HEALTHY PRODUCTS • HEALTHY PLANET

U.S. DAIRY'S ENVIRONMENTAL FOOTPRINT

A summary of findings, 2008-2012

Life Cycle Management

Farm to table, grass to glass



Assess
Manage
Improve

What is dairy's impact?

Dairy's environmental footprint is being measured by independent researchers on behalf of the Innovation Center for U.S. Dairy®, which was established by dairy producers. This report summarizes the body of environmental research conducted from 2008 to 2012. The studies utilized an open-source, transparent and collaborative research process which includes peer-review and publication, as described later in this report.

With this body of work, the U.S. dairy industry is striving to create the most transparent and documented dairy life cycle assessment (LCA) database available. It will be the pilot industry participating in the U.S. LCA Digital Commons, a project by the National Agricultural Library of United States Department of Agriculture (USDA) to provide an open access, prototype life cycle assessment database and tools.

Just as important as making those measurements is determining what to do with them. To that end, the Innovation Center is also developing science-based Smart Tools that help dairy farmers and business managers identify opportunities for improvement and track progress.

Fluid Milk Comprehensive

Henderson, A., Asselin, A., Heller, M., Vionnet, S., Lessard, L., Humbert, S., Saad, R., Margni, M., Thoma, G., Matlock, M., Burek, J., Kim, D., and Jolliet, O. (2012). U.S. Fluid Milk Comprehensive LCA. University of Michigan & University of Arkansas.

Cheese and Whey

Kim, D., Thoma, G., Nutter, D., Milani, F., Ulrich, R., and Norris, G. (2011). Life cycle assessment of cheese and whey production in the USA. University of Arkansas & University of Wisconsin.

GHG

Thoma, G., Popp, J., Shonnard, D., Nutter, D., Ulrich, R., Matlock, M.D., Kim, D.S., Neiderman, Z., East, C., Adom, F., Kemper, N. & Mayes, A. (2010). Greenhouse Gas Emissions from Production of Fluid Milk in the US. University of Arkansas & Michigan Technological University.

Contents

The U.S. Dairy Sustainability Commitment

As we look ahead to a future with a burgeoning global population and diminishing natural resources, we recognize that we must continue to find ways to produce dairy foods and beverages efficiently and responsibly—in a way that protects our natural resources and the communities and people we touch.

Accordingly, sustainability has become a key business strategy for the U.S. dairy industry. Through the Innovation Center for U.S. Dairy, dairy producers, processors, transporters, and retailers have made a shared commitment to assess, manage and improve the environmental, social and economic sustainability of U.S. dairy, from farm to table.

Sustainability Vision

We commit to being leaders in sustainability, ensuring the health and well-being of our planet, communities, consumers and the industry.

Today's Dairy Cow—Dairy cows play an important role in the global food system.

- The average dairy cow in the U.S. produced 72 pounds of milk per day in 2012. This is enough milk to provide an 8-ounce glass of milk to 144 people every day.[1]
- A dairy cow in the U.S. produces, on average, four times more milk than the average dairy cow worldwide.[2]
- Dairy cows are a particular type of herbivore called a ruminant. Plant cellular contents can be digested by most animals (including humans) but cows also digest the plant cell wall (i.e. structural carbohydrates, also called fiber.) This means a dairy cow can thrive on feedstuffs that people can't.
- Regurgitation allows a cow to chew her food, or cud, again and again. The mechanical action of cud chewing reduces the size of feed particles to promote fiber digestion. Most cows chew at least 50 times per minute and spend 10 hours a day chewing their cud in order to aid in digestion.
- This process, as well as a cow's manure, is a source of methane, a powerful greenhouse gas (GHG). Identifying mitigation strategies is a top research priority for the dairy industry.
- The milk, and ultimately dairy foods and beverages, that a cow produces provide a unique package of essential nutrients that improve overall diet quality and promote good health.
- Dollar for dollar, dairy foods are one of the most economical sources of nutrition in the grocery store.[3] At less than 25 cents a glass, milk is America's number one food source of calcium, potassium and vitamin D—three nutrients that American diets fall short on.[4,5]
- Dairy cows' manure contains valuable nutrients for the soil. The manure is applied to the farm field to fertilize crops such as corn and alfalfa that, in turn, are feed sources for her. Her 17 gallons of manure daily have enough nutrients to grow 56 pounds of corn.[6]

[1]National Milk Producers Federation. Dairy Data Highlights. Arlington, VA: National Milk Producers Federation, 2012. Print.

[2]National Milk Producers Federation. Dairy Data Highlights. 2012.

[3] Drewnowski A. (2010). The cost of US foods as related to their nutritive value. Amer J of Clin Nutr.

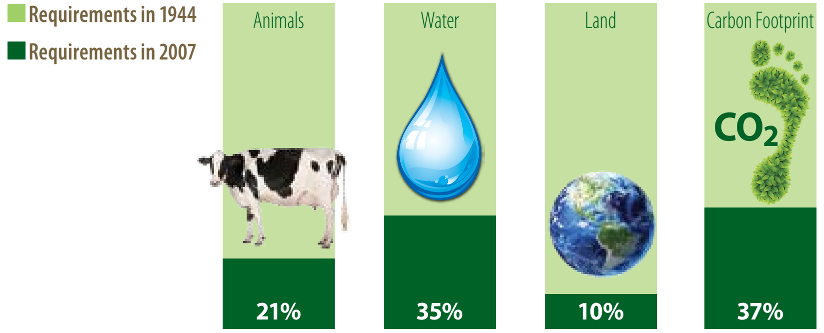
[4] Dairy Research Institute®. NHANES (2003-2006). Data Source: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey Data. Hyattsville, MD:_U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, [2003-2004; 2005-2006].

[5] Drewnowski A. (2010). The Nutrient Rich Foods Index helps to identify healthy, affordable foods. Am J Clin Nutr.

[6] Erb, Kevin. "Manure 101: Nutrient Management and the Dairy Industry." University of Wisconsin Extension. Madison.

Life Cycle Management

Producing 1 billion kg of milk: 1944 vs. 2007



Source: Capper et al., 2009, *Journal of Animal Science*

As one of the largest milk producers in the world, the U.S. dairy industry has already demonstrated significant efficiencies—doing more with less—through the use of best practices and innovations at all stages of the supply chain. These improvements have not only reduced environmental impact, but they also have enhanced the economic and social sustainability of dairy farms, businesses, and communities.

There is still room for improvement. The life cycle management approach is the leading method for determining and managing opportunities for change and adaptation, and it has been employed by the dairy industry through the Innovation Center for U.S. Dairy since 2008.

Life cycle science provides a research-based understanding of the impacts of the dairy industry and directs us to key risks and opportunities.

The U.S. dairy industry is focusing first on evaluating sustainability in the following areas:

Environmental	Economic	Social
Greenhouse gas emissions	Local economic impacts	Animal care
Water use and quality	Financial value across the supply chain	Community contributions
Energy use		Working conditions
Waste and materials		Food safety
Land and biodiversity		Health and nutrition
Crop production		

What is a Life Cycle Assessment?

- A Life Cycle Assessment (LCA) studies the environmental impact throughout a product's life cycle, from farm to table
- An LCA is a science-based and quantifiable approach that provides a clearer picture of the impact of industries and products
- An LCA identifies and helps to prioritize both risks and opportunities that individual farms or businesses can use to set goals, identify improvements, and track progress

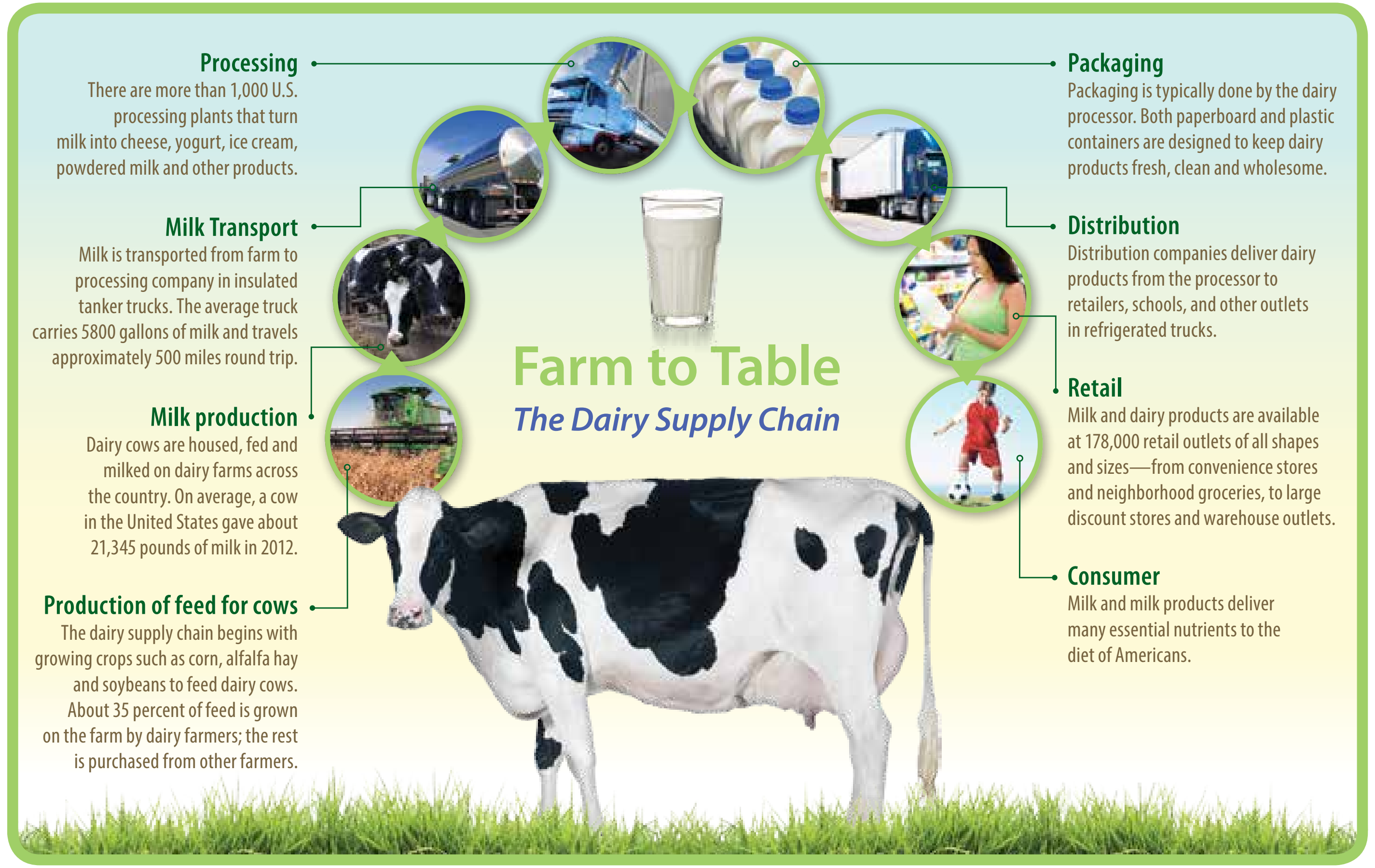
The LCAs for milk and cheese conducted for the dairy industry were unprecedented in size, scope and commitment.

- Environmental science experts from the Applied Sustainability Center at the University of Arkansas were commissioned by the Innovation Center for U.S. Dairy to conduct the first LCA study, the Greenhouse Gas (GHG) LCA for Fluid Milk, to establish a baseline GHG footprint for U.S. dairy.
- While some LCAs may include a few points (or even one point) of data collection—for example, a single dairy farm—the GHG LCA included data from 536 dairy farms. The herd-size demographics reflect national milk production.
- More than 50 processing plants also contributed data, collectively representing 25 percent of fluid milk processed in the U.S., and 16 cheese plants surveyed, representing 22 percent of natural cheese produced in the U.S.
- On the transportation side, the LCA survey included an extensive database of transportation round-trips from farm to processor, with over 210,000 data points.
- The LCAs were subjected to third-party critical reviews to ensure credible results and transparency.
- In addition to third-party critical review, more than 100 dairy experts including industry leaders, land grant university researchers and member-owned dairy cooperative personnel also contributed to and reviewed the studies.
- Ten non-governmental organizations also participated in the review process.
- The dairy LCAs follow ISO 14040, 14044 standards.

ISO 14040: environmental management–International Organization for Standardization. (1997). Environmental management—life cycle assessment—principles and framework, ISO 14040:1997.

International Organization for Standardization. (2006). Environmental management—Life cycle assessment—Requirements and guidelines, ISO 14044:2006.

Dairy LCA: *Understanding Dairy's Impact from Grass to Glass*



Production of Feed: USDA Economic Research Service, 2007; **Milk Production:** USDA, National Agricultural Statistics Service, 2012; **Milk Transport**:"Greenhouse Gas Emissions of Fluid Milk in the U.S.", University of Arkansas, 2010
Processing: USDA, National Agricultural Statistics Service, Agricultural Statistics Board, 2010; **Retail**: Progressive Grocer, 2008

The dairy LCAs have advanced the state of science by identifying these key elements of a successful LCA process

- Clear definition of goals
- Careful selection of the functional unit to be used as the basis for reporting and comparison of results
- Close attention to data sources to ensure underlying assumptions are consistent
- Work with the subject matter experts to gain a complete picture
- Assess impacts appropriately, recognizing limitations of impact assessment models
- Peer review to independently validate the findings
- Documentation and transparency

LCA Scope, Measurement and Application

An LCA examines the environmental impacts of a product through its entire life cycle, from cradle to grave (product creation through disposal). This comprehensive approach makes it possible to determine impacts across the value chain, illustrated on page 6.

LCA studies commissioned by the Innovation Center for U.S. Dairy initially focused on GHG emissions associated with the production of fluid milk. The scope of subsequent LCAs broadened to evaluate other environmental issues and dairy products including cheese and whey.

GHG LCA for Fluid Milk[1]

Completed in 2010, this LCA was the first national carbon footprint of its kind and the largest scale effort in the world at the time. On-farm emissions such as methane, carbon dioxide, and nitrous oxide were studied, and the GHG LCA included a thorough evaluation of general air pollutants and particulate matter linked to dairy farms, plants and transportation systems. Primary data was collected from 536 farms, 50 processing plants and 210,000 round trips transporting milk from farm to processor. The data was published online in April 2013 in the *International Dairy Journal* and will be included in the LCA Digital Commons of the National Agriculture Library.[2]

Comprehensive LCA for Fluid Milk[3]

This study, completed in 2012, built on the GHG LCA by completing a water footprint for the dairy industry, which establishes a baseline from which to evaluate water quality and availability. Findings will help identify better management practices for dairy farms and businesses.

Comprehensive LCA for Cheese[4]

Conducted from 2009 to 2011, this LCA evaluated GHG emissions, land use and water use impacts of cheese production from farm gate to processing to consumer.

Management Tools

The research studies support the development of management tools to help dairy farms and businesses benchmark themselves against the industry average and to calculate what-if scenarios to help with business decisions. See page 15 for more information.

Voluntary Goal and Roadmap

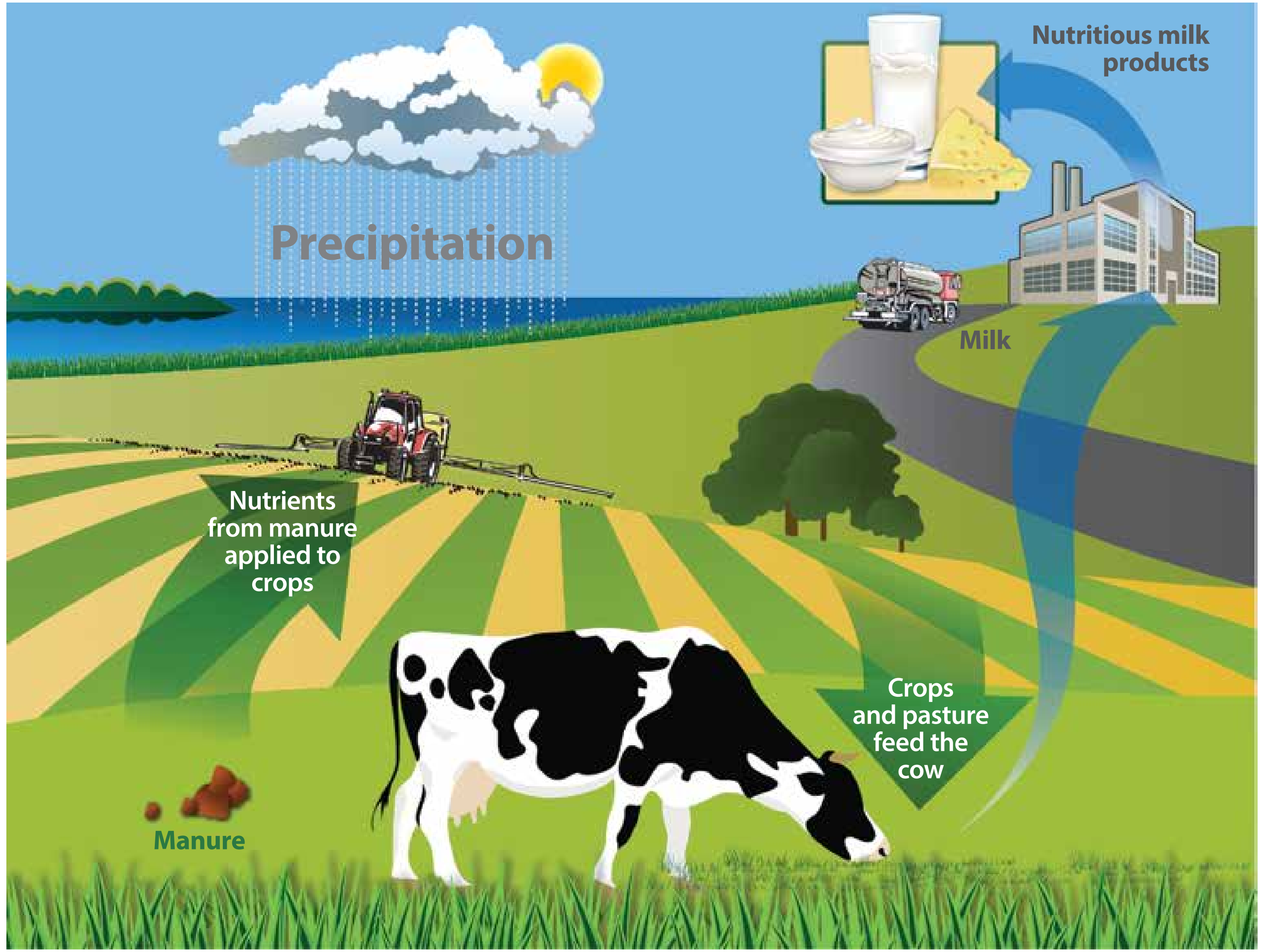
Data from the GHG LCA study enabled the industry to collaborate and commit to a goal and roadmap to reduce GHG emissions for fluid milk by 25 percent and increase business value by $238 million by 2020.[5]

The Takeaway

- An LCA is more than just a collection of data: it provides a baseline footprint, identifies key opportunities and risks, and serves as decision-support.
- With the LCA as guidance, individual members of the dairy supply chain can set their own goals and create a roadmap to real and lasting improvements.
- Because it addresses the entire life cycle, industry members can use the data to assess how management practices affect not only their operation but other stages of the supply chain. This avoids shifting burdens from one segment of the supply chain to another.

[1,5] Thoma et. al, Greenhouse Gas Emissions of Fluid Milk in the U.S., University of Arkansas, 2010.
[2] LCA Digital Commons: Data and Community for Life Cycle Assessment. United States Department of Agriculture, National Agriculture Library.
[3] Henderson, A., Asselin, A., Heller, M., Vionnet, S., Lessard, L., Humbert, S. Saad, L., Margni, M., Thoma, G., Matlock, M., Burek, J., Kim, D., and Jolliet, O. U.S. Fluid Milk Comprehensive LCA. University of Michgan & University of Arkansas, 2012.
[4] Thoma et al., Life Cycle Greenhouse Gas and Energy Demand Assessment for Cheese and Whey Products. University of Arkansas, 2012.

Dairy Nutrient Cycle



Nutrients: Essential for Growth

Dairy cows create an efficient nutrient cycle where the same nutrients are used repeatedly.

- The nutrient cycle for dairy begins with the crops that are grown to provide nourishment to the cow.
- The cow, in turn, produces milk for nutritious dairy products.
- She also produces manure which, when recycled as fertilizer for crops, helps maintain soil fertility and enables the cow to return most of the nutrients from her feed back to the land.

Learning from the LCA

Proper nutrient balances on the farm are critical for managing environmental impact as well as profitability. LCA research is helping by identifying opportunities to maximize nutrient recycling and minimize negative impact on soil, air and water.

Soil and Manure Management

Nitrogen and phosphorus are two nutrients in manure that are beneficial to the farm cycle as an alternative to synthetic fertilizer. Typically, manure is incorporated into crop fields according to a nutrient management plan that takes into account local factors, such as the type of soil, the terrain of the field, and moisture levels.

When a system reaches its limit of nitrogen or phosphorus storage, runoff or leaching occurs, which can lead to water quality issues including freshwater and marine eutrophication. See page 10 for LCA findings related to this topic.

Best practices

Good manure application and nutrient management techniques deliver both environmental and economic benefits. Tools such as the Manure Application Planner (MAP),[1] a computer program offered by soil and water conservation districts, generate thorough nutrient management plans and estimate the savings when using manure compared to commercial fertilizer.

Many current best management practices are employed on dairy farms and crop fields where manure is applied. Direct injection of manure and conservation tillage practices increase the retention of nutrients in the soil and reduce the risk of runoff. A common practice is the use of buffer strips to ensure that manure won't directly reach surface water.

Larger dairy farms, meanwhile, are required to follow detailed manure management plans which are continually updated to reflect new technologies for manure storage and application. In fact, the U.S. dairy industry is one of the most regulated and inspected industries in agriculture.

New technologies will enable dairy farmers to better manage nutrient levels on the dairy farm. Anaerobic digester systems offer the potential to convert manure into valuable by-products including renewable energy, biogas, compost and fiber. There is also the potential for a new bioeconomy that includes the reuse and selling of these valuable nutrients in a packable form.

LCA data show that the application of manure to cropland increases the water-holding capacity of soil by 20 percent, so less groundwater is needed to grow crops.[2]

[1] Schmitt, M., Levins, R., & Richardson, D. (1997). Manure application planner (MAP): software for environmental and economical nutrient planning. *Journal of production agriculture*, 10(3), 441-446

[2] Fulhage, CD. Reduce environmental problems with proper land application of animal manure. Department of Biological and Agricultural Engineering, University of Missouri; EQ201 Web

LCA Findings: Water Use and Quality

Water is a top issue for most industries and organizations worldwide, and the use and quality of water on farms and in milk and dairy processing plants are a significant focus of dairy producers and processors. Analysis of the water footprint of a farm operation or processing plant must take into account local water availability and sources, water stress, and quality of water source. Soil conditions, weather, seasonal changes and management practices add to the mix. The combination of these factors paints a complex water profile that is unique to each facility.

Learning from the LCA

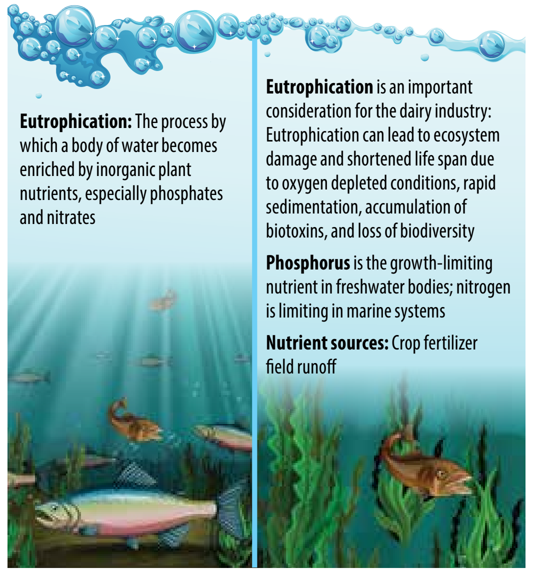
The Dairy LCAs focused on water resource impacts from U.S. dairy production, including water use (scarcity) and water quality (eutrophication). Uses of water include irrigation of crops for dairy feed, providing water for dairy cows, and dairy farm operations, such as cleaning. Water quality is an issue when water that contains nutrients and sediment is discharged back to ground or surface water sources.

Findings will help the industry understand its water-related risks and opportunities, and to deliver best management practices to help crop farmers, dairy producers, processors and manufactures manage their water footprints.

Key takeaway

The LCA showed that water use and water quality impacts are location-specific, depending on characteristics of the region and watershed where on-farm dairy and feed production occur. Thus, water use and quality should be measured and managed in a locally-relevant way with practices best suited to the individual operation.[1]

Water quality terminology



Eutrophication: The process by which a body of water becomes enriched by inorganic plant nutrients, especially phosphates and nitrates

Eutrophication is an important consideration for the dairy industry: Eutrophication can lead to ecosystem damage and shortened life span due to oxygen depleted conditions, rapid sedimentation, accumulation of biotoxins, and loss of biodiversity

Phosphorus is the growth-limiting nutrient in freshwater bodies; nitrogen is limiting in marine systems

Nutrient sources: Crop fertilizer field runoff

Water Management

Feed production accounts for more than 90 percent of water use related to dairy, therefore efficient use of water for feed production is especially crucial. Most dairy production in the U.S. does not occur in water stressed areas with the exception of some western states.

Application of manure and synthetic fertilizer for crops represent dairy's greatest risk of impact to watersheds. If not managed properly, nitrogen and phosphorus can cause marine or freshwater eutrophication. Primary sources of marine eutrophication related to dairy include production of feed for cows (55%) and on-farm milk production (42%.) Primary sources of freshwater eutrophication include feed production (86%) and processing.[2]

Best Practices

Because water is a local issue, best practices must be chosen for the individual operation's unique characteristics.

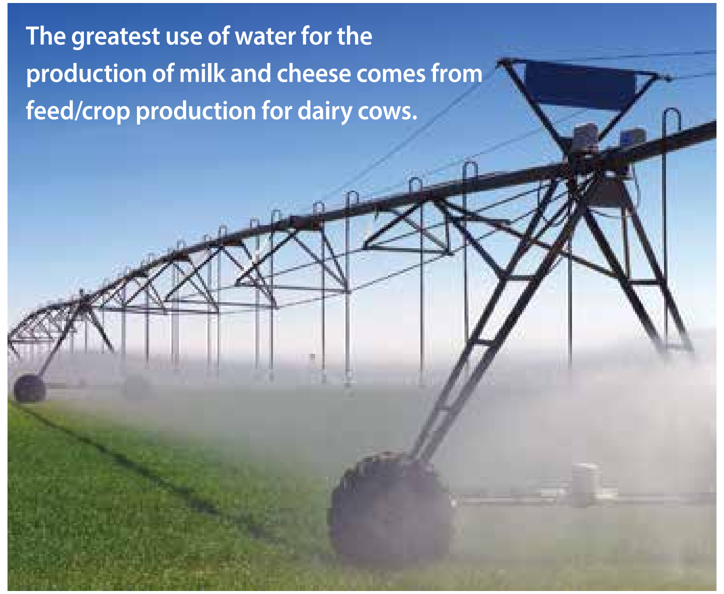
Many conservation practices are in place to re-use water in milk production and processing. On dairy farms, water is typically re-used as many as five or six times. For example, water used to clean milking parlors is reused to clean production areas and then to irrigate fields. Modern dairy farms often use a heat exchanger, a technology that uses cold water to partially cool milk, and then collects this water to use again as drinking water for cows.

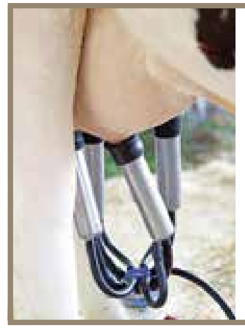
Best practices to mitigate water quality issues are focused on avoidance of runoff or sediment loss. They could include buffer strips, cover crops, tillage management, anaerobic lagoons or digester systems, and other manure management/application practices appropriate for the dairy farm.[3]

[1] Matlock, M., Thoma, G., Cummings, E., Cothren, J., Leh, M., & Wilson, J. (2012). Geospatial analysis of potential water use, water stress, and eutrophication impacts from US dairy production. *International Dairy Journal*.

[2] Henderson, A., Asselin, A., Heller, M., Vionnet, S., Lessard, L., Humbert, S. Saad, L., Margni, M., Thoma, G., Matlock, M., Burek, J., Kim, D., and Jolliet, O. U.S. *Fluid Milk Comprehensive LCA*. University of Michgan & University of Arkansas, 2012.

[3] National Resource Conservation Service, US Department of Agriculture. (2011). *Conservation practices*.





Milk production water withdrawal*

- Feed production accounts for more than **90% of water use related to dairy**
- Dairy feed irrigation is **4.9% of total U.S. water withdrawal**
- On-farm dairy water use is **0.19% of total U.S. water withdrawal**
- Total dairy water use is approximately **5.1% of total U.S. water withdrawal**

*excludes thermal power

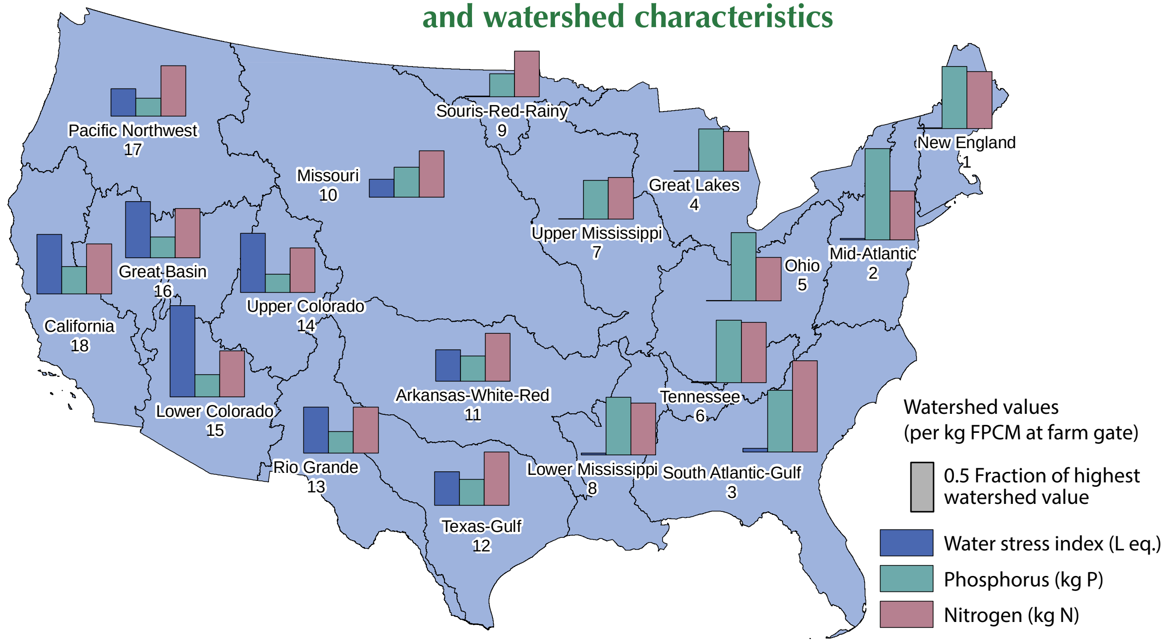
- The water footprint for milk production is **140 liters of water in competition per kilogram of milk consumed** (144.2 gallons of water in competition per gallon of milk consumed)
- The water footprint for cheese is **1.37 cubic meters per kilogram of cheese** consumed (164 gallons per pound of cheese consumed)

Water use by life cycle stage

Life cycle stage	% of total water use
Feed production	93.5%
Milk production	3.6%
Processing	1.0%
Packaging	0.3%
Transport/ Distribution	0.2%
Retail	0.4%
Consumer	1.0%
Total	**100.0%**

Henderson, A., Asselin, A., Heller, M., Vionnet, S., Lessard, L., Humbert, S. Saad, L., Margni, M., Thoma, G., Matlock, M., Burek, J., Kim, D., and Jolliet, O. U.S. Fluid Milk Comprehensive LCA. University of Michgan & University of Arkansas, 2012.

Water is a local issue impacted by both water supply and watershed characteristics



LCA Findings: Greenhouse Gas Emissions

The reduction of GHG emissions was identified as a priority for the dairy industry in 2008. The GHG LCAs for fluid milk and cheese established an accurate baseline for GHG emissions and determined how each step along the dairy value chain contributed.

Production of all dairy products in the U.S. accounts for approximately 2 percent of total U.S. GHG emissions.[1]

Learning from the LCA

The LCA was the foundation for the industry's voluntary goal and roadmap to reduce GHG emissions by 25 percent across the supply chain by 2020. To develop solutions for reducing emissions, LCA findings were analyzed to identify opportunities for reducing emissions across the supply chain. It revealed that almost all (90%) of the industry's carbon footprint can be explained by approximately 20 variables; managing these variables can thus address the factors known to contribute most to the industry's impact.

Milk Production
- Total annual milk production
- Average milk fat content
- Average milk protein content

Herd Management
- Production herd
- Percentage of total herd dry
- Number of replacement heifers
- Number of replacement calves
- Pasturing period
- Mature animals culled for beef
- Average weight of mature culls
- Calves sold for beef

Feed Management
- Average dry matter intake
- Lactating cow ration

Energy Management
- Total annual on-farm electricity purchased
- Percentage of electricity used for dairy activities
- Total gallons fossil fuel purchased
- Percentage used directly for dairy activities
- Total amount of natural gas purchased
- Percentage used directly for dairy activities

Manure Management
- Manure Management System

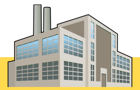
Key Takeaway
- On the farm, management practices matter most for GHG emissions, more than factors such as farm, size, or region.
- Manure management and feed efficiency practices can help dairies reduce their carbon footprint.
- Increasing energy efficiency is important across the supply chain. The impacts from fuel and electricity span all stages of the supply chain; therefore, opportunities for improvement exist at all stages.

Management Practices Matter

On the Farm

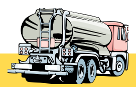
- Increasing feed efficiency
- Ensuring/enhancing herd health
- Reducing enteric methane
- Improving manure management

In the Plant



- Reducing electricity usage
- Consolidating distribution network
- Consider alternative packaging materials

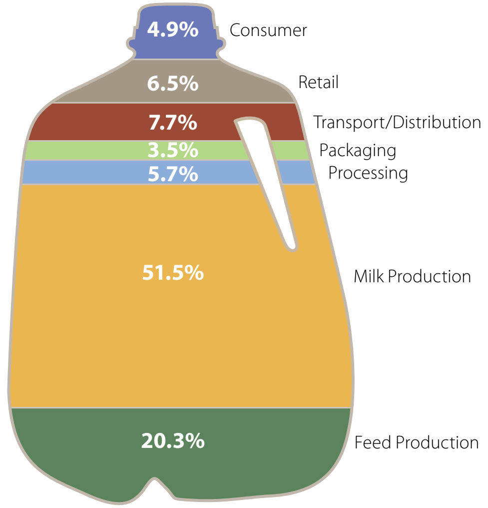
In Transport



- Good truck maintenance
- Better route design
- Reducing long-distance milk hauling

[1]Thoma, G., et al. (2010). *Greenhouse Gas Emissions from Production of Fluid Milk in the US.* University of Arkansas & Michigan Technological University.

U.S. Fluid Milk Carbon Footprint



Greenhouse Gas Emissions for U.S. Fluid Milk: Contribution by Supply Chain

Total CO_2e emissions of fluid milk = 17.6 lbs. per gallon of milk[1]

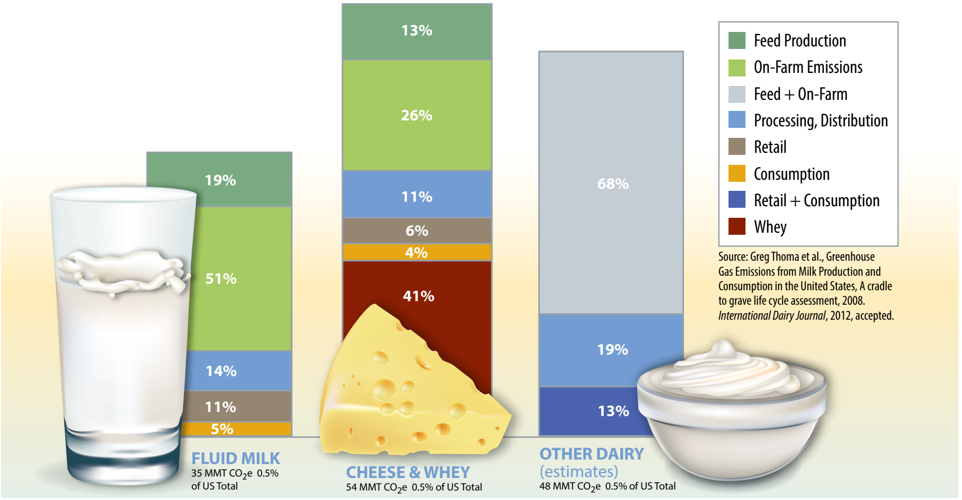
(2.05 kg CO_2e/kg milk consumed)

[1]Thoma et. al, *Greenhouse Gas Emissions of Fluid Milk in the U.S.*, University of Arkansas, 2010. Based on environmental and consumption data from 2007-2008. Carbon footprint of 1 gallon of fluid milk consumed is 17.6 lbs. CO_2e. Ranges from 15.3 to 20.7 lbs. CO_2e due to natural variability and uncertainty. The total fluid milk carbon footprint is approximately 35 million metric tons, with a 95% confidence range from 30 to 45 million metric tons.

The carbon and all other footprints are related to total milk and dairy food production and consumption patterns, according to USDA Economic Research Service surveys. We know that a total of 32% of dairy foods may be lost at the retail and consumption stages.

U.S. Dairy Carbon Footprint—All Products

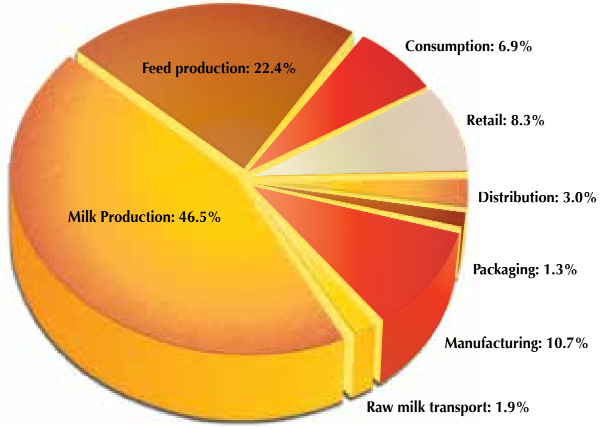
Total emissions = 137 MMT (The entire dairy industry—farm to manufacturer's gate—contributes approximately 2% of total U.S. GHG emissions)



Thoma [e] et al. (2012). *Comprehensive Life Cycle Assessment for Cheese and Whey Products* - Final Report.

U.S. Cheese and Whey Carbon Footprint

Greenhouse Gas Emissions for U.S. Cheese: Contributions from Farm to Processor Gate



Total carbon footprint from the cheese sector (both cheese and whey) is approximately 54 million metric tons (MMT) of CO_2e, or 0.7 percent of the total GHG emissions in the U.S. The entire dairy industry—farm to manufacturer's gate—contributes approximately 2% of total U.S. GHG emissions.

Thoma et al., *Life Cycle Greenhouse Gas and Energy Demand Assessment for Cheese and Whey Products*. University of Arkansas, 2012. Data were collected in 2011 from ten cheddar manufacturing facilities (1.2 billion pounds cumulative production; 35 percent of U.S. annual production) and six mozzarella manufacturing facilities (0.77 billion pounds cumulative production; 22 percent of U.S. annual production). Scaling the study results (24 percent mozzarella production, 38 percent cheddar production and the remaining 38 percent represented by cheddar as proxy) to national scale, the results in a total carbon footprint is for cheese only. Greenhouse gas footprint: 8.3 CO_2e kg/kg (or 8.3 lbs./lbs.) cheese consumed.

LCA Findings: Land use and its implications

Land is one of the most important resources in the food and agriculture sector. The US dairy industry is working to better understand the way that dairy production affects our land resources and to find ways dairy can contribute to meeting the future challenges in this area. The LCA identified the major sources of land use impacts and how those impacts can be managed and mitigated.

Impacts from using land can occur when we transform land from one type of use to another (such as from a forest to a field), as well as when we occupy an amount of land over time. The term land use refers to this land transformation and land occupation.

The amount of land that we transform or occupy has direct effects on the land's flora and fauna, including what those organisms can provide to humans. We refer to these effects as impacts to biodiversity and ecosystem services.

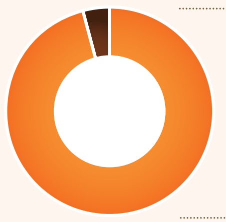
Ecosystem services refers to the benefits that people derive from the ecosystem, including cultural diversity, provisions, regulation of environmental systems and support functions. Impacts to ecosystem services are a newer area of research and include a variety of metrics. The milk LCA measures erosion resistance, groundwater recharge potential, mechanical filtration and physico-chemical filtration, which all tell us about the ability of soils to support life.

Learning from the LCA*

Land is occupied throughout milk's entire value chain. Like water use, by far most land occupation occurs during the production of crops for dairy cow feed.

Land occupation by life cycle stage*

- Feed production **96 %**
- Milk production **0.13 %**
- Post farm gate **3.9 %**



Total Impact
1.67m²-year*

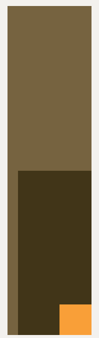
The LCA assumes that no transformation of land to agricultural use is taking place. This assumption has been verified using the FAOSTAT database (http://faostatfao.org/site/291/default.aspx) by reviewing the amount of land area harvested for most crops over the past 20 years.

Land needed to grow crops for dairy cows

A comparison of land use in the US shows that the area needed to grow dairy cow feed crops for 2008 milk production is:
3.7% of TOTAL farmland
8.4% of US cropland

3.6 million acres of agricultural land were lost to development from 2002-2007.[3] Urban sprawl is encroaching on land used for agriculture, including land used to produce milk.

Since the late 1980s, US forest area has increased by ~14 million hectares.[4] Although land occupation impact remains, current agriculture in the US is not causing a net loss of US[5] forest lands.



922 M acres
Total amount of US farmland [1]

406 M acres
Amount of US cropland [1]

34.1 M acres
Land needed to grow crops for dairy cows [2]

[1]US Department of Agriculture. (2012). 2007 Census of Agriculture. United States. Summary and State Data. Table 62.
[1] Includes all three types of farmland as defined by the USDA: prime farmland, unique farmland, and farmland of statewide importance.
[2]Based on the calculated amount of land used for feed production (1.6 m²-y*) and 2008 U.S. milk production, which was 190 billion lb) according to Economic Research Service, US Department of Agriculture. (2014). Dairy Data. Milk production and factors affecting supply (Annual).
[2]Includes all three types of cropland as defined by the USDA: cropland used for crops, cropland pasture and idle cropland.
[3]National Resources Inventory, US Department of Agriculture (2013). 2010 NRI Summary Report.
[4]US EPA (2015) Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2013. EPA 430-R-15-004. Washington, D.C.
[5]Changes to cropland acreage in the US can lead to land transformation in other countries, which may or may not cause a net loss of forest lands in those locations. For example: Searchinger, T., Heimlich, R., Houghton, R.A., Dong, F., Elobeid, A., Fabiosa, J., Tokgoz, S., Hayes, D., Tun-Hsiang, Y. (2008). Use of U.S. Croplands for Biofuels Increases Greenhouse Gases Through Emissions from Land-Use Change. Science, 319, 1238-1240.

Erosion resistance potential
61 t/ha-year per kg FPCM milk

99% of the impact on soil erosion resistance results from land used during dairy cow feed crop production.

Biodiversity
1.4 PDF-m²-year per kg FPCM milk

96% of the impact to biodiversity occurs during the production of crops to feed dairy cows.

Mechanical filtration
2.4 cm/day per kg FPCM milk

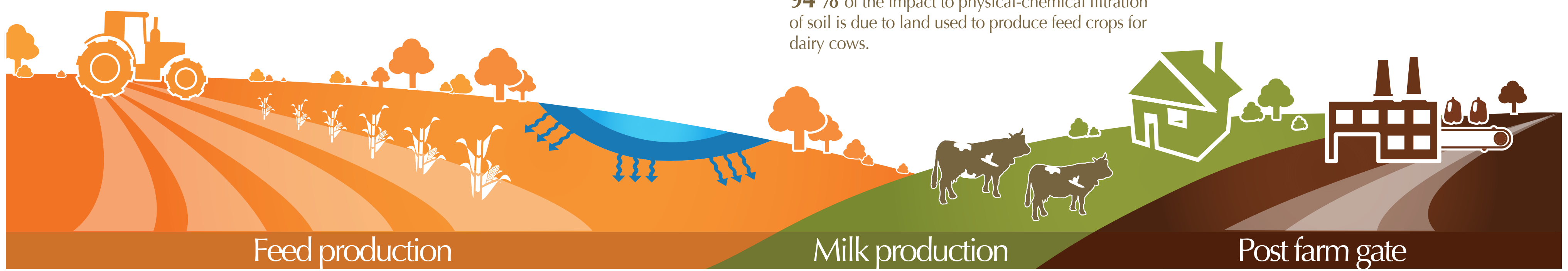
93% of of the impact to mechanical filtration of soils results from the use of land to grow feed for dairy cows.

Physico-chemical filtration
1.4 cmol/day per kg FPCM milk

94% of the impact to physical-chemical filtration of soil is due to land used to produce feed crops for dairy cows.

Groundwater recharge potential
190 mm/year per kg FPCM milk

99% of the impact on groundwater recharge potential is from land used during the production of dairy cow feed crops.



*Henderson, A., Asselin, A., Heller, M., Vionnet, S., Lessard, L., Humbert, S., Saad, L., Margni, M., Thoma, G., Matlock, M., Burek, J., Kim, D., and Jolliet, O., U.S. Fluid Milk Comprehensive LCA. Technical Report to the Innovation Center for U.S. Dairy, University of Michigan & University of Arkansas, 2012.

Defining metrics for land use impacts

Erosion resistance potential is the capacity of ecosystems to stabilize soil and to prevent sediment accumulation downstream. It is measured as ton/ha-year.

Biodiversity is a measure of the vitality of ecosystems. It is assessed by counting the number of different species an area of land is supporting. This count tells us that a forest is generally a healthier ecosystem than a corn field and a much healthier ecosystem than a parking lot. We measure biodiversity as the portion of species affected over a given area of land, or PDF-m²-year where **PDF** stands for "potentially disappeared fraction" of species.

Mechanical filtration refers to the ability of an ecosystem to mechanically remove substances in flowing water. It is measured as cm/day.

Physico-chemical filtration refers to the ability of an ecosystem to remove substances in flowing water due to physico-chemical properties and/or processes. It is measured in cmol/day.

Groundwater recharge potential is the ability of ecosystems to recharge subsurface water bodies. The metric is evaluated in mm/year.

Land occupation is the act of using land. It is measured as an area occupied during a given period of time. This is expressed as m²-year.

Land transformation is the process of changing the way in which land is used. It is measured as an area transformed during a given period of time. Similar to land occupation, this is expressed as m²-year.

FPCM All results are expressed **per kg FPCM** (fat and protein corrected milk)

Dairy's Contribution to America's Health

Dairy's nutrient cycle continues with the delivery of nutrients to humans. Since ancient times when cows were first domesticated, dairy foods have been a part of the human diet and health. As the population grows and resources diminish, there is a greater need to optimize and be more efficient to feed 9 billion people. It's not just more food that's needed, it's nutrient-rich food that becomes essential to nourishing the world. Nutrient-rich dairy foods and beverages offer essential, high-quality nutrition because of their composition, inherent wholesomeness and relative abundance.

Sustainable Diets are those diets with low environmental impacts which contribute to food and nutrition security and to healthy life for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources.
— Food and Agriculture Organization of the United Nations

The dairy food group (milk, cheese and yogurt) is an important source of nutrients in the diet of Americans—at only 10% of the calories consumed. Contributions to daily nutrient intakes in the U.S. diet include:

- more than half of the total calcium and vitamin D
- about one fourth of the total vitamin A, vitamin B_{12}, and riboflavin
- nearly one fifth (18%) of total protein

In fact, milk alone is the number one food source of three of the four nutrients of concern in American's diets—calcium, vitamin D and potassium

Dairy's Triple Value

Dairy foods are important contributors of many nutrients in the U.S. diet that are important for good health. Few other foods deliver these nutrients in such an affordable, appealing and readily available way. It is difficult for most people to meet nutrient recommendations without consuming at least three daily servings of dairy foods.[1-3]

Choose low-fat and fat-free dairy options first

Nutrient contributions[4]

- Calcium
- Protein
- Potassium
- Phosphorus
- Magnesium
- Vitamin A
- Vitamin D
- Vitamin B_{12}
- Riboflavin
- Niacin

(Niacin equivalents)

Low cost[5]

About 25¢ per serving

Healthcare savings[6]

Potential Savings over 5 years with 3-4 Daily Servings of Dairy Foods

$70B	40% reduction in Hypertension
$37.5B	25% reduction in Type 2 Diabetes
$16.5B	10% reduction in Coronary Heart Disease
$14B	20% reduction in Osteoporosis

[1] Nicklas et al. J Am Coll Nutr 2009
[2] Huth et al. Nutr Today 2008
[3] 2010 Dietary Guidelines for Americans
[4] Dairy Research Institute®. NHANES (2003-2006)
[5] Drewnowski A. Am J Clin Nutr. 2010
[6] McCarron DA, Heaney RP. Am J Hypertension. 2004

Research links dairy consumption to lowering certain health risks

The 2010 Dietary Guidelines for Americans indicates that dairy intake is linked to improved bone health, especially in children and adolescents, and is associated with a reduced risk of cardiovascular disease and type 2 diabetes and with lower blood pressure in adults.

Godfray, H. C., Beddington, et al. (2010). Food Security: The Challenge of Feeding 9 Billion People. Science, 327(5967), 812-818.

Dairy Research Institute®. NHANES (2003-2006). Data Source: Centers for Disease Control and Prevention, National Center for Health Statistics, National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, [2003-2004; 2005-2006].

Management Tools for Improvement

The U.S. dairy LCA research allows those in the dairy chain to fill gaps, find new opportunities, and determine solutions to improve the environmental impact of dairy production. This, in turn, will enhance the economic sustainability of dairy farms and businesses, and deliver benefits to the communities in which they operate.

Best practices: Best management practices are at the core of potential improvements stemming from the LCA. Those practices, related to farming, milk production, processing and transporting, are most effective when tailored to a specific operation.

Personal best: The effectiveness of tailored practices is a key finding of the dairy LCAs. For example, the most sustainable practices for water use and quality will depend on the region and sometimes even on the individual location of the dairy farm or business. The same is true for other elements of production, from methane conversion to wastewater treatment to more efficient truck routes and fuel use.

Smart Tools

The dairy LCA's measurement methods are being applied to new "smart tools" developed by the dairy industry, which allow for science-based decision making and a comprehensive performance review.

Farm Smart™

One tool is an integrated online management system called Farm Smart, currently being developed to help dairy producers evaluate their production techniques, assess economic and environmental consequences of potential improvements in management practices, and share the contributions that their farm businesses have made to neighbors, community groups and consumers.

Farm Smart™
ENVIRONMENTAL CALCULATOR

www.USDairy.com/FarmSmart

Dairy Plant Smart™

In the processing plant, processors can track and reduce energy use, emissions and operating costs through an online resource called Dairy Plant Smart. Manufacturers can use case studies on proven energy efficiency approaches that offer cost and energy savings, and they can take part in the complementary ENERGY STAR Challenge from the U.S. EPA.

www.USDairy.com/P

Dairy Fleet Smart™

Improvements are also being incorporated into the transport system with a new tool called Dairy Fleet Smart. Dairy Fleet Smart combines science-based decision-making tools with education on recommended management practices that reduce fuel consumption, costs and GHG emissions. This builds on a U.S. EPA program called SmartWay and supplements it by providing dairy-specific recommendations.

The findings from the dairy LCAs are also leading to the creation of new process-based models that underscore the complexities and interconnectedness between soil, climate, water use/quality and specific farm management practices. Science, then, is used to develop tailored tools that are most likely to be successful in enhancing sustainability while ensuring efficiency and, ultimately, a safe, quality product to be enjoyed.

Bringing science to the decision makers

Life cycle assessment research has helped the dairy value chain study the environmental impact of milk and dairy foods production, and then develop best management practices for producers to implement at the farm level, processors at the plant level and haulers/distributors at the transport level. The science and best practices are built into the Smart Tools developed by the Innovation Center for U.S. Dairy so that dairy farmers and business owners can identify the economic and environmental impact of making changes in their operation. The ultimate goal is to increase the resiliency of dairy production systems, while lessening their environmental impact.

The journey to sustainability includes many small steps that add up.

On the farm

- Better feeding practices have been implemented through research, extension, and education efforts of universities, research institutions and private companies. Today's cows have their diets carefully balanced by animal nutrition experts using advanced computer software.
- Milking practices are managed in order to keep cows infection free.
- Bedding materials, such as water beds and sand, minimize bacteria growth.
- Vaccination programs promote healthy cows.
- Free-stall barns allow a dairy cow to choose when she wants to eat and drink, lie down, or get exercise.
- Animals are housed according to size and age to minimize social stress.
- Fans help circulate fresh air when needed, and sprinklers keep cows cooler.
- Calves are often housed individually in hutches, to prevent overcrowding, so they can exercise, get plenty of fresh air and receive individual feeding and care.

On the road

Transporters have worked to reduce fuel use by introducing best practices such as:

- Utilizing software to efficiently route company trucks, reducing miles and idle time.
- Using single wide tires, aluminum wheels, automatic tire inflation systems, on-board computers, synthetic drive train lubes and extended-life coolant and door switches to prevent refrigerated trailers from running when the door is open.
- Filling trucks on their return trip with product normally shipped by a freight carrier to distribution centers.
- Reducing top speed on company tractors from 68 mph to 65 mph, which saves approximately 52,000 gallons of fuel per year.

In the plant

- Dairies comprise nearly 30 percent of plants participating in the EPA's ENERGY STAR Challenge for Industry.
- Processors are experimenting with blowing bottles with up to 5 percent inorganic filler to reduce the amount of HDPE plastic.

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LCA Review Process

Comprehensive LCA Research

Peer-reviewed scientific research grounds dairy industry decisions. It also informs the development of best practices and helps establish goals and measure accomplishments for every segment of the dairy value chain. The Life Cycle Assessment was initiated by the Innovation Center for U.S. Dairy's Sustainability Council and the final results were released in late 2012.

The expert research team consisted of 15 subject area experts from institutions throughout the United States. Additionally, 62 academic experts and 64 dairy industry leaders were among the reviewers who participated in final evaluation of the research findings.

Non-governmental agencies also were included in the review process:

- World Wildlife Fund
- Environmental Defense Fund
- World Resources Institute
- Winrock International
- United Nations Environmental Programme
- Food and Agriculture Organization of the United Nations
- Field to Market
- Natural Resources Defense Council
- Sustainable Food Laboratory
- National Wildlife Federation

Expert Research Team

- Olivier Jolliet, PhD, Professor of Environmental Health Sciences, University of Michigan
- Andrew Henderson, PhD, Assistant Professor of Environmental Sciences, University of Texas Health Science Center
- Greg Thoma, PhD, Bates Teaching Professor of Chemical Engineering, University of Arkansas
- Marty Matlock, PhD, Professor and Area Director, Center for Agricultural and Rural Sustainability Biological and Agricultural Engineering, University of Arkansas
- Marty Heller, PhD, Research Associate at Center for Sustainable Systems, University of Michigan
- Anne-Claire Asselin, PhD, Consultant in Life Cycle Assessment, University of Michigan
- Dae-Soo Kim, PhD, Post Doc Fellow, University of Arkansas
- Manuele Margni, PhD, Scientific Coordinator, Interuniversity Research Centre for the Life Cycle of Products, Processes and Services (CIRAIG)
- Franco Milani, PhD, Assistant Professor of Food Science, University of Wisconsin
- Greg Norris, PhD, Lecturer on Life Cycle Assessment, Harvard School of Public Health
- Darin Nutter, PhD, Professor of Mechanical Engineering, University of Arkansas
- Jennie Popp, PhD, Professor of Agricultural Economics and Agribusiness, University of Arkansas
- Dean Sommer, Senior Management Team, Wisconsin Center for Dairy Research
- Rick Ulrich, PhD, Professor of Chemical Engineering, University of Arkansas
- Sebastien Humbert, PhD, Co-founder, Quantis-International
- Jon Dettling, U.S. Director, Quantis-International
- Lindsay Lessard, Life Cycle Analyst, Quantis-International
- Ying Wang, PhD, Dairy Research Institute, Innovation Center for U.S. Dairy

Glossary

Anaerobic digester
An anaerobic digester is a manure management technology that turns organic waste into clean, renewable energy. Digesters can reduce greenhouse gas emissions, preserve natural resources, and increase on-farm income.

Atmospheric deposition
Atmospheric deposition occurs when emissions of air pollutants from natural and human-made sources are deposited in the environment.

Biodiversity
Biodiversity is comprised of the sum total of all plants, animals, fungi and microorganisms in the world or in a particular area. This includes all of their individual variations and all the interactions between them.

Carbon footprint study
A carbon footprint study measures the greenhouse gas (GHG) emissions associated with a particular industry or product, such as a gallon of milk. Specifically, a carbon footprint provides a representation of the effect activities have on the climate. It is expressed in terms of the total amount of greenhouse gases produced (measured in units of carbon dioxide).

Carbon sequestration
Agriculture practices use the process of carbon sequestration to remove carbon dioxide (CO_2) from the atmosphere. Because CO_2 is the most important global warming gas emitted by human activities, carbon sequestration can help prevent global climate change by enhancing carbon storage in trees and soils, preserving existing tree and soil carbon, and reducing emissions of CO_2, methane (CH_4) and nitrous oxide (N_20).

Ecosystem
An ecosystem is a system of complex interactions of populations between themselves and with their environment.

Energy efficiency
Energy efficiency occurs when less energy is used to perform the same services.

Energy use
Energy use describes the amount of energy consumed by a system or process, measured in kilowatt hours.

Enteric methane
Enteric methane is the term for methane produced by cows during the process of feed digestion.

Environmental (ecological) footprint
An environmental footprint is the measure of how much land and water is needed to produce a resource and to dispose of the waste that is generated.

Eutrophication
Eutrophication is the process by which a body of water becomes enriched by inorganic plant nutrients, especially phosphates and nitrates.

Feed production
Feed production is the stage in the dairy supply chain that includes the planting, tending, irrigating, and harvesting of animal feed products.

Geospatial analysis
A geospatial analysis is a study analyzing relative impacts on a regional basis, including assessments of the effects of carbon storage, nutrient use, nitrogen, phosphorus, water use, eutrophication, and biodiversity, among others.

Grass-to-glass (farm-to-table) Life Cycle Assessment
A grass-to-glass Life Cycle Assessment covers environmental impacts throughout the life of a product. The dairy industry LCA includes 9 stages: feed production, production, delivery to processor, processing, packaging, distribution, retail, consumption of product, and disposal of the packaging.

Greenhouse gas emissions (GHG)
Some gasses, including carbon dioxide, methane, and nitrous oxide, trap heat from sunlight near the earth's surface. These gasses are termed "greenhouse gasses" because they have the same effect in the atmosphere as glass in a greenhouse.

Heat exchanger (plate cooler)
Heat exchangers, also known as plate coolers, are an energy-saving technology that uses well water to cool milk as it moves from the milking system to a holding tank. Because the milk has been pre-cooled, the storage tank's compressors use less energy to chill the milk to the desired temperature. Water is then collected and used again as drinking water for cows.

Life cycle (dairy)
The dairy life cycle includes all the steps required to produce a dairy product, including feed production, milk production, milk processing, retail and consumption of the product, all the way through to the disposal of the packaging.

Life Cycle Assessment (comprehensive)
A Life Cycle Assessment (LCA) is a method regulated by the International Organization for Standardization (ISO) that provides a standard procedure for assessing environmental impacts. It is a compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product or service throughout its life cycle. It is a science-based and quantifiable approach to determining the product's effects on the environment and provides a clearer picture of the impact of industries and products. Specifically, a Comprehensive Life Cycle Assessment (LCA) is a quantification of 1) the level of energy and raw materials used, 2) the solid, liquid and gaseous wastes produced at every stage of a product's life or process. An LCA can be conducted for a whole process or for part of a process.

Manure management
Manure management is the containing, treating and utilizing of animal waste. Farmers use manure management techniques to minimize pollution and increase opportunities for environmental sustainability, including using manure as a source of renewable energy or crop fertilizer.

Milk production
Milk production is the stage in the dairy supply chain that includes on-farm practices directly contributing to the production of milk.

Nitrogen
Nitrogen is one of the most important nutrients in crop production. It has many important functions in plants, including storage and transfer of energy through the plant. In marine systems, Nitrogen is a growth-limiting nutrient.

Nitrogen load
Nitrogen load describes the pollution resulting from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification.

Non-point source pollution
Non-point source pollution is pollution resulting from land runoff, precipitation, atmospheric deposition, drainage, seepage or hydrologic modification. The term "non-point source" means any source of water pollution that does not meet the legal definition of "point source," per the Clean Water Act.

Nutrient sources
Crop fertilizer field runoff is a source of nutrients in water.

Peer-reviewed studies
Peer-reviewed studies have been evaluated professionally by other experts in a field.

Phosphorus
Phosphorus is a nutrient essential for growing crops. In freshwater bodies, it is a growth-limiting nutrient.

Renewable energy
Renewable energy is energy generated from naturally replenished sources. Examples include solar power, wind power, methane digesters, and hydroelectricity.

Supply chain
The supply chain is the network that produces, handles, and distributes a product. The dairy supply chain can be broadly divided into 8 stages: feed production, milk production, delivery to processor, processing, packaging, distribution, retail, consumption, and disposal.

Sustainability
Sustainability means providing consumers with the nutritious dairy products they want, in a way that makes the industry, people and the earth economically, environmentally and socially better—now and for future generations.

Water consumption
Water consumption is water that is withdrawn and will not return back to the source.

Water in competition
Water in competition describes the portion of water use that, if not used in the present application, will be used for other purposes.

Water quality
Water quality is a term used to describe the chemical, physical, and biological characteristics of water. It is usually used to determine water's suitability for a particular purpose.

Water stress index
A water stress index compares water use to water availability.

Water withdrawal
Water withdrawal describes water removed from any water body.

Watershed
A watershed is the land area that drains water to a particular stream, river, or lake. Watersheds can be identified by tracing a line along the highest elevations between two areas on a map. Thousands of smaller watersheds are found within large watersheds, such as the Mississippi River basin.

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Resources

Innovation Center for U.S. Dairy provides a forum for the dairy industry to work together to address barriers and opportunities to foster innovation. The Innovation Center aligns the collective resources of the industry to offer consumers nutritious dairy products and ingredients, and promote the health of people, communities, the planet and the industry. The Innovation Center was established in 2008 under the leadership of America's dairy farmers through Dairy Management Inc.™ (DMI), the nonprofit organization that manages the producer checkoff program. It is the first of its kind to bring together milk producers, processors and manufacturers, to offer consumers the products they want—when and where they want them.

Visit: **http://www.usdairy.com**

INNOVATION CENTER FOR U.S. DAIRY.
HEALTHY PEOPLE • HEALTHY PRODUCTS • HEALTHY PLANET

Dairy Management Inc. (DMI) is a non-profit domestic and international planning and management organization, responsible for increasing demand for U.S.-produced dairy products and ingredients on behalf of America's dairy producers. DMI manages the American Dairy Association, National Dairy Council and U.S. Dairy Export Council.

Visit: **http://dairyinfo.com/**

DMI DAIRY MANAGEMENT INC.™

Together, the Innovation Center for U.S. Dairy and Dairy Management Inc. (DMI) formed the Dairy Research Institute, a non-profit organization created to strengthen the dairy industry's access to and investment in the technical research needed to drive global demand for dairy products and ingredients.

Dairy Research Institute® was established under the leadership of America's dairy farmers with a commitment to nutrition, product and sustainability research. The Dairy Research Institute is a 501(c)(3) non-profit organization created to strengthen the dairy industry's access to and investment in the technical research required to drive innovation and demand for dairy products and ingredients globally. The Institute works with and through industry, academic, government and commercial partners to drive pre-competitive research in nutrition, products and sustainability on behalf of the Innovation Center for U.S. Dairy®, National Dairy Council® and other partners. The Dairy Research Institute is primarily funded by the national dairy checkoff program managed by Dairy Management Inc.™

Visit: **http://www.usdairy.com/DairyResearchInstitute**

DAIRY RESEARCH INSTITUTE®
NUTRITION • PRODUCTS • SUSTAINABILITY

Additional resources

The Natural Resource Conservation Service: h**ttp://www.nrcs.usda.gov/**

The United States Environmental Protection Agency: **http://www.epa.gov**

The EPA Energy Star Challenge: **http://www.energystar.gov/index.cfm?c=challenge.bus_challenge**

The EPA Smart Way program: **http://www.epa.gov/smartway/index.htm**

University of Arkansas Center for Agricultural and Rural Sustainability: **http://www.uark.edu/ua/cars/**

University of Michigan School of Public Health:**http://www.sph.umich.edu/**

University of Michigan Center for Sustainable Systems: **http://css.snre.umich.edu/**

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