# Regional Analysis of Greenhouse Gas Emissions from Milk Production Practices in the United States

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**ABSTRACT**

GHG emissions were evaluated for milk production (corrected to 4% fat and 3.3% protein) in the United States. Five production regions were defined and regional scale analysis of crop and milk production was performed. We present a detailed analysis derived from 530 surveys collected from dairy farmers nation-wide. Feed rations for different animal classes, including an accounting for time on pasture, were used in determination of the feed contribution to the footprint. Crude protein content of the feed was used to enforce the nitrogen balance for estimation of nitrous oxide emissions from manure management systems. A robust mathematical model, driven by feed consumption, for enteric methane production was adopted from the literature. A physical / biological approach for allocation of on-farm burdens between the co products milk and beef was developed and utilized for this study. The weighted national average farm-gate footprint was 1.2 kg $CO_2$e per kg FPCM.

*Keywords*: GHG emissions, US dairy, milk production, regional analysis, fat and protein corrected milk

## 1. Introduction

Consumers are becoming more aware that food choices they make have an impact on health and the environment. They are changing how and what they buy, and how they dispose of products, in order to lead a more environmentally-friendly lifestyle. Meanwhile, major retail companies are adding environmental reporting requirements for their suppliers as companies, and for the products they purchase from those suppliers.

To better meet these evolving needs of the marketplace, the US dairy industry decided to take a proactive approach that would drive innovation in products and processes. As a first step, they chose to undertake a life cycle assessment for fluid milk with the recognition that what gets measured gets managed. In order to address environmental impacts appropriately and effectively, the industry needs a benchmark against which to set goals and measure progress. Additionally, an LCA provides insight into where the industry can innovate to achieve the greatest gains.

Sustainability is a broad topic and encompasses many environmental and social impact areas. For the purposes of this study, the LCA was limited to greenhouse gas emissions in order to estimate a carbon footprint for US dairy operations (fluid milk). The LCA follows ISO protocols to provide credibility, transparency and objectivity of the methods, data and results. Nonetheless, to be fully ISO compliant the study should include additional environmental impact areas.

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## 2. Goal, Scope, and Functional Unit

This life cycle assessment is a cradle-to-gate analysis of the carbon footprint of fluid milk. The primary time frame for the study was 2007-2008. The system boundary extended to extractions from nature for production of fuels and fertilizer, and ended at the dairy farm gate. We adopted a 1% cut off criterion, based on initial estimation of flows that contribute less than 1% of the GHG emissions. The scope of this project does not extend to other environmental effects such as nutrient runoff, topsoil loss, or depletion of freshwater supplies; it focuses on evaluation, at a large regional scale, the GHG emissions attributable to production of fluid milk in the United States. We have chosen 1kg of 4% fat, 3.3% protein corrected milk (FPCM, also known as energy corrected milk). The following relationship was used to convert reported farm production to FPCM (based on true, not crude protein):

$$\frac{0.0929Fat+0.05882Protein+0.192}{0.0929*(4\%)+0.05882*(3.3\%)+0.192} = \frac{0.0929Fat+0.05882Protein+0.192}{0.7577} \quad (1)$$

## 3. Life Cycle Inventory Data Collection and Results

Data were collected from many sources including the USDA's National Agricultural Statistics Service and Economic Research Service, an extensive survey of dairy farming practices by region (Figure 1), the peer reviewed literature, other technical literature and consultation with experts in different fields. All data were critically assessed as to the quality and suitability for use in this analysis. SimaPro© 7.1 was used as the primary modeling software; the EcoInvent database provided information on the 'upstream' burdens associated with materials like primary fuels and fertilizers. Data from the surveys and other US specific information was incorporated to the extent that it was available.

### 3.1 Feed Production

Based on the recent literature (Mowrey and Spain, 1999) and information from the farm survey regarding the composition of dairy feed, we have identified the most common feedstuffs and have collected available information from farm extension and the National Agricultural Statistical Service (NASS) regarding the energy and chemical inputs associated with production of these crops on a regional basis. In addition, the analysis of the producer survey led to identification of some additional, commonly used, feeds which were added to our database which included 108 distinct feeds.

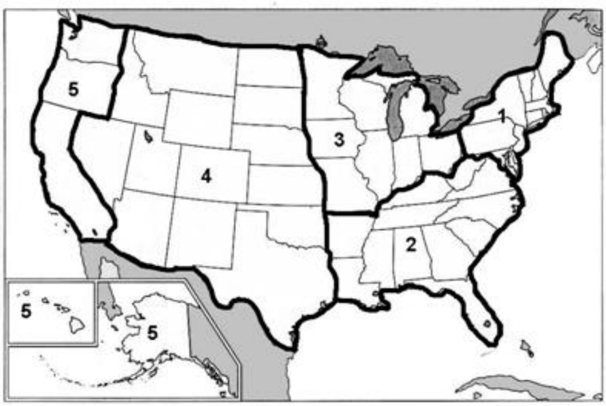


**Figure 1:** Dairy production regions used for this study

### 3.2 Fertilizer Profiles

The USDA NASS database provides the best available information on the amount of nitrogen applied to a wide variety of crops; but it does not provide the type of nitrogen fertilizer. We have taken the approach that the US nitrogen fertilizer production profile is a reasonable surrogate for the crop application profile. While this may not represent actual application rates for individual crops, in the absence of reported information on the type of nitrogen applied, this approach provides a reasonable approximation, and captures the overall average impact of fertilizer production in the United States.

## 3.3 Feed

Figure 2 presents the footprint of several feeds, showing the differences between regions. Feed represents a major contribution to GHG and an opportunity associated with conservation and no-till operations in the feed supply chain remains; it is a singular opportunity for the dairy farmers who grow their own feeds or have some control through contracts with the crop production farms. This study considered biogenic carbon-- which is carbon in the relatively short-term cycle from the atmosphere through crops and back to the atmosphere -- to be neutral with respect to GHG emissions; therefore carbon sequestration by plants and the respiration of the animals was considered to balance and were not specifically accounted.

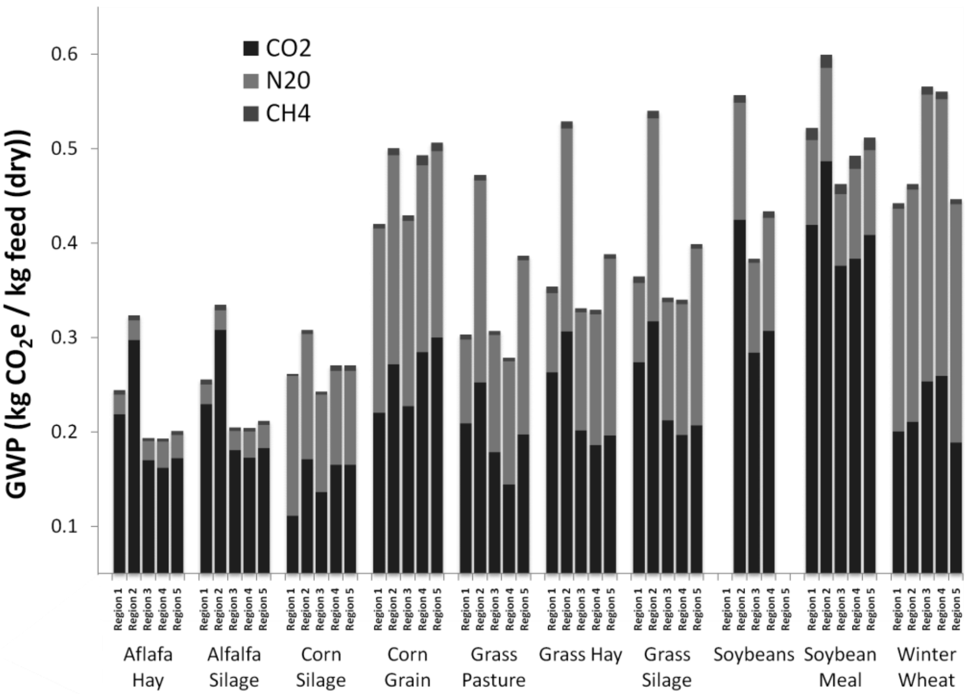


**Figure 2:** GHG inventory of feed production by region. Feed production represents just over 25% of farm-gate burdens

## 3.4 Enteric Fermentation

Methane from enteric fermentation is known to be dependent on the animal's diet, and a large body of research focuses on the effect of diet on methanogenesis in ruminants. Methane release can vary as much as 50% between low-quality diets, high quality, and 90%-

concentrate diets (Johnson and Ward, 1996). Much effort has been expended modeling and predicting methane from cows fed specific diets, with moderate success (Moe and Tyrrell, 1979; Blaxter and Clapperton, 1965; Ellis *et al.*, 2007; Hindrichsen, *et al*., 2005; Mills *et al.*, 2003). It is clear that on-farm methane measurements are not feasible as a general method for estimation of enteric methane production. Thus we are faced with the task of choosing among a number of published models. We evaluated a series of models against measured methane emissions (with known rations) and found the model proposed by Ellis *et al*., (2007) had the lowest average error. While this model is most robust, it is also the simplest, requiring only dry matter intake; thus dietary effects are not accounted in this study.

### 3.5 GHG Emissions from Manure Management

We used standardized methodologies as described in the IPCC 2006 guidelines in estimating the annual $CH_4$ and $N_2O$ emission factors from livestock manure. The farm survey requested specific information about on-farm manure management. Temperature is an important parameter in the estimation of methane release associated with each of the manure management techniques, and local average temperatures retrieved from the NOAA National Climatic Data Center were used. Eighteen manure management techniques (daily spread, lagoons, liquid slurry etc) used to manage liquid, dry or slurry manure were incorporated.

### 3.6 On-farm Energy

We tabulated on-farm fossil fuel and electricity use. When the response provided the dollar amount spent on energy; we used state average fuel prices for 2008 to convert to quantities. We used the unit processes from the EcoInvent database for the three US interconnect zones of the US electricity grid to model emissions associated with electricity consumption because there is essentially no electricity transfer across interconnect boundaries.

### 3.7 Milk to Beef Allocation

The milk to beef allocation ratio at the farm gate is an important consideration in the LCA for fluid milk due to the large contribution to the entire supply chain which results from farming activities. The allocation algorithm that we have adopted is conceptually similar to the biological allocation presented by Cederberg and Stadig (2003) where an estimate of the feed energy deposited in the beef and milk products is estimated, and the ratio of those input feed energies is used to allocate the overall environmental burdens. In the algorithm used for this study, the incoming feed energy is estimated from the reported quantity of beef and milk produced and the known nutritional characteristics of the specific feeds consumed by the animals. The ratio of the feed energy deposited as milk to the total feed energy deposited as milk and beef is then used to define the allocation ratio. In the United States, the Nutrient Requirements of Dairy Cattle presents information regarding the energy content of common feeds as well as mathematical models for estimating the amount of feed energy deposited as tissue or milk (National Research Council, 2001).

## 4. Summary

Significant effort was put into creating, distributing, and analyzing the dairy farm survey. Two principal questions were posed at the time the survey was created: are there significant regional or farm/herd size differences in the carbon footprint? The simplistic answer is yes.

However, there is not strong explanatory power in these differences. Figure 3 presents a summary of the dairy farm-gate results from the analysis of 530 respondents. The overall footprint is created from the combination of fuel, feed, enteric and manure management contributions. Broadly speaking Regions 1 and 3 have lower footprints than the other regions, and larger farms tend to have slightly lower footprints than smaller farms, except in Region 4. We had a relatively low response rate from Region 2, and therefore considerable caution is needed to make strong conclusions regarding production in that region. The contribution of on-farm fuel (excluding crop production) does decrease with dairy farm size, suggesting an efficiency of scale; however, as farm size increases, so does the contribution from manure, which offsets the fuel efficiency gains.

A full statistical analysis of the farm survey was conducted. Some important results of this analysis are:

- Solid storage, dry lot, and deep bedding (stored more than one month) are the top three manure management practices nationwide; anaerobic lagoons were in the top ten practices only in regions 2 and 4.
- Only 55% of respondents reported the use of production enhancement practices.
- Feed conversion efficiency is a significant factor in determining the footprint; primarily because of this, farms which rely more on pasture for the animal's feed have a larger footprint on a production basis. Pasture diets generally comprise a larger fraction of less digestible material (more cellulose and less starch), and therefore require more energy to digest the forage in the rumen, resulting in somewhat lower feed conversion efficiency.
- The top four feeds, accounting for approximately 55% of all feeds are corn silage, alfalfa

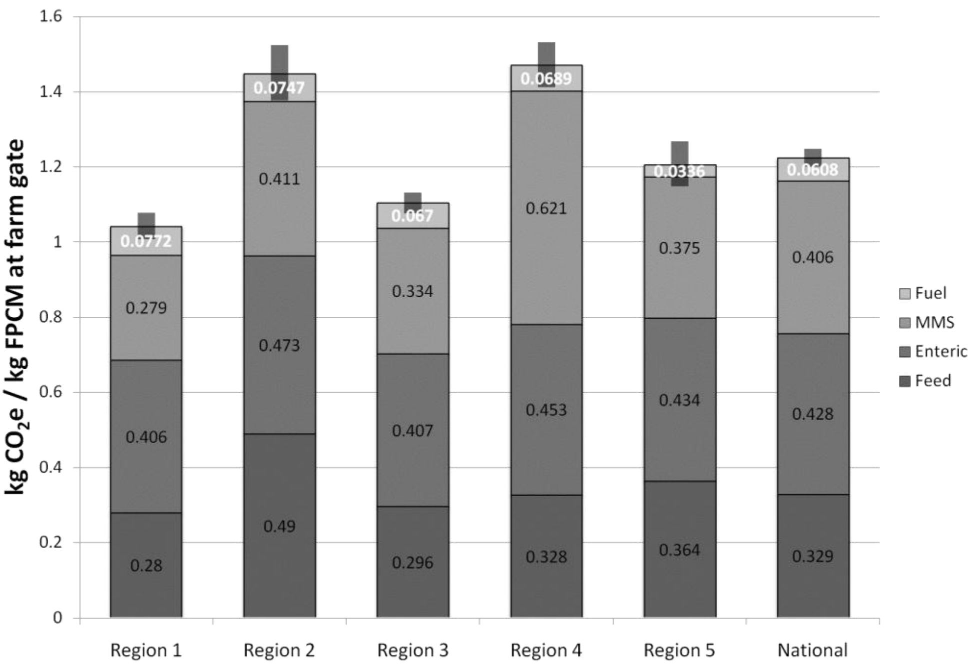


**Figure 3:.** Comparison of cradle to farm gate footprints by production region, and national average, in the United States. Gray bars represent the 95% confidence intervals for the mean GHG emissions for the region.

hay and silage and corn grain. These feeds plus distiller's grains, supplements, protein mix and soybean meal account for 70% of the carbon footprint of the feed. Supplements, distiller's grains and protein mix have a disproportionately large contribution to the footprint due to the additional processing necessary for their preparation.
- Region 2 (the southeast) has the largest feed footprint for most crops grown locally. This is the result of higher fertilizer application rates – both N and lime fertilizers are notably higher for this region. Lime, more precisely crushed limestone, is applied at over twice the levels of other regions, and as it neutralizes the acidic soils, releases carbon dioxide.

The single most important factor in explaining differences in GHG emissions across all farms is feed conversion efficiency. This is not a particularly surprising result: feed is a major farm input and directly affects both enteric emissions and the quantity of manure excreted. Opportunities with some of the larger farms in Region 4 where anaerobic lagoons are a common management system may be significant. In addition, further work to continue increasing feed conversion efficiency is also important, as this variable alone explains over 50% of the observed variability in the feed and enteric methane contribution to the farm-gate footprint.

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