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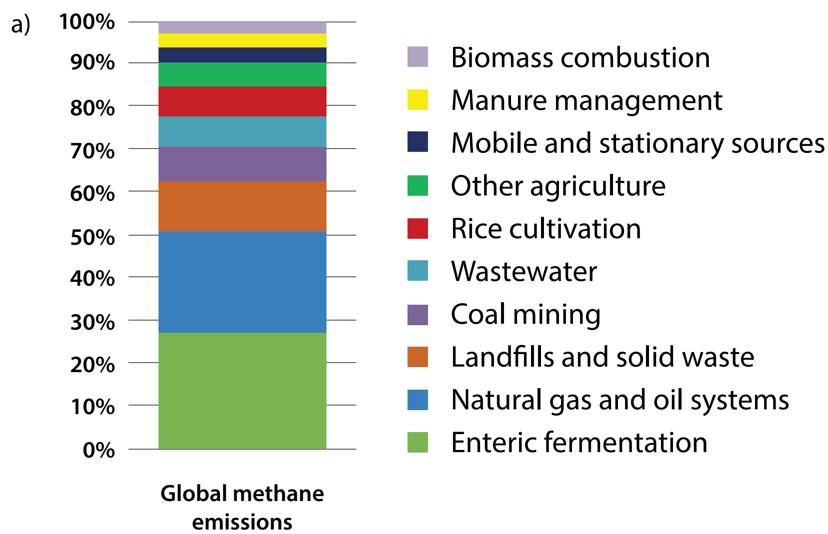
# Methane Emissions from Dairy Cattle

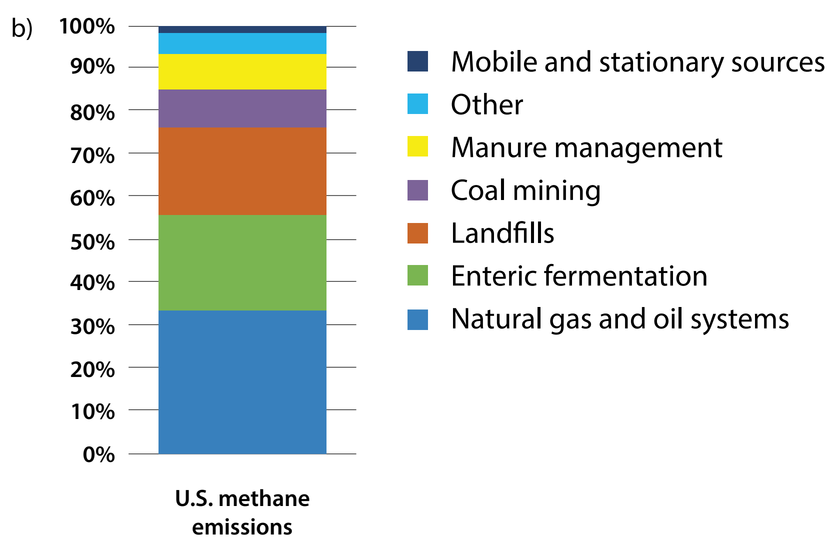
*An Overview*

## Introduction

Methane ($CH_4$) is a gas produced largely from bacteria that live in soil, water and the stomachs of ruminant animals (mammals that have a stomach with four compartments that ferment food as a major part of the digestion process). Methane is considered a greenhouse gas (GHG) because it can trap infrared radiation in the atmosphere, causing an increase in air temperatures. Methane is the second most abundant global man-made GHG, behind carbon dioxide ($CO_2$), which comes largely from fossil fuel combustion (IPCC 2014). Methane, once emitted, will exist in the atmosphere for 12 years, which is shorter than the lifetime of $CO_2$. However, methane is able to trap more radiation compared to $CO_2$ resulting in 28-34x greater global warming potential (see inset on Global Warming Potential). Overall, methane represents 16% of annual GHG emitted to the Earth's atmosphere based on its Global Warming Potential.

**Figure 1.** a) Global man-made $CH_4$ emissions (Source: USEPA 2012), b) U.S. man-made $CH_4$ emissions (USEPA, 2016), and c) on-farm GHG emissions breakdown per gas type (Aguirre-Villegas et al. 2015). Mobile sources include on-road and off-road vehicles, ships and boats, trains, and aircraft. Stationary sources include factories, refineries, boilers, and power plants. (Continued on next page).



**Global Warming Potential**

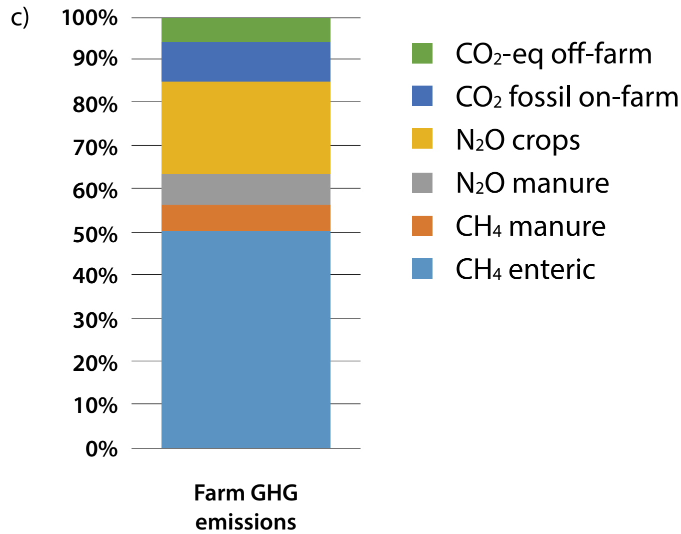
The atmospheric lifetime of a GHG, or how long a greenhouse gas remains in the atmosphere, determines how long it will increase the temperature of the Earth. The measure of how much energy a GHG traps in the atmosphere over a period of time (commonly 20 or 100 years) relative to $CO_2$ is called its global warming potential (GWP). GWP is expressed in terms of $CO_2$ equivalents ($CO_2$-eq) (Table 1). For example, if the 100-year GWP potential of methane is 28, then one methane molecule ($CH_4$) has the same greenhouse effect as 28 molecules of $CO_2$. The GWP of methane is larger for shorter periods of time when compared to $CO_2$; the 20-year GWP for methane increases to 84. Standardizing GHGs based on GWP provides a common unit of measure to compare all GHGs. This is very useful in comparing different scenarios that could guide emission reduction strategies.

The Intergovernmental Panel on Climate Change (IPCC) has set the standard values for methane's GWP over the past 20 years as compared to $CO_2$. These values have been increasing over time for two reasons: the diminishing ability of oceans and soils to absorb $CO_2$ as temperature rises (climate-carbon feedback), and the production of additional $CO_2$ from the oxidation of existing $CH_4$ in the atmosphere.

Table 1. Global warming potential of $CH_4$

| **IPCC Report** | IPCC 2013 – AR5 |
|---|---|
| **GWP** $_{100\ years}$ | 28[a] – 34[b] |
| **GWP** $_{20\ years}$ | 84[a] – 86[b] |

Myhre et al. 2013
a Without including climate-carbon feedbacks
b Including climate-carbon feedbacks




Methane can be emitted from both natural and man-made sources. Wetlands account for 82% of natural sources. The high moisture and low oxygen conditions of wetlands are ideal for methanogens (the bacteria that produce methane) to decompose dead plant material (USEPA 2010). But not all land types are methane emitters. Dry upland soils act as sinks (the soil consumes more methane than it emits) for atmospheric methane that is used by bacteria in the soil as a source of carbon. Overall, man-made emissions of methane are greater than from natural sources and account for 63% of the total methane that enters the atmosphere (USEPA 2010). Man-made contributions of methane include emissions from enteric fermentation, natural gas and oil production, landfills and solid waste, rice cultivation, wastewater, manure management, biomass combustion, coal mining, static and mobile combustion and other agricultural activities (Figure 1a).

On a global basis, agriculture (enteric fermentation, manure management, rice cultivation, and other agriculture) contributes 41% of man-made methane emissions. Livestock is the major single source, accounting for 73%, of agricultural methane emissions (USEPA 2013).

## U.S. methane production and dairy

Man-made methane emissions in the U.S. are 731 million tons $CO_2$-eq, which is equivalent to the emissions from 154 million passenger vehicles driven in one year (USEPA 2016[a,b]). Livestock represents 31% of the total methane emissions produced from human activities in the U.S., with beef and dairy cattle as the major contributors. More specifically, enteric methane from livestock is the second largest source of methane emissions in the U.S. and dairy cattle alone accounted for 26% of total enteric emissions (USEPA 2016[a]). Methane production from enteric fermentation is part of the normal digestive process in animals, especially ruminants, where microbes that live in their digestive system ferment the food they eat. These emissions are primarily the result of animals belching or exhaling, as only 5% of the total methane from a dairy cow comes out the back end of the animal.

Manure is also an important emission contributor of methane (Figure 1b). Dairy cattle alone are responsible for 53% of total methane emissions from manure management in the U.S. (USEPA 2016[a]). Methane is produced by the microbial decomposition of organic material in manure in the absence of oxygen. In these conditions, anaerobic microorganisms dominate the decomposition processes and produce methane as a part of their anaerobic respiration. As a result, methane is mainly emitted from slurry and liquid manures as they are

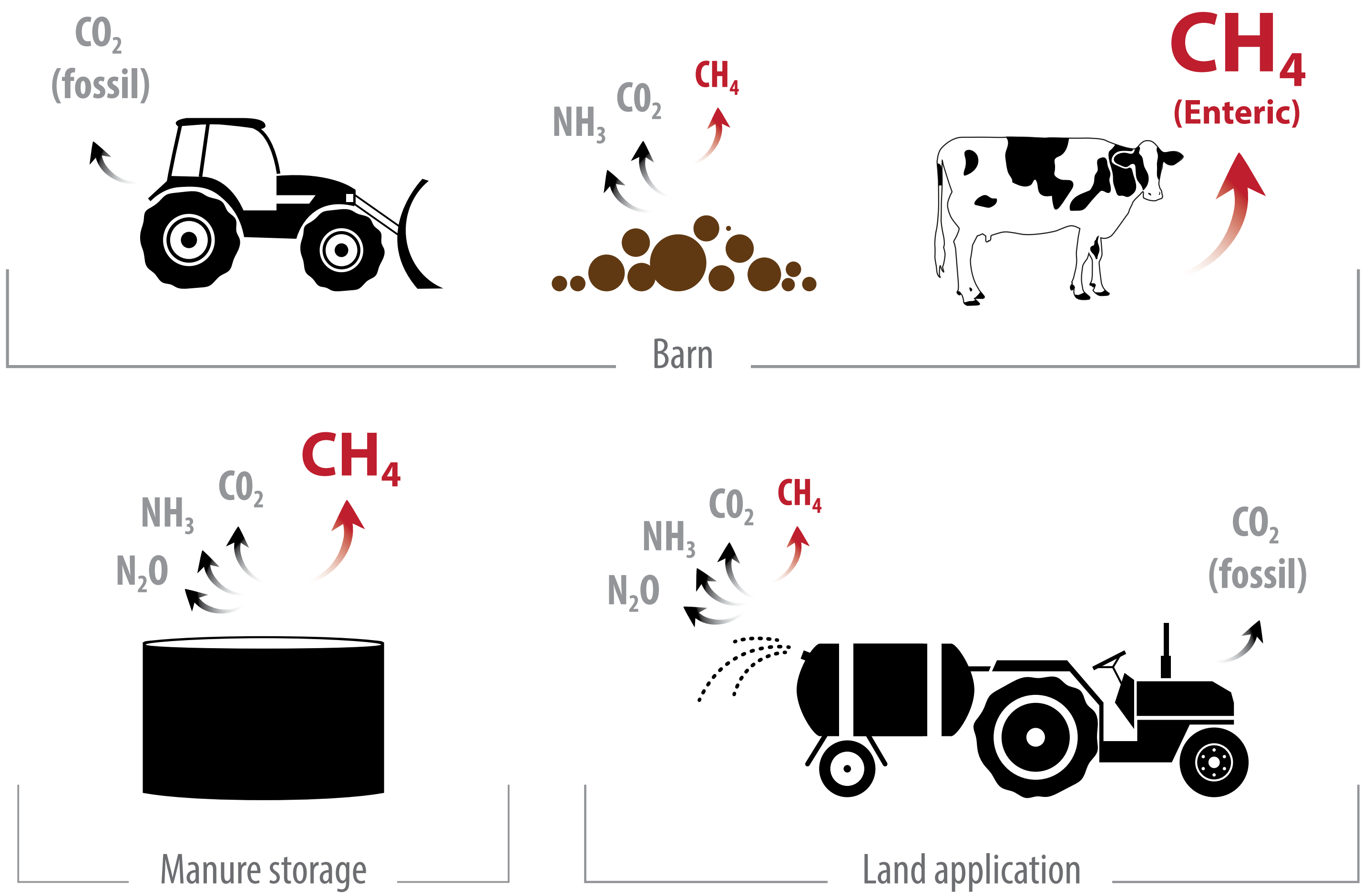



**Figure 2.** Sources of methane emissions.

handled under conditions with low oxygen levels. During manure handling, methane is emitted mostly from storage and land application. Manure storage is common in large confined operations where the anaerobic conditions and prolonged storage times are ideal for microorganisms to produce methane. To a lesser extent, manure land application also contributes to methane emissions, especially if manure is injected in the soil as this creates anaerobic conditions (Chadwick 2011).

The life cycle assessment method can be used to estimate emissions from a farm. Using this method, Thoma et al. (2013) reported that 72% of the GHG emissions related to general fluid milk production in the U.S. occur within the boundaries of the dairy farm, where more than 50% of these emissions are from methane. The remaining 28% are emitted during the transport, processing, distribution, consumption and final disposal of milk and meat. Based on Aguirre-Villegas et al. (2015), the production of one gallon of milk at the dairy farm produces nearly 3.8 kg $CO_2$-eq, which is equivalent to the emissions from driving an average passenger vehicle for nine miles (USEPA 2016[b]). More than half of these emissions are in the form of methane coming from both the cow's digestive process and the manure handling processes (mainly from manure storage) (Figure 1c).

## Mitigation

There are different strategies to reduce, or mitigate, methane emissions from enteric fermentation and manure at the farm level. Enteric methane is difficult to mitigate as it involves the natural digestion process of the cow, but ongoing work is exploring the potential of genetics and changes in the cow's diet. Genetics involves selective breeding toward cows with higher feed efficiencies to increase milk production without increasing the methane produced. Animal performance can be improved by exploring cow genomics to identify the genes that a cow needs to grow and produce milk and by identifying the management practices that tend to increase productivity. Some strategies that consider changes in the cow's diet to reduce enteric emissions include introducing feed additives to maximize microbial fermentation and improving feed efficiency through diet quality. For example, Arndt et al. (2015) found that the amount and source of fiber as well as the amount of starch fermented had an impact on enteric methane production. Corn silage yielded substantially more enteric methane than the fermentation of alfalfa silage in the rumen of dairy cows.

To reduce methane emissions from manure, the focus has been on changing the characteristics of the manure to reduce the degradation of solids or designing manure systems to contain or capture emissions. Some strategies include composting, manure separation, manure storage covers and capturing methane from manure using anaerobic digestion systems to combust and convert the methane to carbon dioxide. For example, Aguirre-Villegas et al. (2014) found that GHG emissions from manure management can be reduced by nearly 50% with the installation of an anaerobic digester without even considering the benefits of replacing grid electricity. An anaerobic digester is a tank containing manure in which microorganisms produce methane in the absence of oxygen. With this controlled process, the produced methane can be easily captured to produce heat or electricity. Other processing techniques, such as separating the solid and liquid components of manure, can reduce methane losses during storage by 20%. Integrating these practices requires careful consideration of many factors including cost, operational issues, regulations and other environmental concerns.

## Summary

Methane is produced on dairy farms mainly through enteric fermentation and manure storage. Methane accounts for 11% of greenhouse gas emissions each year in the U.S., of which 31% is from livestock. Methane emissions from enteric fermentation represent the largest fraction of the emissions from a dairy farm, but they are difficult to mitigate. Methane emissions from manure storage are also important, and there are technologies that currently exist (anaerobic digestion and liquid-solid separation among others) that can lead to dramatic reductions in methane from a dairy farm.

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