# Energy in Dairy Systems

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## Renewable Energy Summer Intern

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**Abstract:**

The goal of my research on energy use in agriculture and dairy systems is to communicate and educate the general public about this energy use. Dairy farms use a large amount of energy for feed production, maintaining the dairy herd, harvesting milk from the dairy cows, and storing the harvested milk. To communicate with the general public, I developed multiple handouts and two videos about energy use in various types of dairy systems and agriculture; while, showing the general public the opportunities to decrease this energy use.

## Energy Use in the U.S.

The U.S. economy used over 100 quadrillion BTUs of energy in 2007, of this consumption 85% of it came from fossil fuels (Canning, Charles, Huang, Polenske, & Waters). This shows how the U.S. economy is dependent on fossil fuel consumption; however, there is not an infinite supply of them for continued use. Eventually, this supply of fossil fuels will be used up and the developing nations will have to find an alternative energy source to power their growing economies, yet there are other options for energy sources and ways to decrease energy consumption, such as renewable energy and energy efficiency.

## Energy in Agriculture

Food production systems use 19% of total U.S. fossil energy consumption; of this 19% about 7% is consumed in on-farm agricultural practices every year (Pimentel). Over all energy sources, 2 quadrillion BTUs of energy were used in agriculture in 2002 (*U.S. Food System*). The industrialization of agriculture and the increasing demand of food from the growing population have forced food manufactures to be dependent on fossil fuels and other energy sources to produce enough food in a small amount of time (*Energy and Agriculture)*.

Energy is categorized as fuels, heat, renewable energy, and electricity. The energy that is considered in agricultural production is the energy consumed within the farms limits and the energy used in production of products used in farm operations. There are two types of energy consumed in agriculture: direct and indirect energy. Direct energy is energy used on the farm or in farming operations; examples of direct energy are consumption of diesel fuel, gasoline, and

electricity (WCROC). Indirect energy comes from purchased products used on the farm or in farming operations; such as, the use of fertilizers and pesticides. Fertilizer use alone resulted in more than half of the indirect energy use in U.S. agriculture in 2011; while, consumption of direct energy accounts for 63% of agriculture's energy use due to the immense amount of use of farm equipment and electricity in farms (Beckman, Borchers, & Jones).

## Renewable Energy

Agriculture has the opportunity to reduce its energy consumption through becoming more sustainable with the use of renewable energy sources. Sustainable agriculture creates large amounts of food without depleting the earth's resources or increasing pollution (Earles). Renewable energy is energy that regenerates itself; it also can replace fossil fuels so that the amount of pollutants in the air decreases (Svejkovsky). It also contributes to the local economy by developing jobs, and keeping the energy dollars within the local community.

The two most developed types of renewable energy are wind and solar energy. Wind turbines take the kinetic energy in the wind and change that into mechanical power that goes to a generator and creates clean energy (Svejkovsky). A small wind turbine can decrease a farmer's electricity bill, prevent power interruptions, and is non-polluting. While, the other type of renewable energy is solar energy. Solar energy uses the sun to produce electricity and heat water without any noise disturbance or air pollutions. The most common type of solar energy systems is a Photovoltaic (PV) system. This system creates electricity from direct sunlight. Solar panels can also heat water for use throughout a farm, saving farmers money on energy costs.

## Dairy Farms

Dairy farms are farms where livestock, usually cows, are raised for the harvesting of their milk for sale. Dairy farms are located all over the U.S. and Puerto Rico, and 97% of them are family owned. Dairy farming is the most energy consuming agricultural operation since either indirect or direct energy is used in every step of the operation (Pressman). Every cow on a dairy farm averages 7 gallons of milk per day, which totals to a little over 2,500 gallons of milk per year. Not only do dairy farms provide the general public with milk, but the dairy industry has an economic output of $140 billion and has created over 900,000 jobs (*The U.S. Dairy Industry: A Vital Contributor to Economic Development*).

## Energy Used in Dairy Production

The process of harvesting milk from the dairy cows—whether they are organic or conventional—involves many steps to arrive at the point where the milk is ready to be shipped. For a dairy farm to be labeled as organic the livestock has to be fed organic feed, housed in spacious pens, have access to the outdoors, and cannot be treated with hormones or antibiotics. Conventional and organic dairy farms usually differ in feed production and animal housing agricultural practices and energy use. However, both systems consume large amounts of energy throughout the dairy production.

### Feed Production

Farmers have two options for how they grow the feed for their livestock: organically and conventionally. Conventional and organic crop productions are similar in the fact that they both utilize farm equipment to plant and harvest the crops, along with tilling and irrigation systems; yet, conventional feed production incorporates the use of chemically produced fertilizers and

pesticides to enhance the growing of the crops. On the other hand, organic farming utilizes livestock manure as a substitute for fertilizers and the use of a rotary hoe for weed control.

Energy used in both conventional and organic cropping systems includes the diesel fuel required to power farm equipment for planting and harvesting the feed and the power necessary to maintain irrigation systems for the fields. Energy used in conventional cropping systems include the use of fossil fuels to create fertilizers and pesticides, diesel fuel for farm equipment to plant and harvest the crops, and electricity for irrigation systems. Organic cropping systems also consume energy in the form of diesel fuel for farming equipment and electricity for irrigation systems; however, organic systems do not use chemically produced fertilizers and pesticides, reducing the use of fossil fuels. Though this reduces fossil fuel consumption, it increases diesel fuel consumption because farmers must cultivate their fields with a rotatory hoe once a month to manage the weeds.

**Animal Housing**

The energy used in maintenance of animal housing differs depending on whether the dairy cows live in pastures or barns, which is sometimes determined by whether the dairy cows are raised organically or conventionally. Conventional cows usually live in barns close to the milking parlor, where the barn's environment is set to maintain comfort for the dairy cows and feed and fresh water is brought to them. Organic cows are usually housed in a set of pastures—that they rotate between to maintain the health of the pastures—then are transported every day to the milking parlor. Though this is usually the case for livestock housing on organic and

conventional farms, there is variation in livestock housing strategies for organic and conventional dairy farms.

Pastures and barns consume energy differently. If the livestock live in pastures the energy consumed is due to the powering the electric fence, as well as the fuel needed to transport the livestock between pastures. Also, if a farmer houses the livestock in pastures and is not organic, there is energy used in creating weed killers to maintain the pasture's grass. The energy consumed with livestock housed in barns is used in lighting the barn, ventilation, cleaning the stalls, bedding for animals, transportation of feed and fresh water for the dairy cows, and structural costs of the barn. However, for both living spaces cows are required to move from their pasture or barn to the milking parlor; this consumes energy if farmers use equipment requiring fuel to lead the cows to the milking parlor.

## Milk Harvesting

Milking dairy cows is one of the most energy consuming processes in dairy production. Harvesting milk on an average dairy farm results in 18% of the energy use. To harvest the milk from the dairy cows, farmers use a vacuum pump that creates a negative air pressure pulling the milk from the cow to a receiving bowl; the vacuum pump consumes 20-25% of the electrical energy on a dairy farm (Pressman). This harvesting of milk from the dairy cows takes place two or more times during a day. The final step in harvesting milk is the sanitation of milking equipment by sending water through the milking system with the use of the vacuum pump after each use, preserving a clean area for the dairy cows (*Animal Care on Dairy Farms Fact Sheet*).

Energy is also consumed in the milking parlor building operations; such as, light fixtures, ventilation system, and water heaters. Light fixtures account for 17% of this energy use on dairy farms (Pressman). A proper ventilation system is necessary to a dairy farm to maintain its productivity, while assisting with keeping the livestock healthy and having quality milk (*Animal Care on Dairy Farms Fact Sheet*). Water heaters are an important part of the harvesting of milk because hot water is needed for proper cleaning of the milking equipment, which increases health in the dairy cows and quality of milk (Pressman).

### Milk Cooling and Storage

Cooling milk accounts for 26% of electrical energy use on a dairy farm (Pressman). The harvested milk needs to be cooled quickly from 99˚F to 38˚F to maintain milk quality, this process involves the use of two different systems—a compressor and refrigeration tank (Pressman). An average dairy farm utilizes a reciprocating compressor to cool the milk, the refrigeration system then maintains the cooled milks temperature; which pumps a refrigeration coolant through a cycle (Pressman). Once the milk is fully cooled it is stored in a tank that maintains a constant temperature for the milk until it is taken to the processing plant in a refrigerated tanker that is cleaned after each shipment of the milk (*Where is milk stored on the farm?*).

## Decreasing Energy Use on Dairy Farms

With the immense amount of energy consumed on dairy farms there are many opportunities to decrease energy consumption. These opportunities include renewable energy,

manure management, and energy efficient equipment (*Sustainability and Dairy Farm Fact Sheet*).

Renewable energy can be utilized on dairy farms to decrease energy consumption by converting equipment that is currently power by the electric grid to be powered by a wind turbine or a PV solar system. Solar panels also decrease energy costs and consumption by heating water without using electricity. A wind turbine that is connected to the electrical grid reduces consumption of the utility electricity needed; because when enough energy is not created then the utility will cover the remaining, while if there is extra then that energy can be sold to the utility companies (Svejkovsky). For a PV solar system the energy generated varies depending on the sunlight it receives, therefore connecting the PV to the electric grid will allow the building to still receive power when the sun is not shining as bright (Svejkovsky). Though both of these options may not be able to completely replace dependence on the electric grid, they do reduce the current dependence and provide clean energy that will continue to regenerate itself.

Manure management can be very energy efficient on a dairy farm. Manure is very highly concentrated with methane, which is also an energy source; therefore, dairy farms have the option of investing in a methane digester to re-use this resource. A methane digester converts manure into a biogas through anaerobic digestion, which is when bacteria decomposes the manure into organic matter with the lack of oxygen creating a gas that is majorly methane yet containing carbon dioxide. This biogas is useful in powering an engine generator along with combatable a water heater (*Sustainability and Dairy Farming Fact Sheet*).

Manure can also be used as fertilizer for livestock feed. This method reduces pollution and the need for commercial fertilizers. A benefit of fertilizing crops with manure is to assist with conserving water, the water holding capacity of soil is increased by 20% (*Dairy Farms & the Environment Fact Sheet).* Not only will re-using manure decrease pollution from fertilizers, but it saves money for dairy farmers and makes production of feed more energy efficient.

Energy efficient equipment can help reduce energy consumption on a dairy farm, while reducing energy costs for dairy farmers because of the decreased energy consumption from equipment.

A variable-speed drive can be used to control the speed of the vacuum pump during harvesting milk and cleaning equipment (Pressman). A normal vacuum pump runs at full speed at all times, while a variable-speed drive adjusts the speed of the vacuum pump to a level necessary for the amount of energy needed at that time. Incorporating a variable-speed drive into the milking process of a farm will decrease energy costs by up to 60% (Pressman).

Cooling the harvested milk consumes a lot of energy on a dairy farm. A pre-cooler uses cold well water to draw the heat from the milk before it enters the refrigeration system, reducing the refrigeration use by 60% (*Opportunities Abound for Dairy Farm Energy Efficiency*). This system, however, does not completely cool the milk from its harvested temperature to its proper storing temperature of 34˚F; it only can pre-cool the milk to 5-10˚F from the groundwater temperature (*Opportunities Abound for Dairy Farm Energy Efficiency*). This allows colder milk to enter the refrigeration tank, resulting in less energy consumed in the refrigeration system. The most common type of pre-cooler is a plate heat exchanger, which

contains a set of ribbed plates arranged side by side with two separate circuits between the plates; where the milk and cold water flow in opposite circuits, exchanging heat through the plates (Huyser, Petersen, & Sanford). The warm water that comes from this process can then be used in washing or drinking water.

Another piece of energy efficient equipment is a variable-speed milk transfer pump, which decreases the flow of milk through the heat exchanger or right into the storage tank, using this causes the milk to be cooled an additional 15-20˚F before entering the storage tank (Pressman). Then since the milk is already pre-cooled, the storage tank uses less energy to lower the temperature of the milk (*Dairy Farms-Energy Saving Ideas*).

Energy efficient equipment that can be used in the refrigeration system is a refrigeration heat recovery unit and a scroll compressor. A refrigeration heat recovery unit is designed to capture the extra refrigeration heat to preheat the water before in goes to the water heater; it can also recover 20-60% of the energy originally needed to cool the milk (Pressman). A reciprocating compressor is typically used in the refrigeration system of dairy farms. It compresses the cold, low pressure refrigerant gas to a hot, high pressure state for condensing. However, using a scroll compressor saves 15-20% on electrical costs compared to a reciprocating compressor (Huyser, Petersen, & Sanford). Scroll compressors work by compressing the refrigerant using two scrolls. One scroll circles the other fixed scroll, resulting in constant compression and removes the need for mechanical valves.

By replacing current light fixtures with more energy efficient light fixtures, energy costs will decrease throughout the usefulness of the lamp (Pressman). Also, maintaining the quality

of the ventilation fans in the animal barns and milking parlor and installing high volume, low speed fans—that allow farmers to move large amounts of air with less noise—will improve their efficiency and save energy costs (*Agricultural Energy*). By dairy farmers upgrading to energy efficient equipment they have the opportunity to save money and energy.

## Methods of Communication

My targeted audience for the handouts and videos is the general public because they are not as well informed about the energy use in agriculture or dairy systems as they should; therefore, informing the general public on energy use in these systems will allow the general public to be aware of where energy is used and how to decrease this energy use. With this information the general public will be able to make more informed decisions as consumers. I did not target all of the handouts and videos to a more advanced audience—such as, farmers and industrial leaders—because it would be very difficult to make a general handout or video to every farmer's situation. Therefore, creating a general handout that is aimed at the general public can also provide an introduction to a more advanced topic for farmers.

I am using handouts that contain information about energy use in various aspects of dairy farms and agriculture to communicate with the general public. I have created handouts titled *Energy in Agriculture, Energy in Dairy Systems, Organic vs. Conventional in Dairy Systems, Pasture vs. Barn Dairy Systems, Dairy Farming and the Environment,* and *Energy Efficient Equipment for Dairy Farms.* To accompany these handouts, I am using videos titled *Energy in Dairy Systems* and *Energy in Agriculture* to assist in informing the general public on the energy use in dairy farms and in agriculture.

To develop these handouts and videos, I did online research about energy use in agriculture and dairy systems and read previous made handouts from the WCROC. I also visited the dairy and other agricultural systems sights to get a first-hand look at the operations. With this information I was able to write text for the handouts and scripts for the videos. Along with the research I did, I also went throughout the WCROC grounds with my supervisor and partner taking pictures and videos to accompany our work.

The purpose of the *Energy in Agriculture* handout is to inform the general public about the energy consumed in agriculture and also to show opportunities for decreasing energy use in agriculture. The *Energy in Dairy Systems* handout is important because it educates the general public on what a dairy system is and what consumes energy within it. Along with this, the handout will point out places where dairy farms can decrease their energy use. *Dairy Farming and the Environment* handout is useful to the general public because is informs them on the impact that dairy farming has on the environment, and on ways dairy farming can reduce its effect on the environment. *Energy Efficient Equipment for Dairy Farms* handout is to inform dairy farm personal on the energy saving techniques and equipment available to save dairy farmers money on energy costs.

The purpose of an *Organic vs. Conventional in Dairy Systems* handout is to tell the general public the difference between dairy cows raised organically and conventionally and the energy consumed in each method of dairy farming. The handout entitled *Pasture vs. Barn Dairy Systems* is meant to inform the general public on the difference between dairy systems that

raise their livestock in barns and ones that raise the livestock in pastures. This handout also outlines the difference in energy consumption between these options of raising dairy cows.

The *Energy in Dairy Systems* video will accompany the *Energy in Dairy Systems* handout in explaining to the general public where energy is used within dairy systems. This video will also compare energy use in various types of dairy systems—conventional vs. organic and pasture vs. barn—and outline techniques that dairy farmers can use to decrease their energy use throughout their operations.

The *Energy in Agriculture* video follows the *Energy in Agriculture* handout in informing the general public on the use of energy in agriculture also on the ways of decreasing this energy use. This helps the general public understand the amount of energy put into agriculture and the steps necessary to make agriculture more sustainable.

## Conclusion

In conclusion, there is an immense amount of energy consumed in agricultural practices, and dairy farms are a large contributor to this energy consumption. However, with the opportunity to decrease this consumption level in dairy farms through the use of renewable energy, manure management, and energy efficient equipment and the current research on making agriculture and dairy farms more sustainable this value can decrease dramatically while still providing the growing U.S. population with enough food. Also, by providing the general public with materials about the energy used in agriculture and dairy systems, they will be able to make more informed decisions as a consumer and help promote sustainability.

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