ENERGY USE IN U.S. AGRICULTURE: AN OVERVIEW

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INTRODUCTION

The agricultural industry in the United States relies on a variety of tools and methods to accommodate the intensive and highly efficient production processes considered necessary to meet current demand. Farms implement energy-intensive practices such as machinery use, transportation, and pesticides and other chemical inputs to efficiently produce large quantities of quality crops or livestock products. In 2012 alone, the U.S. agriculture industry used about 800 trillion British Thermal Units (BTU) of energy.[1] The hidden costs of efficient agricultural production include the impacts of the fossil-fuel based energy that is used to produce our everyday foods.

Energy use in agriculture is classified as either direct or indirect energy use. Direct energy use is the consumption and use of fuels on the farm. These are very clearly seen on farms at the time of production and include most commonly propane, natural gas, electricity, and distillate fuels (diesel).[2] Indirect energy use is the use of fuels to make products that will later be used on farms. This use of energy is much less obvious as a contribution to agricultural energy consumption since it is not directly consumed on the farm. However, because the agricultural process includes any aspect that plays a role in bringing the finished product to market, an accurate assessment of energy use in agriculture will include indirect energy use.[3]

Energy is consumed in four general phases of agricultural production: agriculture, fertilizer production, transportation, and processing. Agriculture is the growing and harvesting of crops and the care and slaughter of livestock. Transportation is the process of sending agricultural products by any means of transportation to the next step of production. Processing is needed for food that is not able to be consumed directly after leaving the farm. Additionally, processing often requires additional transportation to processing facilities. Lastly, food and other agricultural products go through the handling phase. At this point food and products are packaged, canned and sold into the market.[4]

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[1] Susan Hicks, U.S. Energy Information Admin., *Energy For Growing And Harvesting Crops is a Large Component of Farm Operating Costs*, https://www.eia.gov/todayinenergy/detail.php?id=18431.

[2] U.S. Energy Information Admin., Glossary, https://www.eia.gov/tools/glossary/index.php?id=distillate.

[3] Susan Hicks, *supra* note 1.

[4] *American Food Production Requires More Energy than You'd Think*, *Save On Energy Blog* (Dec. 6, 2019), www.saveonenergy.com/learning-center/post/american-food-production-requires-energy/.

The agricultural industry is a complex system with advanced technology and farming practices that consume a large amount of energy.[5] For example, 4% of California electricity consumption is used in agriculture and 5% of the state's natural gas use is attributable to food production.[6] The United States uses a staggering amount of fossil fuels to produce foods like vegetables, milk and meat, resulting in the large carbon footprint left by U.S. food production. Extreme energy use exists at all levels of the farming industry from small organic farms to large industrial farms.

DIRECT ENERGY

While every species of plant and animal has its own needs, it may require more uses of energy, such as needing extra care or more fertilizers. Direct energy use is the most obvious use of energy in agriculture. Direct energy is the development and consumption of energy within the inner workings of an entity and its activities, structures, as well as upkeep.[7] Direct energy use can be from any type of renewable or non-renewable energy. However, the majority of energy used on U.S. farms is non-renewable energy such as diesel, electricity liquefied petroleum, natural gas and gasoline.[8]

The amount of energy used directly on farms is evident in the large amounts of money spent on energy use in both crop and livestock industries. The average expenditures of agriculture can be analyzed to begin understanding how much these industries are investing in their energy consumption. First, 2012 data reported by the U.S. Energy Information Administration (EIA) indicates that crop farms consume more energy than livestock farms in every energy source category.[9]

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[5] *Agriculture and Energy Consumption*, https://foodprint.org/issues/agriculture-energy-consumption/#easy-footnote-bottom-4-1293 (last visited July 26, 2020).
[6] California Energy Commission, *Energy in Agriculture Program* (2017), http://www.energy.ca.gov/process/agriculture/; *see also* Emma G. Fitzsimmons, *Tap Water Ban for Toledo Residents,* The New York Times (August 3, 2014), https://www.nytimes.com/2014/08/04/us/toledo-faces-second-day-of-water-ban.html?_r=0.
[7] *Direct and Indirect Energy Consumption by Source*, *FenRIAM* 1 (July 18, 2020), www.fenriam.eu/direct-and-indirect-energy-consumption-by-source.html.
[8] *Id.*
[9] Susan Hicks, *supra* note 1.

Second, the expenditures on agricultural energy use are informative. For context, the total U.S. expenditure on fuel in 2017 was $12,000,000. This number consists of both indirect and direct energy sources.[10] Fuel is 3.3% of the agriculture's total overall expenditures.[11]

Farm Production Expenditures by Year – United States: 2013-2017

[For definitions of terms used in this table, see Terms and Definitions. Excluding Alaska and Hawaii]

Expenditure	2013	2014	2015	2016	2017
	(million dollars)	(million dollars)	(million dollars)	(million dollars)	(million dollars)
Livestock, poultry, and related expenses	34,200	45,100	45,400	40,000	42,100
Feed	62,400	63,700	58,500	55,600	55,200
Farm services	39,000	45,300	41,600	41,700	43,800
Rent	31,400	32,600	31,000	29,800	29,700
Agricultural chemicals	14,600	15,800	14,600	15,200	15,500
Fertilizer, lime, and soil conditioners	28,300	28,000	25,500	23,500	22,000
Interest	8,700	9,700	9,500	9,100	9,900
Taxes	11,700	13,600	12,800	11,900	13,000
Labor	32,000	34,200	31,800	34,100	35,100
Fuel	16,400	16,700	12,300	11,300	12,000
Farm supplies and repairs	18,700	19,900	18,700	17,600	18,300
Farm improvements and construction	16,600	18,200	16,100	14,500	16,400
Tractors and self-propelled farm machinery	17,100	16,900	11,900	10,600	12,600
Other farm machinery	8,800	9,000	6,100	5,000	5,900
Seeds and plants	21,900	22,100	21,300	21,800	22,200
Trucks and autos	4,990	6,200	5,000	4,400	5,500
Miscellaneous capital expenses	480	600	700	800	600
Total farm production expenditures	367,270	397,600	362,800	346,900	359,800

Crops use an average $8,511 per farm on fuel and livestock spend an average of 3,906 per farm. Crop farms are going to be using more tractors, self-propelled, and farm machinery than livestock farms therefore it makes sense for them to be spending more on these objects as well. Crops on average spend $9,139 on tractors/self-propelled farm machinery and $4,227 on other farm machinery. Livestock farms spend more money on trucks and automobiles than crops at an average of $2,696 per farm.[12] The amount spent on trucks, tractors, and machinery indicates how much energy within each category.

Today there are multiple practices used to care and grow crops which require equipment of various fuels. There is a long list of uses on a farm that derives the use of some type of fuel or energy source.[13] In almost every action on a farm you can drive energy. Crop farms derive more energy overall than livestock farms do. On a crop farm the energy use that occurs in the beginning of production occurs in the form of field work using some type of large operating equipment such as mowers, tractors, plow and combines. Different types of equipment are needed to manage the soil like weeding, harvesting, tillage, fertilizing and seed distribution. Farmers tend to use either equipment hooked to their tractors to perform these tasks or purchase additional machinery that is capable of performing these tasks individually. Whichever method is used in the field, diesel and gasoline are the fuels that are needed to power these highly important

[10] U.S. Dep't of Agric., *2015 Energy Balance for the Corn-Ethanol Industry* 8 (2016).
[11] Nat'l Agric. Statistics Serv., U.S. Dep't of Agric, 2017 Census of Agriculture (2019).
[12] *Id.*
[13] Jodi Ziesemer, *Energy Use in Organic Food Systems* (2007), http://www.fao.org/docs/eims/upload/233069/energy-use-oa.pdf.

and large tools. However, these are under traditional crop farming standards that do not include electricity for lights and heat from greenhouses or propane powered fire weeding and many more methods that farmers use to accommodate their unique crop. For example, orchids use heaters to prevent frost.

Livestock farming is uniquely different compared to crop farming. Livestock farms use mostly direct energy to care for its animals. Since most of the operations occur inside, farms put more energy into powering the building with lights, heat and ventilation just to make the building safe for workers and animals. When dealing with animals in an industrial farm there is use of many moving parts such as water distribution, waste management and feeding machines. Although these methods are efficient for time and cleanliness, they derive these benefits from the use of large amounts of distillate fuel. Oil is needed to improve flow of the farm through the use of internal conveyors and elevators. These machines move the animals and the product to necessary parts of the farm. The use of the livestock does not alter the need for large refrigeration. Refrigeration derives electricity twenty-four hours a day without being shut off in order to conserve products until they leave the farm. Almost every aspect of livestock production requires some form of direct energy fuel.[14]

INDIRECT ENERGY

While direct energy in agriculture focuses on the activities on the farm, thus making them "direct," indirect energy can include the activities that happen during pre-production and post-production that take place off the farm. Most of the research about indirect energy use in agriculture focuses on fertilizer and pesticides because the production of these two substances accounts for a large portion of the indirect energy. As the population has increased, farmers have used increasing amounts of fertilizers to increase agriculture production. Fertilizer has helped grow the production output of certain crops, including wheat, soybeans, corn, rice, and oats to name a few.[15]

About 70-80% of the energy used to produce fertilizers comes from natural gas, due in part to the high volume of nitrogen fertilizer production.[16] Natural gas is used to create a nitrogen fertilizer called anhydrous ammonia and natural gas is important for the ammonia synthesis done by the Haber-Bosch process, which is commonly used in nitrogen fertilizer production.[17] The Haber-Bosch process became a growing phenomenon after World War II because it made it possible to mass produce fertilizers, therefore contributing along with pesticides and herbicides to the

[14] Susan Hicks, *supra* note 1.
[15] The Fertilizer Institute, *Improving Lives* (2020), www.tfi.org/our-industry/intro-to-fertilizer/improving-lives.
[16] Clark Gellings et al., *Energy Efficiency in Fertilizer Production and Use* (2009).
[17] *Id.*

increase in yields that came about.[18] While this Haber-Bosch process consumes only about 3-5% of the world's natural gas, scientists are working to make it more efficient to help reduce global energy demand.[19]

There are also different fertilizer types. Nitrogen fertilizer is used more than the other two, potash and phosphate.[20] While nitrogen is extracted from air, potash and phosphates are retrieved through mining processes.[21] Phosphate fertilizer production consumes about 5,600 BTUs per pound of phosphate, while potash fertilizer production consumes about 4,700 BTUs per pound of potash.[22] Nitrogen fertilizer production utilizes greater than 75% of all the energy use attributable to total fertilizer production with a consumption of about 25,000 BTUs per pound of nitrogen. Therefore, not only is nitrogen fertilizer used more frequently, but it is also more energy intensive to produce than the other two.[23]

Indirect energy use also includes chemical inputs like pesticides, herbicides, fungicides, and insecticides, which farmers also rely on to increase yields.[24] Although pesticide use consumes less energy than fertilizer use, it is still a significant contributing factor, with more than $9 billion spent on pesticides by U.S. producers in 2012 to protect their yields from potential harm by pests.[25] While less than 15% of energy use in agriculture is ascribed to pesticides, it requires more energy per pound to manufacture pesticides than nitrogen fertilizer.[26] Pesticide production typically uses petroleum sources, as well as some electricity, natural gas, and steam for certain steps of the manufacturing process.[27] However, the amount of energy for the production of different pesticides may depend on the method used to manufacture them and the chemical composition.[28]

Fertilizer and pesticide use varies by agriculture and crop type, with about 1.25 billion pounds of pesticides used each year, most overall used by feed and food grain crops and most

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[18] Vaclav Smil, *Nitrogen Cycle and World Food Production*, http://vaclavsmil.com/wp-content/uploads/docs/smil-article-worldagriculture.pdf.
[19] *Improving Ammonia Synthesis Could Have Major Implications for Agriculture and Energy*, ScienceDaily (2010), https://www.sciencedaily.com/releases/2010/11/101117094031.htm.
[20] Econ. Research Service, *Agricultural Resources and Environmental Indicators* (2019), https://www.ers.usda.gov/webdocs/publications/93026/eib-208.pdf?v=4419.7.
[21] The Fertilizer Institute, *Fertilizer Production* (2020), https://www.tfi.org/our-industry/intro-to-fertilizer/fertilizer-production.
[22] U.S. Dep't of Agric., Cooperative Extension Serv., *Energy-Efficient Use of Fertilizer and Other Nutrients in Agriculture* (2019), https://farm-energy.extension.org/energy-efficient-use-of-fertilizer-and-other-nutrients-in-agriculture/.
[23] *Id.*
[24] Jodi Ziesemer, *supra* note 13, at 11.
[25] *Agricultural Resources and Environmental Indicators*, *supra* note 20, at 35.
[26] U.S. Dep't of Agric., Cooperative Extension Serv., *Energy Use and Efficiency in Pest Control, Including Pesticide Production, Use, and Management Options* (2019), https://farm-energy.extension.org/energy-use-and-efficiency-in-pest-control-including-pesticide-production-use-and-management-options/#4.%20Stout,%20B.A.
[27] *Id.*
[28] *Id.*

used per acre by fruit and vegetable crops.[29] For fertilizer, corn has the highest percentage of expenditures, but low expenditures for direct energy.[30] Types of agriculture vary in their energy uses as well, considering livestock agriculture doesn't have a need for fertilizers and pesticides like crop agriculture does. Crop agriculture uses more energy and has a higher percentage of energy expenditures than livestock agriculture.[31] The variations in fertilizer and pesticide use can then be broken down even more, when examining organic crop agriculture, which does not make use of energy-intensive fertilizers and pesticides like industrial crop agriculture does.[32]

In addition to the production of fertilizers and pesticides, their post-production aspects also contribute to the total indirect energy use in agriculture. This can include processing, distributing, and transportation.[33] The Fertilizer Institute describes the steps of the fertilizer supply chain as first the collection of raw materials, which are the three types previously discussed: nitrogen, phosphate, potash, then the manufacturing at a production facility, followed by storage and distribution to a retailer who may create nutrient blends specific to their needs, and then to the farm.[34] These post-production aspects of energy use for fertilizers and pesticides are difficult to measure because they vary based on numerous factors, including type of transportation and distance travelled as well as type of packaging and processing methods.[35] For fertilizers, about 4,000 BTUs per ton are required to move a mile by truck and about 1,600 BTUs per ton for a mile by rail.[36] For pesticides, oil-based ones are estimated to use about 430 BTUs per pound for transportation.[37]

Fertilizers and pesticides are mostly used in "conventional agriculture" as opposed to organic agriculture which relies on less inputs.[38] Much of what is considered "inefficient" in conventional agriculture is due to the amount of energy consumed during the manufacturing of fertilizers and pesticides, as well as the energy consumed while transporting and distributing them.[39] Conventional farming depends more on energy-intensive fertilizers, pesticides, and concentrated feed, another aspect of indirect energy, than organic farms do.[40] There are ways however, that farmers can utilize fertilizers and pesticides more efficiently to save energy. Soil testing is one option for farmers to assess which soil patches have a lack of nutrients and therefore have more need for fertilizer.[41] This saves energy by not utilizing extra fertilizers on

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[29] *Id.*
[30] Susan Hicks, *supra* note 1.
[31] *Id.*
[32] Jodi Ziesemer, *supra* note 13.
[33] Ziesemer, *supra* note 13, at 17.
[34] The Fertilizer Institute, *supra* note 7.
[35] *Energy-Efficient Use of Fertilizer and Other Nutrients in Agriculture*, *supra* note 22.
[36] *Id.*
[37] *Energy Use and Efficiency in Pest Control*,, *supra* note 26.
[38] Ziesemer, *supra* note 13, at 10.
[39] *Id.*
[40] Ziesemer, *supra* note 13, at 4.
[41] *Energy Use and Efficiency in Pest Control*,, *supra* note 26.

areas where it is not necessary and instead applying those fertilizers to soils with a lack of nutrients.[42] Placement of fertilizer close to the seed during planting is another more effective method, as well as liming soil to the crop's optimal pH, crop rotation, and timing the application of fertilizer based on what research has shown to produce the most effective results can also help with energy reduction.[43] For pesticides, one main method to reduce energy is to utilize integrated pest management through carefully searching for pests and determining when it is economically best to spray preventative pesticides instead of spraying them constantly.[44]

Animal feed manufacturing is another category of indirect energy use. Concentrated feed can be produced off-farm, making them indirect consumers of energy, however determining if they fall under indirect or direct energy use can depend on if they are produced on the farm or not, which they usually are for organic farms and are usually not for conventional farms.[45] Production of feed for livestock tends to be intensive and makes use of chemicals and fertilizers, adding to the inefficiency of energy use.[46] Similar to fertilizers and pesticides, much of the energy used for livestock feed is due to production, processing, and transportation, amounting to about 2/3rds specifically for conventional livestock feed.[47]

Post-production activities such as processing and packaging can have various definitions on if they are direct or indirect energy consumers. For the purposes of this project, if they are performed on-site at the farm they are considered direct and if they are performed off-site they are indirect. Packaging can be a large consumer of energy, with one evaluation by Heller et al. finding that packaging had exceeded the total combined amount of energy used in production, processing, and transportation.[48] However, packaging is important because it prevents food spoilage, which would be an inefficient use of energy, and there are ways to utilize more recycled and biodegradable materials for packaging, as seen on some organic farms.[49]

Storage is another component that depending on locational factors could be considered direct or indirect energy consumption. Refrigeration, pest and fungal control contribute to energy consumption for storage for both conventional and organic farms, and synthetic preservatives and other chemicals may also contribute to energy use for conventional agriculture.[50] Distribution and transportation are typically the next steps after storage, and as touched on previously depend on the type of transportation, fuel, loading efficiency, distance, and consumer

[42] *Id.*
[43] *Id.*
[44] *Energy Use and Efficiency in Pest Control*, *supra* note 26.
[45] Ziesemer, *supra* note 13, at 14.
[46] *Id.*
[47] *Id.*
[48] Ziesemer, *supra* note 13, at 16.
[49] *Id.*
[50] Ziesemer, *supra* note 13, at 17.

travel.[51] However, low energy use in one aspect of post-production may offset some energy expenditures for transportation and there are different methods that can cut energy use, such as delivery or pick up to a nearby center can cut costs of transportation by about 37-43% as well as supplying a local wholesaler.[52] There was a finding however, that while locally sourced food may decrease energy use in some cases, other times it may not due to the use of smaller vehicles and lower loads.[53] Nevertheless, finding local food can be an important step to reducing an individual's energy footprint because it is common for food nowadays to be imported internationally.[54] Even within the United States, agriculture is concentrated in certain areas and large percentages of certain crops are grown in specific regions, largely due to industrial farming.[55] Organic agriculture will sometimes put an emphasis on buying locally to reduce individual energy use, which is an important thing to do, but does not take away from the large-scale changes that are needed by the energy and agriculture industries to reduce their ecological footprints.

While measuring indirect energy use, it's important to consider those energy consumers that aren't always obvious. As mentioned above, there can be many layers to indirect energy use. The production of fertilizers and pesticides is a large portion of indirect energy consumption, but the transportation and handling of these substances is another layer, as well as the transportation and handling of the crops on which these fertilizers and pesticides are used. Some other indirect energy uses that might be considered are food intake by workers[56], as well as energy used in manufacturing equipment, even though that's done only once, and the energy wasted from food waste.

CONCLUSION

Throughout history, as the population has grown there has been an increasing demand for industrial farming and the ability to feed a large number of people. Certain developments of fertilizers and pesticides that help increase agricultural outputs may help yield efficiency, but in order to use these in the large amounts that they're used in, they do consume significant amounts of energy. While there are many direct and indirect energy factors at play when it comes to overall energy consumption in agriculture, it's important to find renewable energy options and sustainable alternatives for all factors. Finding renewable options not only may benefit the natural environment, but it may help with environmental justice concerning humans who deal

[51] *Id.*
[52] *Id.*
[53] *Id.*
[54] *Eating Sustainably: An Introduction to Sustainable Food* (2011), https://sustainability.emory.edu/wp-content/uploads/2018/02/Sustainable_Food_Information_Booklet.pdf.
[55] *Id.*
[56] Ziesemer, *supra* note 13, at 20.

with water and air contamination from chemicals, fossil fuels, and other harmful toxins from the energy and agriculture industries.

Organic agriculture was mentioned earlier as having lower energy inputs, which can be a sustainable alternative to more conventional and industrial farms.[57] While this system tends to require less energy and has less greenhouse gas emissions, it is not a perfect system that can still have large energy uses in certain areas, such as large travel distances, even international. Buying local food was one option of a change that consumers can make in their lives. One source gives a few other important lifestyle changes to be aware of, such as being aware of the energy required to produce the food that makes up your diet because meats and animal products tend to require a lot of energy.[58] Other steps for consumers they describe are meal planning to decrease food waste and energy efficient storage to decrease energy consumption by refrigerators.[59]

While working to reduce energy consumption at the consumer level can be important, it is not always accessible for everyone due to different life situations. This makes it even more important that the energy and agriculture industries work to reduce their large amounts of fossil fuel usages. Some farms have already implemented renewable energy sources on-site like wind, solar and biomass technologies, as well as implemented methods to rotate crops to fix nitrogen in soil to make use of less fossil fuels.[60] Many farms may have the potential to include renewable resources, and different policies may have the ability to incentivize these practices which is hopefully a shift that we will see in the near future.

[57] Ziesemer, *supra* note 13, at 4.
[58] Save on Energy Team, American Food Production Requires More Energy Than You Think (2019), https://www.saveonenergy.com/learning-center/post/american-food-production-requires-energy/.
[59] *Id.*
[60] *Agriculture and Energy Consumption* (2020), https://foodprint.org/issues/agriculture-energy-consumption/.