ENERGY RETURN ON ENERGY INVESTMENT EMPIRICAL MODEL

OF AN INTEGRATED FARM IN SCOTT COUNTY KENTUCKY

by

MATTHEW S. DEASON

(Under the Direction of JOHN R. SCHRAMSKI)

ABSTRACT

The energy return on investment (EROI) was determined for an integrated (i.e. combined animal husbandry and vegetable production) USDA Certified Organic, Community Supported Agriculture (CSA) farm in Scott County Kentucky for the calendar year 2014. The resulting EROI was calculated at 0.13 which corresponds to 7.7 units of input energy for each caloric unit of output energy. The highest energy inputs (representing > 80% of the model) were indirect labor, equipment, liquid fuels, electricity and poultry feed. The highest energy outputs (representing > 80% of the model) were beef, sweet corn, broilers, eggs, potatoes, sweet potatoes, beans, broccoli, tomatoes, turkey, and yellow squash. Modern US agricultural practices and food delivery systems are energy intense, representing more than 15% of the total US energy consumption. Comparatively, typical livestock operations can require EROIs as low as 0.02 corresponding to 50 units of input energy for each calorie produced.

INDEX WORDS: Energy, Integrated Agricultural Systems, Organic, Energy Return on Investment, EROI, Sustainability

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DEDICATION

This work is dedicated to my spouse Kimberly Deason, my family and my trusted circle of friends. You know your place in my story. Know that your support and counsel was essential to the completion of this work. It is important to also recognize the efforts of John and Ambi Bell, their family and farm workers who collected data associated with this work. Without their vision for sustainability and dedicated data collection, this work would be impossible. Finally, it is important to recognize the constant positive impact Dr. John Schramski has had in my professional and academic career. There is so much I can attribute to his wise and thoughtful mentorship. To all of these, I am truly grateful.

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CHAPTER 1

INTRODUCTION

The concept of sustainability is variable. Commonly cited is a definition provided by the World Commission on the Environment and Development Report of 1987 (The Brundtland Report) '. . . development that meets the needs of the present without comprising the ability of future generations to meet their own needs'. Although this statement is simplistic in concept, numerically measuring sustainability in the human socioeconomic world presents complex considerations. Vos, 2007 presented sustainability as the reciprocating and respectful interconnections of the elements 'economy, environment, and society.' Developments in one element shall support and preserve the requirements of the other two elements.

Excluding the modern human, all species maintain a balance within the allotted solar and earth energies (Schramski, et al., 2013). This maintains a balance of nonhuman species to energy availability; naturally limiting populations to utilize relatively short lived energy sources. Furthermore, all species must also acquire more energy than it uses to survive (Hall et al., 2009) thus creating the concepts of energy "surplus". The rate of energy collection shall be adequate to feed the species, construct protection from elements, and avoid risks from the environment. Energy acquisition is at the very core of all species sustainability.

Functional ecosystems contain producers, consumers and reducers (Pimentel and Pimentel, 2008). Solar energy is used by producers to convert elemental components to organic energy compounds and useful biochemical structures. Consumers harvest the useful energy and biochemical structures from producers and other consumers. Reducers degrade matter left behind by both consumers and producers to elemental components and the cycle repeats. Sustaining this cycle is made possible by evolutionary controls; preventing species from propagating without bounds or over consuming resources that leads to ecological failure.

Evolution naturally advances these controls establishing a species so-called operating environment (Pimentel and Pimentel, 2008). Defense mechanisms and ecological controls are interdependently formed as each species survives from generation to generation. The expressions of genes are allowed to propagate based on their ability to live to maturity, find mates and advance the next generation. Likewise, constraints on available solar energy tend to favor specie variations with limits to over consumption. This evolutionary process created a rich diversity of creatures, able to withstand various environmental pressures. Diversity of species can adjust to changes within the environment over evolutionary timescales and continue cycling energy and matter.

Humans are crafty creatures; exploiting massive biomass energy stores in the form of oil, coal, natural gas, and wood well beyond evolutionary solar energy allotments. This has allowed humans to not only ensure survival but to construct comfort and unprecedented prosperity while propagating populations into the billions. The food system feeding this prosperity is overwhelmingly supplemented with this stored energy. However, the remaining stored energies are expected to become increasingly harder to collect (Hall et al., 2014), raising concerns of limitations.

The modern agricultural system is a perfect illustration of human exploitation of stored energy (Pimentel et al., 1983; Sartori et al., 2005; Pimentel, 2006; Pimentel and Pimentel, 2008; Cao et al., 2010; Moore, 2010; Schramski et al., 2011; Schramski et al., 2013, Atlason et al., 2015). Low economic costs of fossil fuels (stored energy) allow farmers to increase production of homogenous crops designed to maximize profits and improve their economic condition. Increased production creates new demands from the market. Farmers respond with new technologies to capitalize on new market demands and the cycle continues. Furthermore, organization of homogenous species requires energy; energy to move water for irrigation, to replenish lost nutrients, to reduce competition pressure from other species, and to organize species to grow in a specific plot of land. This system can continue to grow as long as stored energy remains economically and energetically advantageous. However, collection limits of stored energy equate to limits of the modern agricultural system.

Another apparent result of the efficient collection of stored energy is the exit of individuals from the food collection process to pursue other interests. Currently, approximately 1% of Americans provide agricultural goods to the remaining American population and countless international populations (Heller and Keoleian, 2000), (see also Chapter 4.1 of this work for how this was verified for current validity). This fact has been touted as great efficiency given few feed so many.

Energy return on investment (EROI) is an energy accounting modeling method used to determine the overall efficiency of a species collection of energy. The concept was established while describing how fish migration energy was used to capitalize on available ecosystem energy (Hall, 1972). During his studies of New Hope Creek in North

Carolina, Hall determined a fish used one unit of energy to migrate and collect a minimum of three units of energy. In drought conditions, due to extra inputs from the ecosystem, this was calculated to be 25-fold collection. Thus migration allows fish to capitalize energetically within their ecosystem.

The first use of the actual term EROI may have been from studies conducted by Cleveland et al., 1984 and Hall et al., 1986 (Murphy and Hall, 2010). These studies applied energy collecting concepts required for species survival to the collection of economic energy. The years following these works, the concept of EROI can be found in hundreds of peer reviewed publications; with significant interest beginning in 2010.

The general concept of EROI is a ratio of energy gained in the energy collection process compared to the energy expended to collect that energy. Ratios greater than one (EROI>1) indicate net energy collection. Ratios less than one (EROI<1) indicate net energy usage. In an ecological sense, energy is collected to be used by the species to ensure survival. Any activity not resulting in more energy must yield products of intrinsic value (shelter, protection, reproduction, etc.). Species unable to collect an appropriate level of surplus are doomed to extinction.

Although the current EROI of collecting stored energy is falling, it remains much greater than one (Hall et al., 2014). As this ratio falls, human well-being may be negatively impacted. In an attempt to correlate this effect, Lambert et al., 2014 considered the well-being of citizens of countries with varying societal EROIs, an estimated ratio of energy collection across a complete society. Well-being was defined numerically by life expectancy at birth, adult literacy, combined educational enrollment, and per capita GDP. This work suggested two important EROIsoc values. Well-being values may saturate around EROIs of 20:1 and may begin to suffer below 8:1. This study also demonstrates a "net energy cliff"; the decline in well-being differences between EROI ratios of 20:1 and 19:1 are not as severe as 5:1 to 4:1. Unfortunately, the EROI of many of our potential replacement energies for stored energy are significantly below the 8:1 threshold. Wind energy appears to be the most hopeful at 18:1 and biomass least hopeful at fractional values (Hall et al., 2014).

The careful definition of boundaries regarding EROI analysis is extremely important in understanding the ratio's significance (Murphy and Hall, 2010). The concept of "order" was promoted by Mulder and Hagens, 2008. First order analyses consider only the input of direct energy. Typical direct energies would be fuels, electricity and human labor. Second order analyses consider the direct energy sources, the upstream energy required to collect, enrich, and distribute the direct energy sources, and the upstream energy required to collect and enrich non direct energy products (pesticides, fertilizer, equipment, etc.). Third order analyses consider the inputs of both the second and first order inputs plus the energy expenditures required to remedy any environmental impacts of the activities. Examples of third order inputs include remediation energy used for non-point source pollution of pesticides and fertilizers in drinking water sources or health care energy associated with prolonged exposure to pesticides.

Other researchers present analogous concepts: societal EROI, point of use EROI, and extended EROI. Societal EROI was discussed previously. Truly embarking on societal EROI analyses are considered difficult to impossible (Murphy and Hall, 2010). Often researchers approximate this value through other indicators (Lambert et al., 2014). Point of use EROI is the energy ratio of a product at the well head or farm gate. Extended

EROI considers the energies to deliver an energy product and the energy required to maintain this infrastructure, e.g. roads, bridges and vehicles, pipelines, electrical transmission, and retail distribution. In an agricultural EROI, the farm gate value or point of use value would not consider the energy costs to refine (process) raw vegetables, any level of distribution, refrigeration, packaging, home storage, consumption, spoilage, or waste removal and remediation.

Fertilizer and other soil amendments are a necessary when soil elemental components are used by plants, harvested, and leave the farm in the form of products or by-products (straw or cellulose). The most common replacement elements are Nitrogen, Phosphorus, and Potassium. Another common amendment is lime; which is used to buffer the soil and raise the pH to levels optimal for plants to properly absorb nutrients. According to research performed by the United States Department of Agriculture (USDA), fertilizer is the second highest energy expenditure in US modern agriculture, second only to fuels (Beckman et al., 2013). Fertilizer also accounted for over half of the indirect energy (embodied energy).

Most agricultural energy accounting studies demonstrate fertilizer as a significant energy contributor. Pimental and Pimental, 2008 compiles a career long study of energy in agriculture in one book, Food, Energy, and Society. Most studies were from the mid-1960s to early-1980s. U.S. productions for corn, wheat, oats, rice, sorghum, soybeans, dry beans, and peanuts all demonstrated nitrogen, phosphorus, and potassium as the highest indirect energy inputs. A study by Bhat et al., 1994 revisited the energy costs of fertilizer and found small improvements in energy efficiencies (significantly less than 10%) achieved in producing nitrogen and phosphorus fertilizers from the late 1970s to mid to late 1980s (1979-87). Assuming trends continue to improve fertilizer energy efficiency at this rate, technological advances are not expected to make significant impacts of modern agricultural energetics in the near future.

Schramski et al., 2013 conducted an EROI analysis on an USDA Certified Organic teaching Community Supported Agriculture (CSA) operated and managed by the University of Kentucky (UK CSA). Many of the same themes for agriculture energetics were found in this micro model. Fertilizers were considered the highest indirect energy inputs after compost and electricity; accounting for approximately 13% of all indirect inputs. These authors pointed to the idea integrated or closely oriented animal and plant operations may have a significant reduction of fertilizer energy input. This is not a new idea; integrated agriculture was the mainstay of the pre-industrialized U.S. An integrated farming operation combines animal and vegetable/grain production as a means to recycle nutrients.

This research evaluated the EROI of an integrated (i.e. combined animal husbandry and vegetable production) USDA Certified Organic, Community Supported Agriculture (CSA) farm in Scott County Kentucky for the 2014 growing season. This operation uses practices of animal husbandry followed by plantings of vegetables and periods of soil rest (soil is allowed to lay fallow). No fertilizer (chemical or organic) was broadly used on the land. Seeding starts were primed with small amounts of commercially available organic fertilizer. Crushed limestone was used from a local quarry to maintain soil pH neutrality. If the current human food systems are highly reliant on fossil fuels (Pimentel and Pimentel, 2008) and the remaining world fossil fuels energy stores are harder and more costly to extract (Hall et al., 2014), more energy efficient food production (energy collection) has a significant impact on the future prosperity of the human society. This work provides a microscale glimpse regarding the roll integrated agriculture may play in coping with depleting world energy stores (Schramski et al., 2015).

CHAPTER 2

MODEL DESCRIPTION

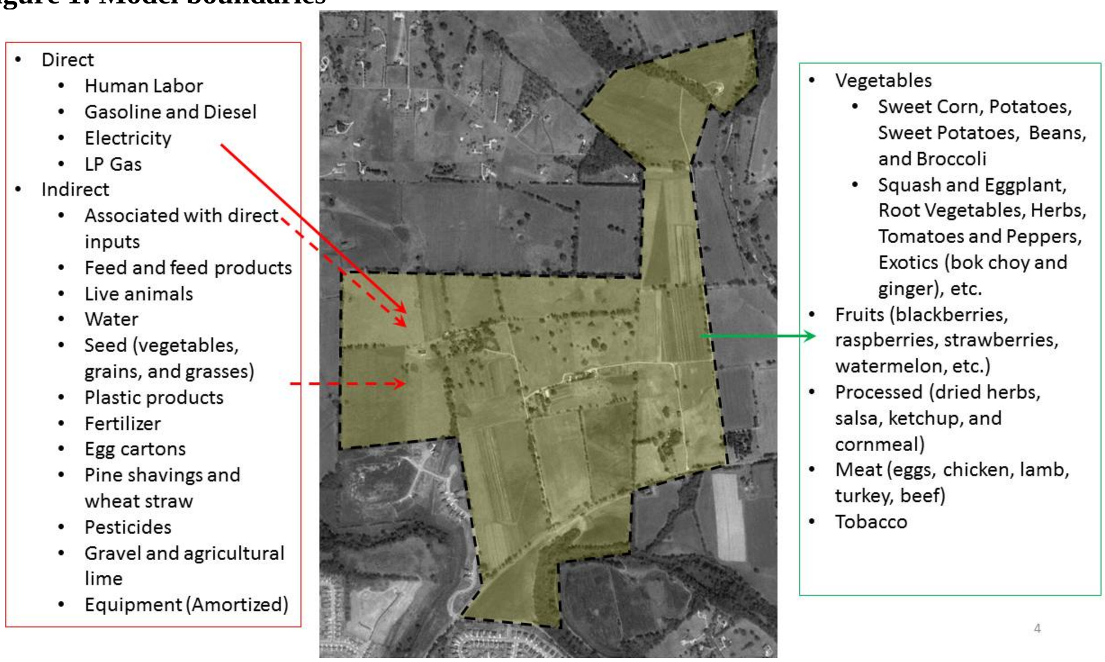
Elmwood Stock Farm (ESF) is a 375 acre integrated farm in Scott County of Eastern Kentucky. The owners/managers practice environmental stewardship by rotating vegetative and animal crops to recycle nutrients and allowing portions of land to lay fallow. Traditional farm inputs, i.e. soil amendments and pesticides, are minimized by farming practices. ESF participates in the USDA program allowing most products the designation of Certified Organic. See “CHAPTER 2.2.6: Seed” for details regarding this designation. Most product offerings are raw vegetables or meat. A few offerings are processed such as salsa and ketchup. The 2014 farming input and output data was recorded by ESF owner/operators.

ESF operates as a Community Supported Agriculture (CSA) farm. The owner/operators sell shares to the community early in the season. Based on this monetary support, the farm provides food products. All expenditures and profits are paid from the sale of shares. Theoretically, shareholders share in the risk and the reward of farming. There are no guaranties regarding expected yields. Products are harvested and distributed to locations near the farm.

A comprehensive review of each recorded input and output is articulated below. This model was created following similar methodologies from established food EROI studies (Pimentel et al., 1983; Sartori et al., 2005; Pimentel, 2006; Pimentel and Pimentel, 2008; Cao et al., 2010; Moore, 2010; Schramski et al., 2011; Schramski et al., 2013, Atlason et al., 2015). Embodied energy values were derived from current literature considering specific conditions or attributes associated with ESF.

The model boundary is the "farm gate", see figure 1. Inputs are the direct (e.g., electricity and diesel fuel) and indirect energies required to operate the farm where indirect energies are the upstream embodied energies required to produce direct energies or materials used by the farm. Outputs were food products including meat, vegetables, and a few processed foods. Products were generally available for market year round.

Figure 1: Model boundaries



CHAPTER 2.1: DIRECT ENERGY INPUTS

The direct energy sources were petroleum fuels, electricity, and human labor. Human labor was recorded as combination of time and physical exertion. Petroleum fuels were recorded as volume or total cost. Electricity was recorded as kilowatt-hours.

Three petroleum fuels; diesel, gasoline and liquid propane (LP) gas were used in farm tractors, small equipment, and heating equipment. The energy of each fuel was converted to mechanical energy and/or wasted as heat. Higher heating values of 34.1

MJ/L and 38.6 MJ/L respectively, as listed by the US Department of Energy, were used for Diesel and Gasoline (E10). LP gas was used to heat farm buildings, process some finished products, and maintain greenhouse operations during colder months. The direct energy of LP gas 50.3 MJ/kg (24.8 MJ/L) was based on the enthalpy of combustion (Rossini, 1934).

Electricity was used to power outbuildings on the farm and operate the irrigation pump. The direct kWh readings from electric meters were converted to MJ by multiplying by 3.6. If 1,000 watts were exerted for an hour, this represents 1.0 MJ/second of energy exerted for 3,600 seconds.

Understanding the direct energy input associated with human labor depends significantly on many factors and conditions. The physical condition, gender and age of the laborer can greatly vary the efficiency of energy conversion. This model uses the methodologies presented in similar energy models (Cox and Atkins, 1979; Pimentel, 1984; Duhon, 1985; SFNB, 1989; Zhengfang, 1994; Tharion et al., 2005; Smil, 2008; Schramski et al.; 2013). Four categories of labor representing graduations of perceived exertion were established. The values of 203, 392, 487 and 581 W were assigned to respective physical exertions one through four, exerted for period resolution intervals of 30 minutes. The owner/operators of ESF recorded physical efforts with fractional values at 1.25, 1.50 and 2.50, thus converting to 250 W, 297 W, and 438 W of physical exertion, respectively for each fraction value. ESF reported no physical effort at level 4.

CHAPTER 2.2: INDIRECT ENERGY INPUTS

Products and equipment were used in the production of food on ESF. Indirect energy, embodied energy, and upstream energy are terms that describe energy required to delivery these goods and equipment for use. Indirect energy represents transportation of raw materials and finished goods, processing, mining, and other energy used to deliver the product or equipment to the farm gate. Indirect energy values were derived from published research and described below. Care was taken to derive indirect energy values that best represent the conditions found at ESF.

CHAPTER 2.2.1: Human Labor

Indirect human labor energy is defined as upstream energy required to maintain a workers energy consumption resulting in the conversion into animated motion and maintain normal physiological functions (Giampeitro and Pimentel, 1990), (Schramski et al., 2013). This calculation comes from the following figures. The average per capita energy usage in the U.S. is 885 MJ/day (EIA, 2012). Approximately 19% of all U.S. energy consumption is used to produce food (Pimentel and Pimentel, 2008). The average per capita food energy consumption is 2500 Calories/day or 10.5 MJ/day (FAO, 2001), (WHO, 1985). Energy required to maintain normal physiological functions is segmented approximately into three main categories: 70% basal metabolism, 20% for animated motion, and 10% for thermoregulation (McArdle, 1986), (Smil, 2008).

The calculation begins by multiplying the U.S. daily per capita energy consumption by the percentage of U.S. energy used in food production (855 MJ/day x 0.19 = 162 MJ/day). A ratio was created to describe the amount of per capita energy used in the U.S. food production to produce a per capita food energy consumption (162

MJ/day / 10.5 MJ/day = 15.4). The energy required for normal physiological functions was derived by considering basal metabolism and thermoregulation are approximately 4 times (70% + 10% = 80%) that of animate motion (20%). Therefore, this model uses a multiplier of 19.4 MJ for every MJ of direct labor (15.4 MJ for the upstream energy and 4 MJ to maintain normal physiological functions) (Schramski, et al., 2013).

CHAPTER 2.2.2: Machinery

ESF used 62 individual pieces of equipment at various times throughout the production year. This comprised of fifteen tractors and similar fuel powered farm machinery, nine trucks/vans, 38 tractor implements and other pieces of equipment. Current literature is not considerate of life cycles beyond ten to twelve years (Smil et al., 1983 and Pimentel et al., 1973). The reality of equipment life expectancy in farming operations vary based on maintenance levels and overall equipment care. Much of ESF equipment is well past 20 years of service. Therefore, utilizing the abovementioned concepts is not appropriate for ESF.

We present a more realistic approach by separating equipment into three categories. The first category applies to tractors, trucks and vans under 10 years of age. This equipment will be amortized according the recommendations of Smil et al., 1983. This approach follows the methodology of Schramski et al., 2013. The second category applies to tractors, trucks and vans over 10 years of age. When the age of the equipment was known or easily estimated, the amortized energy value was calculated over the current age of the equipment. The final and third category applies to tractor implements. Most (but not all) implements are significant simplifications over the other two categories, i.e. moving and wearable parts. This equipment is expected to maintain serviceability well past twelve years. Therefore, this category of equipment was amortized over 20 years. This approach is expected to be conservative given many pieces of equipment used at ESF were believed to be well over 30 years old. This age amortization approach properly rewards a thriftier farm operation. Utilizing equipment beyond typical life expectancies will by definition lower the overall impact on the environment.

CHAPTER 2.2.3: Poultry Inputs

Poultry production may be one of the most energy efficient means to provide terrestrial meat food options to a population (Flachowsky, 2002), (Pimentel and Pimentel, 2008). This is due in part to the low feed conversion ratios; feed weight required to produce live animal weight. Poultry also appears to have the lowest environmental impacts considering life cycle analysis reviews (de Vries and de Boer, 2010). Energy used in poultry production vary greatly from literature sources (15-29 MJ/kg of broiler meat).

ESF produced broilers (meat chicken), turkey and eggs. Inputs from this operation include poultry feed, live one day old broiler chicks, live one day old turkey poults and five month old pullets (young layer hens). All of these inputs are derived from the research of Pelletier, 2008; an extensive Life Cycle Analysis (LCA) of the poultry industry in the United States. Life cycle analysis methods report results based on a function unit (FU). The FU for Pelletier, 2008 was one kg of broiler meat. All embodied energy for the inputs described in this section were values calculated from the FU.

The farm utilized commercially available organic poultry feed to raise broilers and turkey and produce eggs from hens. In review of the organic feeds used at Elmwood, the ingredients include microbial matter such as dried *Bacillus subtilis* fermentation product, dried *Lactobacillus acidophilus* fermentation product, dried *lactobacillus* casing fermentation product, S*accharomyces cerevisiae* yeast and the media on which it was grown. Although somewhat unconventional in ingredient selection, the embodied energy of this feed compared to typical poultry feed reviewed by Pelletier, 2008 is not expected to be significantly lower given the energy necessary to produce and transport these ingredients from non-local suppliers. Given the lack of research for these specific feed or feeds of this type, the Pelletier, 2008 research provides a conservative embodied energy value. The embodied energy value for feed is 7.0 MJ/Kg of feed based on the reported 1.9 feed conversation ratio. The total embodied energy in one bag of feed (50 lb. or 22.7 Kg) is 158.4 MJ.

Feed ingredients, i.e. poultry grit and oyster shell, were used by ESF in addition to the feed above. However, given the lack of information necessary to determine upstream embodied energy values and the overall comparative impact on the model (650 lbs. of ingredients as compared to 87,200 lbs. of feed), these inputs were not included in the model.

The energy to produce one-day-old chicks or poults was calculated per the reported 0.394 MJ of hatchery energy required to produce one kg of finished broiler. A finished broiler was quoted to weight 2.26 kg. Multiplying the two values results in 0.89 MJ/bird (0.394 MJ/kg x 2.26 kg/bird = 0.89 MJ/bird).

The embodied energy for five month old pullets is calculated by considering three values: hatchery, feed and on-farm embodied energy. The hatchery values are calculated in the paragraph above. The Pelletier, 2008 study reported embodied energy values of 30 MJ/bird and 6.6 MJ/bird for feed and on-farm inputs respectively to produce a 48 day broiler. The pullets brought onto ESF were barn raised for 150 days (3.125 times long than broilers). The resulting calculations are 115 MJ/pullet of embodied energy ([(30 MJ/bird + 6.6 MJ/bird) x 3.123] + 0.89 MJ/bird)

ESF used pine shaving bedding in the poultry operations. The product was received compressed and bagged. The embodied energy for pine shavings was derived from research comparing pine chip board with sugarcane bagasse (Dos Santos et al., 2014). This research found 0.3 MJ/kg of energy was used to harvest, transport and process pine logs into shavings. This does not account for energy utilized to produce the pine trees or package each compressed bag.

Paper pulp egg cartons were used to store and deliver chicken eggs. Paper products range from completely recycled from an aggregate of sources to virgin conventional paper. Many developments have cleaned up how paper is manufactured (Salazar et al., 2006). Most improvements were aimed at reducing environmental liquid and vapor waste. However, significant strides have been made to reduce energy given the significant impact on production costs. Little origin information was available regarding the egg cartons used at ESF. Therefore, a more conservative approach was taken when identifying the embodied energy. Considering the paper egg cartons to be conventional pulp from virgin sources yields the highest embodied energy value. This model uses Manda et al., 2012 for conventional pulp at 43.9 MJ/kg.

CHAPTER 2.2.4: Plastic and Styrofoam

Low Density Polyethylene (LDPE) plastic mulch and Styrofoam seed starting trays were used at ESF. The mulch prevents weeds from crowding out plants and moisture from drying too quickly within soil. Plants with significant growing times were started early in the spring to allow some growth prior to warmer weather. Starting plants early prolongs the growing season. Plastic is an energy intensive product with early studies indicate embodied energy values of 143 and 157 MJ/kg (Berry and Makino, 1974), (Hayes, 1976). As plastic materials are used for many components of modern products, significant research and development appears to have lowered the energy impact significantly; mostly likely as a means to remain cost competitive. Most recent farm studies with plastic mulch utilize LCA databases for values for embodied energy as well as other values identified by the International Organization for Standardization (ISO)'s 14040:2006 standard (Romero-Gamez et al., 2014), (Girgenti et al., 2014). This model uses 90 MJ/kg (Lawson and Rudder, 1996) for both plastic and Styrofoam. This value represents plastics generally found in construction. However, this value aligns well with other more recent studies specifically looking specifically at Low Density Polyethylene (LDPE) such as Hammond Wagner and Jones, 2008 (89.3 MJ.kg). Little current research was identified for Styrofoam.

CHAPTER 2.2.5: Water

ESF used water from Kentucky American Water from Lexington, KY. This water system serves over 300,000 households according to the utility company’s website. This meets the definition of a large water system (Mo et al., 2010) of 100,000 households or larger. Therefore, this model utilizes the LCA embodied energy value from this literature of 9.2 MJ/m^3. This value includes energy to process water, the upstream embodied energy of flocculants and other chemicals, and the structural embodied energy of the physical processing plant.

CHAPTER 2.2.6: Seed

Embodied energy associated with organic seed production appears unstudied by other researchers. The process of producing seed for organic farming is steeped deeply in regulation and quality plans (CFR Title 7: subtitle B, chapter I, subchapter M, part 205, 2000). The definition of "organic production" is provided as "a production system that is managed in accordance with the Act and regulations in this part to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity." However, no section of this act was devoted to limiting energy inputs as studied within this work. Therefore, energy used to produce organic seeds is not expected to be significantly different for conventional seeds. This model uses 16.7 MJ/kg (Gliessman, 1998, Schramski et al. 2013), which is defined as the upstream embodied energy of locally produced grass, grain, and vegetable seeds.

CHAPTER 2.2.7 Electricity

Farm electricity was provided by Kentucky Utilities, a Louisville Gas & Electric Company. According to the utility's website, electricity generation consists of coal (73.6%), natural gas (25.2%) and hydroelectric (1.2%). Table 1 includes the generation plants for this utility provider. The indirect energy was derived by considering this mix of generation with the EROI values associated with Weißbach et al., 2013. According to this research the EROI of coal, natural gas and un-buffered hydroelectric generation is 30:1, 28:1 and 50:1 respectively. The un-buffered value considers the plant generates electricity directly to the grid without storage and a 200 year life cycle. Using the below equation, it was determined for every MJ of direct energy there was 0.12 MJ of upstream embodied energy exerted.

$$MJ_{embodied} = 3.6\ kWh_{direct} \left(\frac{73.6\%}{EROI_{coal}} + \frac{25.2\%}{EROI_{Natural\ Gas}} + \frac{1.2\%}{EROI_{hydroelectric}} \right) \quad \text{(Equation 1)}$$

Table 1: Generation plant data from Kentucky Utilities

Plant Name	**Location**	**County (KY)**	**Coal***	**Hydro***	**Natural Gas***
Tyrone	Versailles, KY	Woodford	75		54
E.W. Brown	Harrodsburg, KY	Mercer	759		895
Dix Dam		Garrard		24	
Cane Run	Louisville, KY	Jefferson	563		221
Mill Creek		Jefferson	1472		
Ohio Falls	Louisville, KY	Jefferson		80	
Green River	Central City, KY	Muhlenberg	163		
Trimble County	Bedford, KY	Trimble	1274		960
Ghent		Carrol	1932		
		TOTALS:	6238	104	2130
		%:	73.6%	1.2%	25.2%

* Values in MW of generation

CHAPTER 2.2.8 Petroleum Fuels and LP Gas

Gasoline and Diesel embodied energies were calculated from the latest EROI research (Hall et al., 2014). These researchers reviewed and compiled data from multiple sources and produced an EROI value consistent with Murphy et al., 2011. Calculations to derive EROI were based on both economic and energy specific units. Economic costs were converted to energy costs from industry and government data sources. The current (2007) value for produced and delivered petroleum fuels is somewhere between 11:1 for domestically produced oil and 12:1 for imported. This model considers the domestic value and applies it to US Department of Energy published energy content of E10 gasoline (10% Ethanol) and diesel (31.8 MJ/L and 35.8 MJ/L). The result is 2.89 MJ/L for E10 gasoline and 3.25 MJ/L for Diesel. The above values are somewhat consistent with other researchers (Gliessman, 1998), where the values for "commonly-used industrial cultural inputs" were published at 3.9 MJ/L and 2.72 MJ/L for gasoline and diesel respectively.

Propane is a useful byproduct from the natural gas processing and petroleum refineries. It is scrubbed out and separated from other carbon based fuels and compressed to liquid for transport with an indirect energy of 1.8 MJ/L (Gliessman, 1998) for its processing and delivery.

CHAPTER 2.2.9: Organic Fertilizer

Many past values for fertilizer were based on the individual constituents of the fertilizer (Nitrogen, Phosphorus and Potassium). This is reasonable given many of these nutrient-specific values were derived by distinct ingredients. Most fertilizers are blended from Urea (CH_4N_2O) or Ammonium Sulfate ($(NH_4)_2SO_4$), a phosphorus compound, and Potash. Labelling for conventional fertilizers revolve around the amount of available nitrogen, phosphorus (P_2O_5), and potassium (K_2O). ESF uses Nature Safe products which mostly consist of animal byproducts. Animal by-product fertilizers are perceived to be more homogenous in nature (ingredients include hydrolyzed feather meal, meat and bone meal, blood meal, fish meal, etc.). Therefore, values based on nutrient content were considered inappropriate. This model uses 11 MJ/kg (Spångberg et al., 2011) for the embodied energy of organic fertilizers. The Spångberg et al., 2011 work researched the impact of Animal-By-Products (ABP) used in two systems. The value used in this work was calculated based on "system MM" outlined in the literature.

CHAPTER 2.2.10: Cattle Inputs (Trace Minerals)

Cattle mineral requirements were met with trace mineral products at ESF. These products are grain meal based to serve as a carrier of smaller portions of essential minerals. The manufacturing of these products closely follow feed. The review of past cattle LCA research did not report specific embodied energy values for trace minerals (Pelletier et al., 2010), (Nguyen et al., 2012) demonstrating the low comparative effect on the total analysis. However, this model uses the same values for feed (7.0 MJ/kg) to provide some description of this input.

CHAPTER 2.2.11: Organic Pesticides

The pesticides used on ESF were mostly OMRI certified. Many of these products are derived from bacterial or fungal incubation products. To date, the authors are unaware of any specific studies regarding the embodied energy of such products. Even most recent farm organic EROI studies do not consider organic pesticides in the analysis (Galán et al., 2016), (Pagani et al., 2016). Inorganic pesticide embodied energy values range from 370 MJ/kg (active ingredient) to 101 MJ/kg (Audsley et al., 2009 and Green, 1987 respectively). Organic pesticides are not expected to be significantly less than conventional pesticides given significant energy required to grow, separate and package final products. This model uses 124 MJ/kg (Schramski et al., 2013). This value combines embodied energy values for production, formulation, transportation and packaging using a variety of sources (Leach and Slesser, 1973) and (Green, 1987).

CHAPTER 2.2.12: Commodities (Corn and Roasted Soybeans)

Roasted soybeans and whole corn were used in the cattle production at ESF. The embodied energy for roasted soybeans was derived from Pradhan et al., 2009. This work focused on the LCA of soybean biodiesel. The production and transportation values are derived from this work (1.5 MJ/kg and 0.3 MJ/kg respectively). Given this value describes raw soybeans, a roasting value was derived from literature publish by the manufacturer Dilts-Wetzel. The values was listed in US dollars ($10 of electricity used for 1 ton roasted). This was converted to MJ assuming $0.08/KWh. Roasting requires 0.5 MJ/kg of energy. The total value used is summed from the above steps to be 2.3 MJ/kg.

The embodied energy value for corn was derived from Pelletier, 2008 poultry LCA. After normalizing for the Functional Unit presented in the above work, the embodied energy was found to be 3.5 MJ/kg.

CHAPTER 2.2.13: Wheat Straw

Wheat straw was used by ESF to mulch various crops. Typically, wheat straw is collected from wheat grain operations. According to the USDA Agricultural Census of 2012 provided by National Agricultural Statistics Service, the top wheat production states are Kansas, North Dakota, Montana, Washington and Oklahoma with production values (in million bushels) of 2,687, 2,513, 1,405, 1,091 and 1,051 respectively and represents 61.2% of the total US production. Kentucky produced 77 million bushels which represents 1.5% of the total US production. The wheat straw used at ESF was purchased from a local farm supply store with no origination information. Therefore, we chose to take the top five producing states, along with Kentucky production, and make the broad assumption that production is the most likely probable means of determining origination. The distances from Georgetown, KY to the center of each state (and Kentucky) were multiplied by the production percentages of US total production and added together to form the numerator of this average. This value was then divided by the total percentage considered in this calculation (62.7% of US total wheat production). This value was calculated at an average of 1900 km. Considering transportation in the US averages 2.4 MJ/tonne*km (Eom et al., 2012), the transportation embodied energy is calculated to be 2.7 MJ/kg. The embodied energy used to account for production of wheat straw was 0.3 MJ/kg (Nilsson, 1997). Nilsson's work studied the utilization of wheat straw as a means to heat a district energy hot water plant. The values reported considered a local farm with little transportation energy used to transport. ESF used square bales weighing approximately 13.6 kg (30 lbs.). After all calculations are performed, the embodied energy used in this model is 40.8 MJ/bale.

CHAPTER 2.2.14: Gravel and Agricultural Lime

Agricultural soils require a fairly neutral soil pH to allow plants to appropriately manage the uptake of nutrients. Acidic soils will limit the absorption of needed nutrients such as nitrogen and phosphorus. In some cases, acidic soils will promote the absorption of detrimental nutrients such as aluminum. Most soils become acidic naturally due to rain leaching buffering agents such as calcium. In non-organic commercial operations, this situation is worsened due to the spreading of fertilizers with acidic components. Lime is used in typical commercial farming to raise the pH in soils. Generally, a commercial source of lime will have the value 46.2 MJ/kg of embodied energy (Romanelli and Milan, 2010). This value includes energy to mine, crush, transport and spread on crops.

ESF used gravel to improve driveways and around water tanks to prevent erosion. Reported values for embodied energy of aggregates can be found from literature dedicated to the Life Cycle Analysis of Portland cement and other concrete products used in typical construction (Huntzinger and Eatmon, 2009), (Boesh and Hellweg, 2010), (Marceau et al., 2006), (Dixit et al., 2013), (Petek Gursel et al., 2014), (Galán-Marín et al., 2015), (Jamieson et al., 2015). Literature sources for the embodied energy of gravel vary greatly from 0.0124 to 1.0 MJ/kg (Jamieson et al., 2015). Most of these values include significant embodied energy to account for transportation.

The lime and gravel used at ESF were acquired from a local limestone quarry and transported using reported farm equipment and fuels. Given the locality of this material, this model utilizes an embodied energy based on 20.5 MJ/m^3 (Venkatarama Reddy and Jagadish, 2003) to mine and crush stone only. Considering an average density of 1,653 kg/m^3 (calculated from values provided in Jamieson et al., 2015) this calculates to a value of 0.0124 MJ/kg.

CHAPTER 2.2.15 Inputs reported but not included

Items reported by the owner/operators but not included in this energy model were animal health items such as poultry crates, light bulbs, wormer and vaccinations, motor oil, strawberry plugs, and miscellaneous PVC fittings. The levels of these inputs were extremely small compared to the remaining model; thus the impact on the model was not expected to be high. Motor oil was accounted for in the equipment maintenance values.

Greenhouse media such as dirt, perlite, vermiculite and similar was used and recorded for ESF. However, the research did not accommodate the extraction of a reasonable upstream embodied energy value. The amount recorded was less than four cubic meters. Therefore, the expected impact on the model was expected to be small.

Table 2: Summary of input coefficients used in this model

Input	Reference	Notes
Labor (Direct)	Cox and Atkins, 1979; Pimentel, 1984; Duhon, 1985; SFNB, 1989; Zhengfang, 1994; Tharion et al., 2005; Smil, 2008; Schramski et al.; 2013	
Labor (Indirect)	Schramski et al., 2013	Upstream energy used to supply the labor and to maintain laborer's physiology
Gasoline and Diesel (Direct)	US Department of Energy values for E10	http://www.afdc.energy.gov/fuels/fuel_properties.php
Gasoline and Diesel (Indirect)	Hall et al., 2014	
Gravel and Ag Lime	Venkatarama Reddy and Jagadish, 2003	Local Quarry
Seed (all)	Gliessman, 1998	"Local seed"
Fertilizer	Spångberg et al., 2011	
Feed and Trace Minerals	Pelletier, 2008	
Roasted Soybeans	Pradhan et al., 2009 and manufacturing data from Dilts-Wetzel	
Shavings	M. dos Santos et al., 2015	
Electricity	WeiBback et al., 2013	Formula by probability of generation
Water	Mo et al., 2010	
Pesticides	Leach and Slesser, 1973 and Green, 1987	
Paper Egg Cartons	Manda et al., 2012	Kraft paper values
Plastic and Styrofoam	Lawson and Rudder, 1996	
Wheat Straw	Nilsson, 1997 (for production) and Eom et al., 2012 (for transportation)	Based on top five wheat producing states.
Live birds	Pelletier, 2008	
Whole Corn	Pelletier, 2008	
Machinery	Smil et al., 1983	Amortization based on age

CHAPTER 2.3: OUTPUT ENERGY

ESF vegetable produce, meat, and processed products during the calendar year 2014 were recorded by weight. The caloric values provided by the USDA (2011) database were used to determine output energy. The output energy per product is shown in Table 3.

ESF reported the live weights of animals. The live weights were discounted for expected final carcass weight and bone. This defines the final meat products as muscle proteins and fat typically attained for each animal. Table 4 provides the discounts taken for each animal.

Table 3: Output Calories values per sources

Protein	**Output Name**	**Source**	**USDA Code**	**Calories/kg**
Vegetable	ARUGULA	1	75113080	249
	BASIL	2	2044	229
	BEANS	1	75102000	1,131
	BEETS	1	75102500	430
	BLACKBERRIES	1	63201010	430
	BOK CHOH	1	75104000	130
	BROCCOLI	1	72201100	893
	BRUSSELL SPROUTS	1	75102750	430
	CABBAGE	1	75103000	249
	CARROTS	1	73101010	410
	CELERY	1	75109000	161
	CHARD	1	72104100	190
	COLLARDS	1	72107100	320
	CORNMEAL	2	20020	3,620
	CUCUMBER	1	75111000	119
	DRIED PEPPERS	2	11982	3,450
	DRY BEANS	1	41104020	1,420
	EGG PLANT	1	75111200	249

	FENNEL	1	75109010	311
	GARLIC	1	75111500	1,490
	GARLIC SCAPES	3	Schramski	18
	GINGER	2	11216	800
	HERBS	3	Schramski	18
	KALE	1	72119201	461
	KETCHUP	1	74401010	1,120
	KOHLRABI	1	75112000	269
	LEEKS	2	11246	611
	LETTUCE	1	75113000	141
	MARINARA	1	74404010	489
	MELLONS	1	63127010	359
	MUSTARD GREENS	1	72122100	269
	OKRA	1	75220011	220
	ONIONS	1	75117020	399
	PEAS	1	75120000	809
	PEPPER, BELL	1	75122100	201
	PEPPER, HOT	1	75124000	269
	PEPPERS, OTHER	1	75124000	269
	POPCORN	2	19806	3,821
	POTATOES	1	71001000	769
	PUMPKIN	1	73201000	430
	RADISHES	1	75125000	161
	RASPBERRIES	1	63219000	520
	RED KURI	2	12093	2,240
	SAGE	2	2038	3,150
	SALAD MIX	1	75114000	170
	SALSA, HOT	1	74402100	291
	SALSA, MILD	1	74402100	291
	SPINACH	1	72125100	229
	SQUASH, BABY	1	75128010	170
	SQUASH, BUTTERNUT	1	73302010	340
	SQUASH, DELICATTA	1	73302010	340
	SQUASH, FALL	1	73302010	340
	SQUASH, GREEN	1	75128010	170
	SQUASH, PATTY PAN	1	73302010	340
	SQUASH, SPAGHETTI	1	75233220	269
	SQUASH, YELLOW	1	75128000	161

	STRAWBERRIES	1	63223020	320
	SWEET CORN	1	75109600	860
	SWEET POTATOES	1	73401000	1,069
	TOMATILLAS	2	11954	320
	TOMATOES	1	74101000	181
	TOMATOES, DICED	2	11533	260
	TOMATOES, DRIED	2	11955	2,579
	TURNIP GREENS	1	72128200	359
	TURNIPS	1	75418101	780
	VARIOUS VEGETABLES	2	11583	721
	WATERMELON	1	63149010	300
	WINTER RADISH	1	75125000	161
	WINTER SQUASH	1	73302010	340
Other	Tobacco	3	Schramski	18
Meat	Beef	1	21000100	2,090
	Broilers	1	24100000	1,609
	Eggs	1	31101010	1,431
	Hens	1	24100000	1,609
	Lamb	1	23000100	2,919
	Turkey	1	24201000	1,389

1. USDA database per URL: https://reedir.arsnet.usda.gov/codesearchwebapp/(S(hcyeiz5v1jyddypyms40d5vq))/codesearch.aspx
2. USDA database per URL: http://ndb.nal.usda.gov/ndb/foods
3. Schramski et al., 2015

Table 4: Discounts taken from live weights of animal production

Species	Carcass %	Bone %	Total Discount (Carcass – Bone)	Source
Beef	60 %	10%	50%	1
Lamb	50 %	7%	43%	1
Turkey	76.4%	-	76.4%	2
Hens	73.8%	-	73.8%	3
Broilers	74%	-	74%	2

1. Darre et al., 1991; Table 13
2. Darre et al., 1991; Table 14 (averaged male and female)
3. Darre et al., 1991; Table 14 (female)

CHAPTER 3

MODEL RESULTS

The 2014 ESF model results are provided in sections similar to the model description. The overall first order EROI is 2,8:1.0 and the second order EROI is 7.7:1.0. The total input was calculated at 3,231 GJ of total energy comprising of 1,176 GJ of direct energy and 2,055 GJ of indirect energy. The total output was calculated at 422 GJ comprising of 232 GJ of meat and 190 GJ of vegetables. All values were collected in locally common British Imperial units commonly found in the United States. We convert these values to SI units with the British Imperial values provided as parentheticals

CHAPTER 3.1: DIRECT ENERGY INPUTS

Fuel values for gasoline, diesel and LP gas are listed in table 5. All values were reported in US gallons and converted to liters. Approximately 33% of the gasoline values were provided as monetary value in US dollars. The volumetric values of this 33% were approximated from monetary values using the average gasoline price reported by the US Department of Energy for each time frame the fuel was purchased. The total direct energy for diesel, gasoline and LP gas in the 2014 growing season was 333,902, 264,661 and 180,664 respectively.

Table 5: Diesel, Gasoline, and LP Gas

Month	Diesel L	Gasoline L	LP Gas L	Diesel MJ (39 MJ/L)	Gasoline MJ (34 MJ/L)	LP Gas MJ (25 MJ/L)	Totals MJ
Jan		1,196	1,287		40,764	31,926	72,690
Feb	57	257		2,190	8,772		10,962
Mar	38	254	2,396	1,460	8,643	59,439	69,542
Apr		924	2,555		31,476	63,383	94,859
May	201	1,143		7,738	38,958		46,696
Jun	3,581	1,139		138,116	38,829		176,945
Jul	3,581	1,306		138,116	44,505		182,621
Aug		655			22,317		22,317
Sep		1,058	1,045		36,068	25,916	61,985
Oct		1,278			43,538		43,538
Nov	110	685		4,234	23,349		27,583
Dec	1,090	400		42,048	13,622		55,670
Totals	*8,657	10,295	7,283	333,902	350,841	180,664	865,407

*Value corrected for compounding rounding when converting from US gallons to liters

Electricity was recorded from four utility meters. Table 6 displays the values in KW-h and MJ. The total direct energy from electricity for the 2014 growing season was 264,661 MJ.

Table 6: Recorded electricity in KW-h

Month	Meter 1	Meter 2	Meter 3	Meter 4	Monthly Total
Jan	5,137		4,335	266	9,738
Feb	2,149		4,333	7	6,489
Mar			3,669	381	4,050
Apr	2,341		2,824	459	5,624
May	824	746	4,035	954	6,559
Jun	744	1,196	4,960	291	7,191
Jul	607	1,417	4,950	100	7,074
Aug	805	509	4,739	154	6,207
Sep	586	362	4,366		5,314
Oct	550		4,181		4,731
Nov	1,004		3,698	186	4,888
Dec	1,491		3,957	204	5,652
TOTAL KW-h	*16,238*	*4,230*	*50,047*	*3,002*	*73,517*
TOTAL MJ	**58,457**	**15,228**	**180,169**	**10,807**	**264,661**

Labor was performed by seventeen specific individuals and a nonspecific pool of field workers. Hours for each labor category were reported in quarters (three months) and were spread evenly between the months of each quarter. Therefore, the results appear blocky. The annual total direct energy was calculated at 45,943 MJ. Tables 7 and 8 demonstrate specific monthly and quarterly direct labor input details.

Table 7a: Labor hours

Q	Month	Labor 1	Labor 1.25	Labor 1.5	Labor 2	Labor 2.5	Labor 3
1	Jan	153			532		33
	Feb	153			532		33
	Mar	153			533		34
2	Apr		419		721	229	1,187
	May		419		722	229	1,187
	Jun		419		722	229	1,187
3	Jul		370		1,092	282	2,823
	Aug		370		1,092	282	2,823
	Sep		370		1,093	282	2,823
4	Oct		238	162	657		1,146
	Nov		237	162	657		1,146
	Dec		237	162	657		1,146
Total hours		459	*3,076	*487	*9,009	*1,532	15,568
MJ/hour of labor		*0.7308*	*0.9010*	*1.0711*	*1.4115*	*1.5787*	*1.7459*
MJ/Labor effort		335	2,771	522	12,716	2,419	27,180

*Values reported per 15 minute intervals. Values corrected for compounded rounding

Table 7b: Labor in MJs

Q	Month	Total MJ	Labor 1	Labor 1.25	Labor 1.5	Labor 2	Labor 2.5	Labor 3
1	Jan	921	112			751		58
	Feb	921	112			751		58
	Mar	923	112			752		59
2	Apr	3,830		377		1,018	362	2,073
	May	3,830		377		1,018	362	2,073
	Jun	3,831		377		1,019	362	2,073
3	Jul	7,247		333		1,540	444	4,929
	Aug	7,247		333		1,540	444	4,929
	Sep	7,249		333		1,542	444	4,929
4	Oct	3,315		214	174	927		2,000
	Nov	3,314		213	174	927		2,000
	Dec	3,314		213	174	927		2,000
Totals		***45,943**	*335	*2,771	522	*9,009	*2,419	*27,180

*Values reported per 15 minute intervals. Values corrected for compounded rounding

CHAPTER 3.2: INDIRECT ENERGY INPUTS

CHAPTER 3.2.1: Human Labor

The indirect energy associated with the direct labor energy is 19.4 times the total direct human labor energy. This was calculated to 891,314 MJ for the whole season. Time dependent values are reported in table 8.

Table 8: Indirect labor based on direct labor

Q	Month	Total MJ	Indirect Labor (Total MJx19.4) MJ
1	Jan	921	17,867
	Feb	921	17,867
	Mar	923	17,906
2	Apr	3,830	74,302
	May	3,830	74,302
	Jun	3,831	17,321
3	Jul	7,247	140,592
	Aug	7,247	140,592
	Sep	7,249	140,631
4	Oct	3,315	64,311
	Nov	3,314	64,292
	Dec	3,314	64,292
	Totals	***45,943**	*891,294

*Values reported per 15 minute intervals. Values corrected for compounded rounding

CHAPTER 3.2.2: Machinery

The age of motorized equipment was easily determined. However, this was not the case for non-motorized equipment. Motorized equipment was amortized for 12 years or by the equipment age. All non-motorized equipment was amortized at 20 years unless it was evident by inspection and testimony of farm operators the equipment was over 30 years of age. Refer to table 9a (motorized equipment) and 9b (non-motorized equipment).

Using the tables, powered and non-powered equipment was determined to add 27,300 MJ and 8,944 MJ of indirect energy per month. This calculates to 434,928 MJ per year.

Table 9a: Motorized machinery

Type	Make and Model	Weight (kg)	Year (Age)	Years to Amortize	Monthly MJ
Combine	Gleaner Model K	3629.0	1970 (44)	44	632
4-Wheeler	Yamaha Big Bear 350	247.0	1988 (26)	26	73
Mower	Dixie Chopper SE 2760	551.1	2005 (9)	12	352
Mower	Exmark Metro 36	233.0	2004 (10)	12	149
Sprayer	Hahn Model 312	680.4	1985 (29)	29	180
Tractor	Deutz DX-130	5211.8	1985 (29)	29	1,378
Tractor	Ford 5000	4399.8	1963 (51)	51	661
Tractor	Kubota MX 125	4390.0	2007 (7)	12	2,805
Tractor	Agco Allis 7600	3900.9	1995 (19)	19	1,574
Tractor	Valtra A95	3672.0	2003 (11)	12	2,346
Tractor	Mahindra 6000	2835.0	2005 (9)	12	1,811
Tractor	Mahindra 4500	2604.0	2004 (10)	12	1,664
Tractor	Farmall 140	2189.0	1966 (48)	48	350
Tractor	BCS (walk behind)	125.0	2010 (4)	12	80
Transplanter	Checci & Magli	550.0	1985 (29)	29	145
Trimmer	Stihl FS80R	4.9	2008 (6)	12	3
Truck	Ford F-250	2835.0	2013 (1)	12	1,811
Truck	Ford F-350	2678.9	2001 (13)	13	1,580
Truck	Dodge 1500	2125.0	1995 (19)	19	857
Truck	Ford F-150	1548.0	1984 (30)	30	396
Truck Semi)	Freightliner FL80	17690.1	1990 (24)	24	5,651
Van	Chevy 2500	2289.3	2005 (9)	12	1,463
Van	Ford E350	2165.0	1994 (20)	20	830
Van	Chevy G20	1925.0	1985 (29)	29	509

Table 9b: Non-motorized machinery

Make and Model	Weight (kg)	Monthly MJ
Rototiller	305	117
Oliver Plow 565	* 454	174
Subsoiler	43	16
Plastic Layer (qty. 2)	544	209
Vegetable Washer**	* 227	58
Kuhn Hay Mower GMD 66 CD	452	173
Ward Grain Cart 100 bu	* 680	261
Cultivator	46	18
Trailer	* 907	348
Grain Cart	* 363	139
Potato Digger**	* 4,536	1,159
Wagon Running Gear	406	156
New Holland Square Baler 315	* 1,134	435
M&W Hay Rake	* 363	139
Kuhn Disc Mower GMD 700 G II HD	567	217
IH Disc Harrow 475	* 907	348
Air Compressor 5HP	136	52
Kory Wagon Running Gear 6T	204	78
Mulch Layer	* 1,134	435
Baltic Fertilizer Seed spreader Baltimatic 80	* 136	52
Scraper Blade	* 159	61
Matermacc Air Seeder Magicsem 8000	395	151
Electric Pump	76	29
Sand Filters tr140 (qty. 2)	136	52
Micro Rain 1" travel	143	55
Yetter Rotary Hoe 12 ft	567	217
Maschio Rototiller Fresa B 250 C	770	295
Crown Walk Behind pallet jack WP	325	125
Tank transplanter 5000WD**	* 2,268	580
Ag-Rain/ Kifco Hard hose traveler T200	544	209
Grillo Sickle Mower attatchment 39"	20	8
Kory Wheel Wagon Frame 8 ton 16"	227	87
Vermeer Round Baler 505M Classic	2,608	1,000
New Holland Grinder Mixer 345**	* 1,814	464
John Deere Grain Drill BB 7 ft**	* 454	116
Gravity Flow Grain Wagons (qty. 4)	* 1,814	696
Lilliston Cultivator 2 row	228	87
Lilliston Cultivators 4 row	339	130

* Weights estimated; **Amortized 30 years

CHAPTER 3.2.3: Poultry Inputs

Feed was brought onto the farm in 22.7 kg (50 lbs.) bags. Refer to table 10 for details. The annual total of bags is 1,728, which represents 39,190 kg (86,400 lbs.). Multiplying this value with the indirect energy coefficient of 158.4 MJ/bag the total indirect energy brought onto the farm in the form of feed was 273,715 MJ.

Live pullets, turkey poults and broiler chicks were brought onto the farm according table 11. The annual total live poultry consists of 510 pullets, 2,550 broilers and 100 poults. Utilizing the 115 MJ/pullet, 0.9 MJ/broiler and 0.9 MJ/poult, the indirect energy brought onto the farm is 58,650 MJ, 2,267 MJ and 89 MJ respectively. This totals to 61,009 MJ.

Table 10: Feed quantities in 22.7 kg (50 lbs.) bags

Month	Broiler	Layer	Turkey		Total
Feb	5	38	2		45
Mar	4	41			45
Apr	53	23			76
May	177	128	1		306
Jun	135	90			225
Jul	155	115			270
Aug	191	124			315
Sep	180	71			251
Oct	95	85			180
Nov		15			15
Total	995	730	3		1,728

Table 11: Live poultry

Month	Pullets	Broilers	Poults
Mar		425	
Apr		425	
May	510	850	100
Jun			
Jul		425	
Aug		425	
Total	510	2,550	100

Shavings were brought onto the farm in 0.09 m^3 (3.2 ft^3) bags. Independent testing was conducted to determine the density of pine shavings. Weighing different types of shavings available from a local farm store (Deason's Farm and Garden; Royston, GA) found the average density of pine shavings to be 46.6 kg/m^3 (2.9 lbs./ft^3). The total volume of pine shavings brought onto the farm was 29.0 m^3 (1,024 ft^3) which represents an annual indirect energy total of 10,138 MJ. See table 12 for time dependent input information.

Table 12: Bags of shavings

Month	Bales (0.09 m^3 each)	Total m^3 (ft^3)	
Feb	2	0.18	(6.4)
Mar	20	1.81	(64.0)
Apr	37	3.35	(118.4)
May	58	5.26	(185.6)
Jun	65	5.89	(208.0)
Jul	63	5.71	(201.6)
Aug	35	3.17	(112.0)
Sep	30	2.72	(96.0)
Oct	10	0.91	(32.0)
Totals	320	29.0	(1,024.0)

4665 egg cartons were brought onto ESF for the 2014 egg-laying season. Each carton weight was approximated at 0.06 kg (1/8 lb.). This totals to 264.5 kg (583 lbs.) of total mass. This calculates to an embodied energy impact of 11,616 MJ.

CHAPTER 3.2.4: Plastic and Styrofoam

Throughout the year, a quantity of 300 four inch plastic transplant pots, 320 speedling-style Styrofoam 253 cell count trays, 12,801 meters (42,000 ft.) of 1.22 meter wide (4 ft.) one mil LDPE plastic mulch, 12,801 meters (42,000 ft) of ten mil plastic tape, three rolls of 4.57 meter (15 ft.) by 304.8 meter (1,000 ft.) 0.5 oz. row cover, and three rolls of 7.62 meter (25 ft.) by 304.8 meter (1,000 ft.) 0.5 oz. row cover was used on ESF.

Products were researched from on-line sources to determine appropriate weights for each plastic product. The plastic transplant pots were brought in February with a total mass of 3.6 kg (8 lbs.) contributing 326 MJ. The Styrofoam trays were brought in March with a total mass of 344 kg (759 lbs.) contributing 30,967 MJ. The plastic mulch was brought in April with a total mass of 867 kg (1912 lbs.) contributing 78,010 MJ. The total plastic and Styrofoam contributed 109,303 MJ of embodied energy to the farm.

CHAPTER 3.2.5: Water

Although all water reported in this work came from utilities. Wells and irrigation water from ground sources were considered within the farm gate. Energy needed to pump this water was captured through electrical metering. For the three utility water meters, tables 13a and 13b represent the monthly reported values. The annual total of utility provided water was 5,670,592 liters (1,498,012 US gallons) or 5,670 m^3 which represents 52,131 MJ of indirect energy.

Table 13a: Water in liters

Month	Meter 1	Meter 2	Meter 3	Total
Jan	305,801		20,714	326,514
Feb	155,732		54,692	210,423
Mar	260,497		60,355	320,852
Apr	226,519		74,512	301,031
May	370,925	202,482	29,208	602,615
Jun	512,499	374,275	43,366	930,140
Jul	478,521	640,783	29,208	1,148,513
Aug	260,497	291,643	29,208	581,348
Sep	297,306	52,617	43,366	393,289
Oct	368,093	38,611	34,871	441,576
Nov	167,058		37,703	204,760
Dec	209,530			209,530
Total	3,612,979	1,600,412	457,202	5,670,592

Table 13b: Water meters in US gallons as recorded

Month	Meter 1	Meter 2	Meter 3		Total
Jan	80,784		5,472		86,256
Feb	41,140		14,448		55,588
Mar	68,816		15,944		84,760
Apr	59,840		19,684		79,524
May	97,988	53,490	7,716		159,194
Jun	135,388	98,873	11,456		245,717
Jul	126,412	169,277	7,716		303,405
Aug	68,816	77,044	7,716		153,576
Sep	78,540	13,900	11,456		103,896
Oct	97,240	10,200	9,212		116,652
Nov	44,132		9,960		54,092
Dec	55,352				55,352
Total	954,448	422,784	120,780		1,498,012

CHAPTER 3.2.6: Seed

Grain seed was brought onto the farm in April and October to supplement the forage during summer and winter months respectively. Quantities were 326.6 kg (720 lbs.) and 907.2 kg (2,000 lbs.) respectively. Grass seed was brought in during the same time in quantities of 188.2 kg (415 lbs.) and 77.1 kg (170 lbs.) respectively. It was reported that 34 to 45.4 kg (75 to 100 lbs.) of vegetable seed was brought onto the farm in April. This reported estimation was averaged and counted in the model as 40.1 kg (88.5 lbs.). This totals to 1,539.3 lbs. (3,393.5 lbs.) of seed which represents an annual indirect energy value of 56,671.5 MJ.

CHAPTER 3.2.7: Electricity

The indirect energy associated with electricity was calculated for each monthly total and shown in table 14. The annual total KW-h associated with the four reported electricity meters was 16,230 for meter one, 4,230 for meter two, 50,047 for meter three and 3,002 for meter four. This totals to 73,517 KW-h or 264,661 MJ of energy for the year. Utilizing the 0.12 MJ of indirect energy per each 1.0 MJ of direct energy the total indirect energy associated with electricity was 32,392 MJ.

Table 14: Electricity indirect energy

Month	Monthly Total Direct Energy KW-h	Monthly Total Direct Energy MJ		Monthly Total Indirect Energy (0.12 MJ/MJ)
Jan	9,738	35,057		4,291
Feb	6,489	23,360		2,859
Mar	4,050	14,580		1,784
Apr	5,624	20,246		2,478
May	6,559	23,612		2,890
Jun	7,191	25,888		3,168
Jul	7,074	25,466		3,117
Aug	6,207	22,345		2,735
Sep	5,314	19,131		2,341
Oct	4,731	17,032		2,085
Nov	4,888	17,597		2,154
Dec	5,652	20,347		2,490
Totals	**73,517**	**264,661**		**32,392**

CHAPTER 3.2.8: Petroleum Fuels and LP Gas

The indirect energy values for all fuels used on ESF were original calculated per US gallons (12.3, 10.9, and 6.94 MJ/gal of diesel, gasoline and LP gas respectively). The total indirect energies associated with fuels were 28,130 MJ for diesel, 29,645 MJ for gasoline and 13,353 MJ for LP gas. This totals to 71,128 MJ for the 2014 production year. Monthly totals are reported in table 15.

Table 15: Diesel, Gasoline and LP Gas indirect energy

Month	Diesel L	Gasoline L	LP Gas L	*Diesel MJ (3.25 MJ/L)	*Gasoline MJ (2.89 MJ/L)	*LP Gas MJ (1.8 MJ/L)	Totals MJ
Jan		1,196	1,287		3,444	2,360	5,804
Feb	57	257		184	741		925
Mar	38	254	2,396	123	730	4,393	5,246
Apr		924	2,555		2,660	4,685	7,345
May	201	1,143		652	3,292		3,944
Jun	3,581	1,139		11,636	3,282		14,918
Jul	3,581	1,306		11,636	3,761		15,397
Aug		655			1,886		1,886
Sep		1,058	1,045		3,048	1,915	4,963
Oct		1,278			3,679		3,679
Nov	110	685		357	1,972		2,329
Dec	1,090	400		3,542	1,150		4,692
Totals	*8,657	10,295	7,283	28,130	29,645	13,353	71,128

*Indirect energy values were original calculated per US gallons (12.3, 10.9, and 6.94 MJ/gal of diesel, gasoline and LP gas respectively). Values reported are shown based on these multipliers.

CHAPTER 3.2.9: Organic Fertilizer

Organic fertilizer was brought onto the farm during the months of February, April, June and July in the quantities of 27.2 kg (60 lbs.), 6.8 kg (15 lbs.), 907.2 kg (2,000 lbs.) and 90.7 kg (200 lbs.) respectively. The total annual organic fertilizer was 1,031.9 kg (2,275 lbs.) which represents 18,792 MJ of indirect energy.

CHAPTER 3.2.10: Cattle Inputs (Trace Minerals)

Trace minerals were brought onto the farm during the months of February, March and July in the quantities of 907.2 kg (2,000 lbs.), 68 kg (150 lbs.) and 907.2 kg (2,000 lbs.) respectively. The total trace minerals were 1,882.4 kg (4,150 lbs.) which represents 13,147 MJ of indirect energy.

CHAPTER 3.2.11: Pesticides

Products used to control pests were limited to eight products which were applied only during production months. See tables 16a and 16b for product details. Monthly use is provided in tables 17a and 17b. The annual total was 86.3 kg (190 lbs.) which represents 10,689 MJ of indirect energy.

Table 16a: Pesticides in kg

Product Name	Active Ingredient	Form	Liquid Density (kg/L)	Used (liters)	Used (kg)
Mycotrol O	*B. bassaina* (Fungus)	Liquid	0.93	3.79	3.52
Entrust	Spinosad (fermentation product)	Solid	N/A	N/A	0.77
Dipel Dust	*B. thuringiensis* (bacteria)	Solid	N/A	N/A	0.45
M-Pede	Potassium Salt of Fatty Acids	Liquid	1.02	6.62	6.76
Nordox	Copper Sulfate	Solid	N/A	N/A	2.04
O-TAC	Fatty Alcohols	Liquid	0.85	75.71	64.35
Neemix	Azadirachtin	Liquid	0.95	1.66	1.57
Surround	Kaolin	Solid	N/A	N/A	6.80
				Total:	86.27

Table 16b: Pesticides in lbs.

Product Name	Active Ingredient	Form	Liquid Density (lb/gallon)	Used (gallons)	Used (lbs.)
Mycotrol O	*B. bassaina* (Fungus)	Liquid	7.76	1.00	7.76
Entrust	spinosad (fermentation product)	Solid	N/A	N/A	1.71
Dipel Dust	*B. thuringiensis* (bacteria)	Solid	N/A	N/A	1.00
M-Pede	Potassium Salt of Fatty Acids	Liquid	8.51	1.75	14.89
Nordox	Copper Sulfate	Solid	N/A	N/A	4.50
O-TAC	Fatty Alcohols	Liquid	7.09	20.00	141.87
Neemix	Azadirachtin	Liquid	7.90	0.44	3.46
Surround	Kaolin	Solid	N/A	N/A	15.00
				Total:	190.19

Annual

Table 17a: Monthly pesticide use (kg)

	Mycotrol O	Entrust	Dipel Dust	M-Pede	Nordox	O-TAC	Neemix	Surround		Monthly Totals
Jan										
Feb										
Mar										
Apr										
May	0.88							6.80		7.68
Jun	1.76	0.23	0.45	2.90						5.34
Jul	0.88	0.26		2.90			0.90			4.93
Aug		0.14			2.04	64.35	0.67			67.21
Sep		0.04		0.97						1.00
Oct		0.11								0.11
Nov										
Dec										
Totals	3.52	0.77	0.45	6.76	2.04	64.35	1.57	6.80		86.27

Table 17b: Monthly pesticide use (lbs.)

	Mycotrol O	Entrust	Dipel Dust	M-Pede	Nordox	O-TAC	Neemix	Surround		Monthly Totals
Jan										
Feb										
Mar										
Apr										
May	1.94							15.00		16.94
Jun	3.88	0.50	1.00	6.38						11.76
Jul	1.94	0.56		6.38			1.98			10.86
Aug		0.31			4.50	141.87	1.48			148.17
Sep		0.08		2.13						2.21
Oct		0.25								0.25
Nov										
Dec										
Totals	7.76	1.71	1.00	14.89	4.50	141.87	3.46	15.00		190.19

CHAPTER 3.2.12: Commodities

Roasted soybeans were brought onto the farm in 907.2 kg (2,000 lbs.) allotments during the months of March and May. This totals to 1,814.4 kg (4,000 lbs.) and represents 4,000 MJ of annual indirect energy. Whole corn was brought onto the farm in November in the quantity of 63.5 kg (140 lbs.). This represents 224 MJ of annual indirect energy.

CHAPTER 3.2.13: Wheat Straw

Wheat straw was brought onto the farm in the month of November. The quantity of 70 bales at approximately 13.6 kg (30 lbs.) each multiplied with the coefficient of 40.8 MJ/bale represents 2,856 MJ of annual indirect energy.

CHAPTER 3.2.14: Gravel and Agricultural Lime

Gravel was retrieved from the local quarry during the months of January, November and December at recorded values of 17,700 kg (28,000 lbs.), 2,270 kg (5,000 lbs.) and 27,000 kg (59,600 lbs.) respectively. Agricultural lime was retrieved from the same quarry during the month of May at the recorded value of 6,350 kg (14,000 lbs.). This represents a 2014 total of 48,400 kg (106,600 lbs.). Multiplying this value with the indirect energy coefficient of 0.012 MJ/kg the total indirect energy brought onto the farm in the form of gravel and agricultural lime was 600 MJ.

CHAPTER 3.3: OUTPUT ENERGY

Farm production was recorded in 966 lines of data. Therefore, a complete listing of data will not be provided in this section. The total output was 100,418,649 Calories (421,758 MJ) and was made up of 55,276,306 Calories (232,160 MJ) of meat and 45,142,343 Calories (189,598 MJ) of vegetables. The largest total production months were July, September and October with the largest meat production months December, July and September and the largest vegetable production months July, August and September. The top vegetable contributors, representing better than 50% of total vegetable output, were sweet corn, potatoes, sweet potatoes, beans and broccoli with 40,847 MJ, 17,931 MJ, 17,197 MJ, 13,953 MJ and 10,774 MJ.

CHAPTER 4

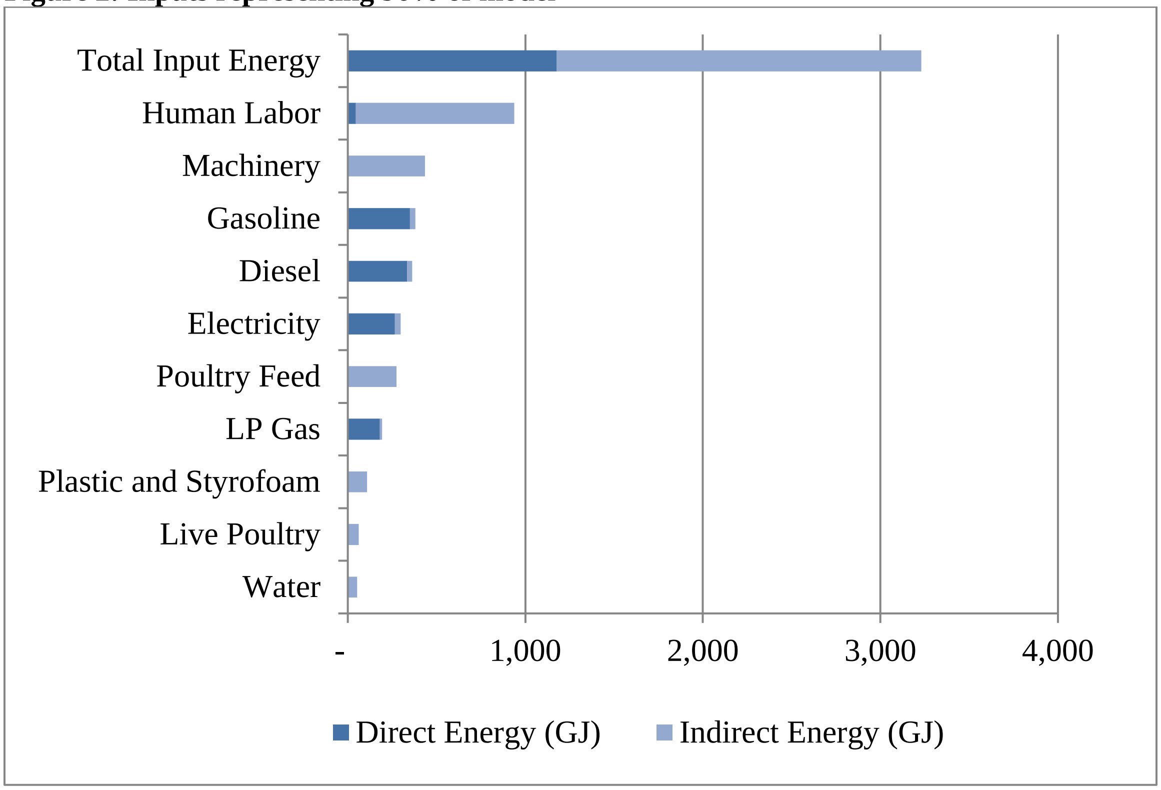
DISCUSSION

Approximately 96% of the model input energy consists of ten items: human labor, machinery, gasoline, diesel, electricity, poultry feed, LP gas, plastic and Styrofoam, live poultry birds, and water. See figure 2 for more details. Although labor provides the least amount of direct energy input, the indirect energy attributed to supply that direct energy was significant. Direct and indirect labor energy accounts for 29% of the total input energy representing 2.2 MJ of the total 7.7 MJ of input energy for every 1.0 MJ of output energy. It was approximately twice that of the next energy input, machinery, at 13.5%.

The ESF 891 GJ of indirect labor energy value is compelling evidence of the significant solar energy imbalance the human species imposes on the earth. This value is greater than twice the model output described in Chapter 3.3. This is a conservative estimate, as nothing was considered for the energy each worker used to live any particular lifestyle. Energy costs associated with providing and managing a household, providing an education, participating in leisure activities, maintaining healthcare, etc. would inflate this value significantly.

Societal energy studies began in the middle of the last century (White, 2007). Achieving good return on energy investments (low input: high output) allows for the development and progression of art, culture, leisure, and other non-intrinsic energy expenditures. The 19.4:1 ratio used for the indirect labor embodied energy in this model does not consider laborer use of surplus societal energy. To develop such a correlation would require extensive studies into the habits of the varying socioeconomic classes found in the agricultural industries. Particular to this model one should consider three classifications: owner laborers, outside permanent employees (those employed for an overwhelming majority of the annum), and temporary labors (specifically H2A). Most likely, those with the highest monetary compensation would use this compensation for energy intensive activities, surplus societal energy. Conversely, the lowest monetarily compensated laborers would use less surplus societal energy.

Figure 2: Inputs representing 96% of model



Equipment was the second highest input contribution. The abundant variety of equipment operated at ESF summed to an approximate 90 tonnes. Referring back to chapters 2.2.14 and 3.2.14, the calculations for equipment amortization was careful considered to ensure a more accurate impact on energy accounting. Even with this more reasonable approach, 435 GJ of indirect energy was attributed to the 2014 year. The equipment annual indirect energy contribution represents almost a one to one relationship with the overall output energy. Given the definitions we proposed in this text, this value will continue to decline as equipment ages. The average calculated age for ESF equipment was 23.4. Assuming no equipment was replaced for ten years, the energy impact would decrease. See table 19 for more details. In practicality, it may be unreasonable to assume that some equipment would not be replaced during the next ten years. As evidence, ESF possessed nine of a total of 62 pieces of equipment that were less than twelve years of age in 2014 (14.5%).

Table 18: Hypothetical declination of indirect energy as equipment aged

Year	MJ	Average Age	% change *
2014	36,243	23.4	Current Year
2015	34,757	24.4	4.1%
2016	33,388	25.4	3.9%
2017	32,123	26.4	3.8%
2018	30,950	27.4	3.7%
2019	29,860	28.4	3.5%
2020	28,844	29.4	3.4%
2021	27,894	30.4	3.3%
2022	27,006	31.4	3.2%
2023	26,172	32.4	3.1%
2024	25,388	33.4	3.0%

*Change calculated from the previous year in the table

The combined inputs of gasoline, diesel, electricity and LP gas accounted for 38.2% of the input energy representing 2.9 MJ of the total 7.7 MJ of input energy for every 1.0 MJ of output energy. This value is commonly high in agricultural EROI models. See figure 3 for more details. The liquid fuels (Gasoline and Diesel) direct energy for the 2014 season was 685 GJ. This calculates to approximately 1.8 GJ/acre. Comparing this to the U.S. agricultural energy use is somewhat complex; especially when considering vegetable operations. Data obtained from https://quickstats.nass.usda.gov/, a database website operated by the National Agricultural Statistics Service (NASS) of the USDA and data obtained from http://www.eia.gov/dnav/pet/PET_PRI_GND_DCUS_NUS_A.htm, a database website operated by the U.S. Energy Information Administration (EIA) of the USDOE, provides some insight. While the data from EIA is collect annually, the fuel energy data from the NASS is collect and provided for every five years; with 2012 being the closest production year to the ESF model. During the 2012 production year, 846 million acres (NASS) of agricultural land used $16,573 million (NASS) worth of fuel at an average U.S. price for a gallon of diesel fuel at $3.97 (EIA). Unfortunately, the percentages of diesel and gasoline utilized in farm operations were not apparent; Diesel will be used to provide some comparison. Approximately 5 gallons of diesel fuel was used per acre of agricultural land totaling 0.7 GJ of direct energy per acre.

It is obvious ESF uses significantly more fuel than the average U.S. consumption per agricultural acre. However, this may be an inappropriate comparison for ESF. Not all US agricultural production directly results in food products (i.e. timber and cotton). Significant US agricultural production also becomes input products for other food producing operations (i.e. grains for livestock). As evidence, approximately 0.20% of agricultural land is dedicated to the vegetable production (top 34 vegetables) compared to the remaining dedicated to non-vegetable production. Unfortunately, no petroleum use data in vegetable only, livestock only, or integrated operations was available to compare ESF liquid fuel use.

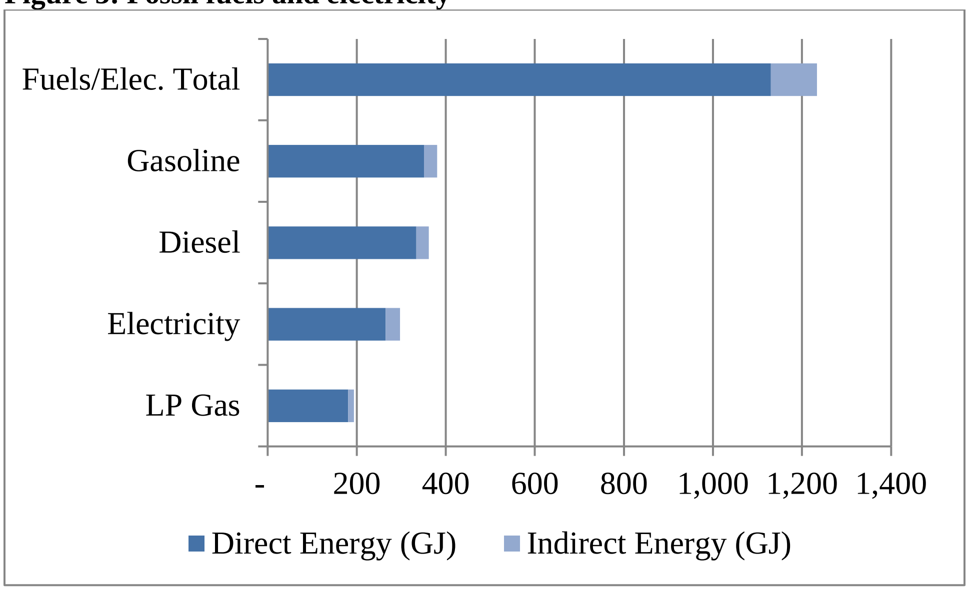
Some research suggests direct energy use (liquid fuels and electricity) on U.S. farms is steady (or even declining) around 1,100 Trillion BTUs or 1.16 EJ in 2011

(Beckman et al., 2013). Using the agricultural acreage data from NASS database, the total direct energy averages around 1.4 GJ per acre in production year 2012. Reviewing this against the NASS database through four production years, 1997, 2002, 2007, and 2012, reveals the costs of fuels has significantly risen but at a rate lower than the average costs of gasoline or diesel used in agricultural operations. Please see Table 18 for more details. This demonstrates agricultural fuel energy use may be in decline.

Table 19: Agricultural fuel use in the US

NASS data	1997	% chg	2002	% chg	2007	% chg	2012
Costs of Fuel ($1,000,000)	6,716	-0.6%	6,675	93.4%	12,912	28.4%	16,573
Costs of Gasoline per Gallon	$ 1.24	11.4%	$ 1.39	105.2%	$ 2.84	29.4%	$ 3.68
Costs of Diesel per Gallon	$ 1.20	10.1%	$ 1.32	118.7%	$ 2.89	37.5%	$ 3.97

Figure 3: Fossil fuels and electricity



Poultry feed represented 274 GJ of indirect energy. The remaining poultry inputs were live poultry, egg cartons, and pine shavings. These inputs contributed 61 GJ, 12 GJ, and 10 GJ respectively. The annual output for all poultry products, broilers, eggs, hens, and turkey totaled to 72 GJ of output energy. This calculates an EROI for the ESF 2014 poultry operation at 4.9:1.0 (input to output). The data suggests this farm is less energy efficient that reported by Pimentel and Pimentel, 2008 (4:1) and Pelletier et al., 2008 (3:1). However, energy intensity studies for organic feed were not available during this research. If many of the organic feed ingredients are provided via waste streams, embodied energy reductions may be appropriate. Likewise, if the ingredients are shipped from locales across the country may add significant embodied energy. More study of currently available organic feed options is needed to fully measure the energy intensity of organic poultry operations. Unfortunately, this industry is young and evolving with many different ingredient inputs; a comprehensive study would be complex.

Intensive poultry grazing could replace external feed, effectively lowering the energy intensity of poultry production. Careful consideration should be given to such an endeavor. Although poultry birds are omnivorous, limits on dietary amino acids, mainly methionine, make growing typical commercial poultry breeds on foraging operations difficult, if not impossible, without supplementation (Burley et al., 2016). The latest studies suggest a significant effort should be taken to breed instinctual foraging; birds naturally determine dietary needs found in foraging conditions. Foraging birds may also greatly benefit from insects as much as grass and grains (Jozefiak et al., 2016). Therefore, foraging operation may include plantings that attract beneficial insect species. However, insect attraction must avoid creating devastation to neighboring agricultural operations. Using the neighboring ecosystem (i.e. a natural ecological buffer) may be the only plausible consideration. This means foraging poultry operations would also need to be ecologically insulated from neighboring agriculture.

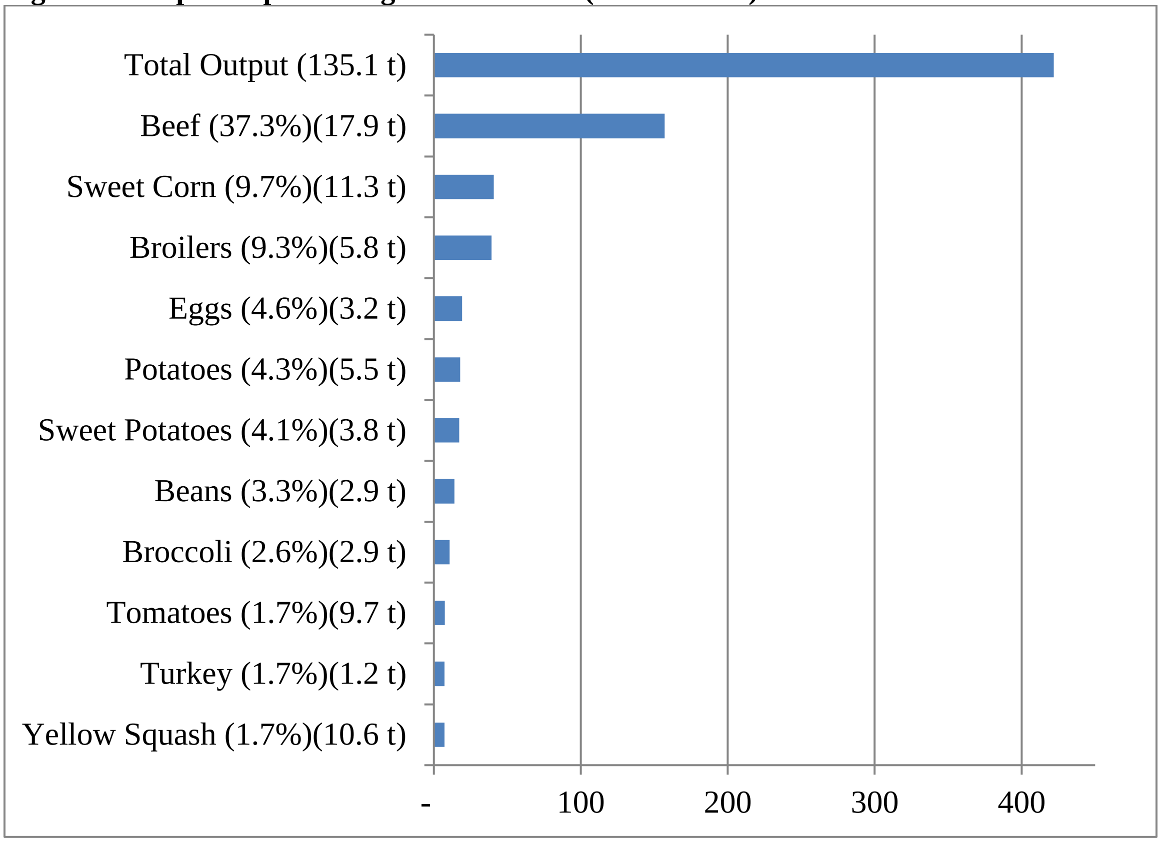
Plastic, Styrofoam, and water complete the remaining significant inputs. Plastic and Styrofoam products significantly reduce manual labor in cultivation activities (weeding) and starting vegetables from seed. Water used from municipal sources was used to irrigate seedling starts, wash vegetables, process some products (salsa and ketchup), and provide lunch meals to workers. These three combined indirect energies were 161 GJ representing 5.0% of the overall inputs.

Chemical fertilizers were not broadly used in the ESF production process. ESF relied on cycling soil nutrients through the integration of animal husbandry and maintained a neutral soil pH through the use of crushed limestone from a nearby quarry. The quantity of 1,032 kg of commercially available organic fertilizer was used for seedling starts. Energy associated with this fertilizer and crushed limestone was 19 GJ; representing approximately 0.6% of the total inputs. To provide some perspective, if ESF followed the typical US agricultural operation as found by Beckman et al., 2013, indirect inputs would make up 33% of the total energy inputs with fertilizer representing approximately half of the indirect energy inputs. Direct energies in the Beckman et al., 2013 research were fuels and electricity and indirect energies were fertilizer, pesticide chemicals, and "other" indirect inputs. The analogous direct energy values in the ESF model were gasoline, diesel, electricity, and LP gas, which calculated to 1,130 GJ. If this was an average US farm, the indirect energy values would be approximately one-third or 550 GJ and fertilizer would have a hypothetical energy value closer to 280 GJ. From a fertilizer perspective, the ESF operation is approximately fifteen times more energy efficient than the average US operation.

The ESF operation also sparingly used organic pesticides; representing 11 GJ of indirect energy input or 0.3% of the total inputs. Following a similar comparison for fertilizers, Beckman et al., 2013 found an approximate indirect energy ratio of 5:1 fertilizer to pesticides. If the hypothetical fertilizer indirect energy value was 280 GJ, the hypothetical pesticides indirect energy value would be closer to 56 GJ. From a pesticides perspective, ESF operation is approximately five times more energy efficient than the average US operation.

Approximately 80% of the ESF output energy was comprised of eleven products, four meat and seven vegetables. See figure 4 for more details. The farm produced 74 other agricultural products that comprised the remaining 20%. Beef was the top product with a calculated energy output value of 157 GJ, representing 37.3% of energy produced. This energy was four times the next highest product, sweet corn, with the calculated energy output value of 41 GJ, representing 9.7% of energy produced. The typical US beef supply system is comprised of two general operations. Cow-calf operations provide calves to finishing operations (feedlots). Feedlots provide finished beef for slaughter. The process is energy intense at the feedlot operation and the transportation associated with moving live animals. The ESF cattle are grass fed (input is seed for forage varieties and fuels for seeding forage), receive some trace mineral inputs, and a few commodities (corn and roasted soybeans), avoiding most of the typical energy intensive inputs. According to Pimentel and Pimentel, 2008, conventional cow-calf and feedlot beef systems have an average energy ratio of 40:1 (input to output) and grass-fed beef systems have an average energy ratio of 20:1. Another study by Pelletier et al., 2010 found the same respective operations to be 8.7:1 and 11.1:1 (input to output). Considering these previous studies, the integrated animal-vegetable ESF production scheme appears less energy intense than conventional meat production systems.

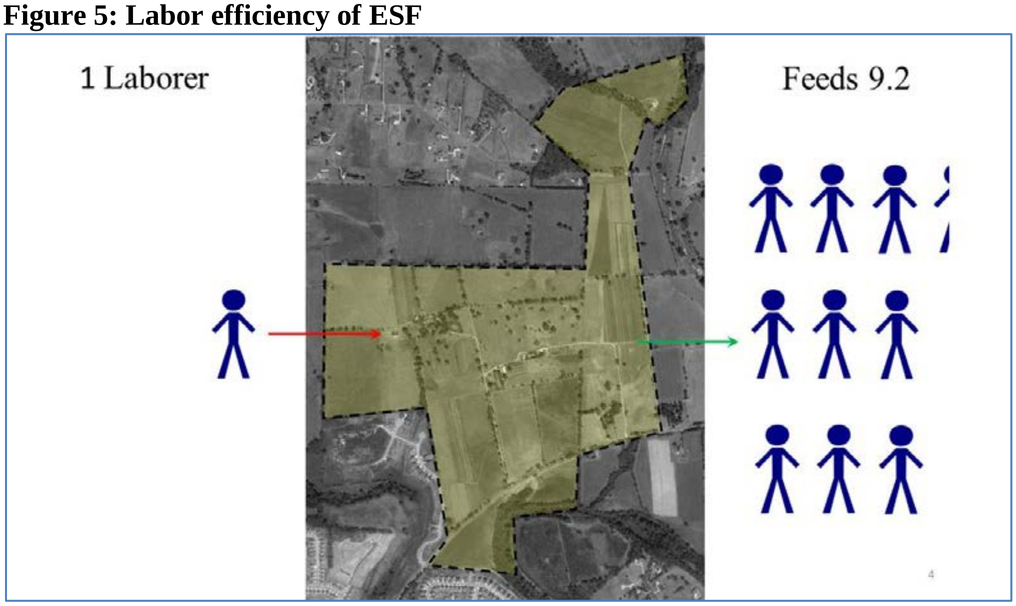
Figure 4: Outputs representing 80% of model (values in GJ)



The primary purpose of all non-labor inputs in the modern agricultural system is to reduce direct human labor input. According to a graphical website operated by the US Census Bureau (http://www.census.gov/popclock/?intcmp=home_pop) approximately +320 million US people are fed by approximately 3.2 million (2012 value) agricultural operators (https://quickstats.nass.usda.gov/). This is approximately 1% of the US population involved directly in agriculture. Considering much of agriculture production supplies other economic sectors (e.g. textiles and paper) and significant exports of US food are bound to international destinations, this percentage is most likely less. Note: this calculation does not consider people dedicated to processing, packaging or distributing food. Reductions in non-labor inputs could result in significant shifts from our modern industrialized society to that of an agrarian.

The ESF model is an illustration of the above suggested phenomenon. Although the ESF operation appears less energy intense than the typical US agricultural system, more labor energy was required. The total 2014 production of ESF was calculated to 422 GJ of total energy. Considering the average daily Caloric input is 2,500, this farm is providing enough food to feed approximately 110 individuals for one year. Human direct energy input was calculated to 46 GJ, representing approximately 12.0 human years of energy (assuming 2,500 Calories of energy average consumption). This calculates to a 9.2:1.0 food output Calories to human effort Calories. If the ESF production scheme was adopted throughout the US, approximately 10.9% of the population would be required to produce food. This is significantly less efficient from the human labor aspect than the current US agricultural system. If fossil fuels were depleted, it is obvious significant portions of the US population would be required to return to an agrarian lifestyle. See figure 5 for an illustration of ESF labor efficiency.

Figure 5: Labor efficiency of ESF



The EROI project conducted by Schramski et al., 2013 (UK CSA) was the nexus for the ESF project. Materials and methods for determining energy coefficients were similar. The over-all reported EROI for this farm during the 2011 growing season was 40:1 (input:output). However, the following should be amended to properly compare this study to the ESF model.

The UK CSA electricity was calculated at 381 GJ comprising of 116 GJ direct and 265 GJ of indirect energy. The method of calculating the indirect energy of electricity was significantly different than the ESF model. Using the Weißbach et al., 2013 study and the results from equation 1 of 0.12 MJ of embodied energy per 1.0 MJ of produced energy, the indirect energy would be 14 GJ and the total electrical energy contribution would be 130 GJ. The comprehensive Weißbach et al., 2013 study relied on in ESF model was not available during the compiling of the Schramski et al., 2013 work.

The University of Kentucky operated multiple research and teaching operations along with the UK CSA farm. Liquid fuels were acquired from a common source for all operations, not just the UK CSA. To overcome this data collection challenge, the tractor hours were kept while use on the UK CSA operation. The Nebraska Tractor Test was used to determine the direct energy. The latest EROI study of fuels from Hall et al., 2014 was not available during this project and an older indirect energy value from Fluck, 1992 was used. The fuel overall energy value reported in this study was 184 GJ of total energy comprising of 85 GJ of direct and 99 GJ of indirect. Correcting for the Hall et al., 2014 study the fuels are closer 8 GJ of indirect energy and 93 GJ of total energy.

After corrections are made for electricity and fuels, the EROI of the Schramski et al., 2013 study would be closer to 33:1 (input:output). Compared to the ESF model, 4.3

times more energy was used on the vegetable only UK CSA farm compared to the integrated ESF. Further inspection illuminate significant operational differences. The UK CSA used natural gas in a greenhouse operation to start plants. Nature gas was the highest input at 554 GJ of energy comprising of 509 GJ of direct and 45 GJ of indirect energy. Additionally, significant indirect energy was accounted for in compost brought onto the UK CSA farm at 472 GJ. The authors admittedly noted that compost energy intensity was “still a widely uncertain value”. The ESF model created compost directly on the farm with fuels and other inputs recorded within the model. Unfortunately, the amount of compost produced was not recorded nor were the specific inputs segregated from the remaining operation. However, the significant gains in energy efficiency of the ESF operation may suggest compost embodied energy may be lower than the value used by Schramski et al., 2013. Regardless of precision, the ESF operation did not used external compost, thus no energy input.

The output of the UK CSA was significantly lower than ESF. This is due mostly to size of the growing area (6.3 acres compared to 375 acres). The ESF rotations allowed for fallow fields and significant land was devoted to animal husbandry. The overall food/land output efficiency of the UK CSA was almost 8 GJ/acre for the 2011 growing season and the ESF was 1.1 GJ/acre for the 2014 growing season. Therefore, the smaller area of the UK CSA may require more inputs to achieve 8 GJ/acre efficiency. This is another common discovery in agriculture energy studies; more energy inputs are required to produce more food per land area (Atlason et al., 2015), (Pagani et al., 2016).

For final consideration, the soil amendments of the ESF vegetable production were compared to the UK CSA vegetable production (no ESF animal production considered). The UK CSA reported 472 GJ of compost and 165 GJ of fertilizers accounting for a total of 637 GJ. The ESF reported 0.8 GJ of agricultural lime and 18 GJ of organic fertilizer for a total of 19 GJ associated with soil amendments. Given the UK CSA produced 50 GJ of vegetables and the ESF produced 190 GJ of vegetables, the comparison is quite clear.

The operators of ESF established practices to sustain proper stewardship of their entrusted land. Multiple generations of the same family imparted a sense of pride in growing quality food in a manner that complements the land and their community. The business model incorporates philosophies to balance and complement the sustainable elements of economy, environment, and society as described by Vos, 2007. The operators understand the significant impacts these practices have on sustaining proper soil ecology. Referring to the producer, consumer, and reducer discussion in the introduction, grazing livestock constantly feed the soil ecology energy and matter from manure to breakdown elemental soil nutrient components. These components are used to grow vegetables avoiding the need of chemical fertilizers or other soil amendments. This soil ecology energy remained within the boundaries of the model, thus no value was established. However, the ESF operators understand this energy provides significant contributions to sustainability.

CHAPTER 5

CONCLUSION AND FUTURE CONSIDERATIONS

The conclusion of this study is integrated animal and plant operations reduce the energy intensity of growing food. Soil nutrients were recycled from the manure of grazing animals, eliminating the need for energy intensive chemical fertilizers and other soil amendments. The ESF EROI also benefited from good stewardship of equipment and greatly reduced reliance on chemical pesticides/herbicides. However, the human energy required to run similar operations throughout the US would be 10.9% of the population which is approximately eleven times more than the current US agricultural system.

Future agricultural EROI studies should focus on three energy intensity topics: organic fertilizer, organic pest controls, and organic feed production. This model uses one of the few organic fertilizer studies to develop a rudimentary understanding of the energy impact. However, organic products, i.e. fertilizers, are on not largely commoditized as chemical fertilizers. Ingredients are greatly different from product to product; some are waste streams and others are new materials manufactured/produced specifically for this industry. Future studies should focus on the differences of both and develop guidelines for establishing embodied energy values.

Organic pesticides/herbicides are similarly difficult. However, most organic pesticides/herbicides ingredients are not from waste streams. A recommended approach would begin with the determination of the highest production of each pesticide/herbicide classification. For instance, Dipel Dust is a marketed biological control for caterpillars.

The active ingredient is *B. thuringiensis* (bacteria). There are plenty of other biological control products with other bacteria and could draw strong correlation to a study of Dipel Dust.

Organic feed is found in most organic poultry, swine, and turkey operations. Products vary greatly in ingredients from species to species as well as manufacturer to manufacturer. However, most remain grain based. Ingredients are typically Genetically Modified Organism (GMO) grain/plant free. Most GMOs are produced so cultivation (weeding) activities can be lowered or eliminated. Cultivation is energy intense from a fuels, human labor, and equipment use. Developing a study comparing cultivation to herbicidal use (glyphosate) would advise researchers to the energy costs or benefits of organic feeds produced from non GMO grains.

Significant unknowns remain regarding societal energy impacts on agricultural operations. The definition of indirect labor used in this work does not consider societal energy: leisure, medical care, education, and others. Categorizing the lifestyles of various socioeconomic brackets to determine use of other societal energy could be used to better model indirect labor energy values. Unfortunately, there is little direction this work can propose in undertaking such a study.

Future studies should consider the reduced energy impacts of equipment amortized beyond traditional years. Equipment maintained in working condition well past ten and twelve years will reduce the energy footprint of agriculture. Most studies do not consider this effect and blindly amortize all equipment ten or twelve years. This is not only unreasonable from an accounting perspective, but does not properly reward agricultural operators practicing good equipment stewardship. As the agricultural community becomes aware of agricultural energy intensities, competition for energy resources will dictate new energy strategies. Amortizing equipment energy based on true age after ten or twelve years of service could foster better agricultural equipment stewardship.

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Model Input: ESF 2014 Growing Season

1,176,011	Annual Direct MJ
2,054,634	Annual Indirect MJ
3,230,646	Total Annual Input MJ

01 January

108,667	Monthly Direct MJ
69,919	Monthly Indirect MJ
178,586	Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	523	Electricity	kWh	3.6	0.4406	0.0
0	571	Water	gallons	0	0.0348	0.0
2.9	19	Labor 1	hours	0.7308	0	2.1
6.4	328	Shavings	ft^3	0	9.9	63.4
10	300	LP Gas	gallons	93.9	6.94	1,008.4
22	28	Labor 2	hours	1.4115	0	31.1
23.25	16	Labor 2	hours	1.4115	0	32.8
27	10	Labor 2	hours	1.4115	0	38.1
31.2	22	Labor 2	hours	1.4115	0	44.0
33	4	Labor 3	hours	1.7459	0	57.6
41.8	25	Labor 2	hours	1.4115	0	59.0
49	172	Gasoline	gallons	129	10.9	6,855.1
69	184	Gasoline	gallons	129	10.9	9,653.1
79	173	Gasoline	gallons	129	10.9	11,052.1
97.22	647	Machinery	kg	0	92	8,944.2
119	174	Gasoline	gallons	129	10.9	16,648.1
150	7	Labor 1	hours	0.7308	0	109.6
187	13	Labor 2	hours	1.4115	0	264.0
200	1	Labor 2	hours	1.4115	0	282.3
266	547	Electricity	kWh	3.6	0.4406	1,074.8
296.74	602	Machinery	kg	0	92	27,300.1
330	299	LP Gas	gallons	93.9	6.94	33,277.2

921	160	Human Labor (Indirect)	MJ (Ind irect)/M	0	19.4	17,867.4
1000	337	Egg Cartons	each	0	2.49	2,490.0
4335	535	Electricity	kWh	3.6	0.4406	17,516.0
5137	511	Electricity	kWh	3.6	0.4406	20,756.6
5472	583	Water	gallons	0	0.0348	190.4
28000	203	Gravel	lb	0	0.005625	157.5
80784	559	Water	gallons	0	0.0348	2,811.3

02 February

35,243 Monthly Direct MJ

74,098 Monthly Indirect MJ

109,340 Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	572	Water	gallons	0	0.0348	0.0
0	524	Electricity	kWh	3.6	0.4406	0.0
2	271	Poultry Feed	50 lb ba	0	158.4	316.8
2.9	20	Labor 1	hours	0.7308	0	2.1
5	272	Poultry Feed	50 lb ba	0	158.4	792.0
7	548	Electricity	kWh	3.6	0.4406	28.3
8	617	Plastic	lb	0	40.8	326.4
15	196	Diesel	gallons	146	12.3	2,374.5
22	29	Labor 2	hours	1.4115	0	31.1
23	17	Labor 2	hours	1.4115	0	32.5
27	11	Labor 2	hours	1.4115	0	38.1
31.2	23	Labor 2	hours	1.4115	0	44.0
33	5	Labor 3	hours	1.7459	0	57.6
38	273	Poultry Feed	50 lb ba	0	158.4	6,019.2
41.8	26	Labor 2	hours	1.4115	0	59.0
60	316	Fertilizer	lb	0	8.26	495.6
68	185	Gasoline	gallons	129	10.9	9,513.2
97.22	648	Machinery	kg	0	92	8,944.2
150	8	Labor 1	hours	0.7308	0	109.6
187	14	Labor 2	hours	1.4115	0	264.0
200	2	Labor 2	hours	1.4115	0	282.3

296.74	603	Machinery	kg	0	92	27,300.1
920	161	Human Labor (Indirect)	MJ (Ind irect)/M	0	19.4	17,848.0
2000	324	Trace Mineral	lb	0	3.168	6,336.0
2149	512	Electricity	kWh	3.6	0.4406	8,683.2
4333	536	Electricity	kWh	3.6	0.4406	17,507.9
14448	584	Water	gallons	0	0.0348	502.8
41140	560	Water	gallons	0	0.0348	1,431.7

85,045 Monthly Direct MJ

105,238 Monthly Indirect MJ

190,283 Total Monthly MJ

03 March

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
	513	Electricity	kWh	3.6	0.4406	
0	525	Electricity	kWh	3.6	0.4406	0.0
0	573	Water	gallons	0	0.0348	0.0
2	340	Labor 2	hours	1.4115	0	2.8
2.95	21	Labor 1	hours	0.7308	0	2.2
4	274	Poultry Feed	50 lb ba gs	0	158.4	633.6
10	197	Diesel	gallons	146	12.3	1,583.0
22	30	Labor 2	hours	1.4115	0	31.1
23	18	Labor 2	hours	1.4115	0	32.5
26	12	Labor 2	hours	1.4115	0	36.7
31.1	24	Labor 2	hours	1.4115	0	43.9
34	6	Labor 3	hours	1.7459	0	59.4
41	275	Poultry Feed	50 lb ba gs	0	158.4	6,494.4
41.9	27	Labor 2	hours	1.4115	0	59.1
64	329	Shavings	ft^3	0	9.9	633.6
67	186	Gasoline	gallons	129	10.9	9,373.3
97.22	649	Machinery	kg	0	92	8,944.2
150	9	Labor 1	hours	0.7308	0	109.6
187	15	Labor 2	hours	1.4115	0	264.0
200	3	Labor 2	hours	1.4115	0	282.3
296.74	604	Machinery	kg	0	92	27,300.1

305	301	LP Gas	gallons	93.9	6.94	30,756.2
328	302	LP Gas	gallons	93.9	6.94	33,075.5
381	549	Electricity	kWh	3.6	0.4406	1,539.5
425	596	Chicks (broilers)	each	0	0.89	378.3
759	618	Styrofoam	lb	0	40.8	30,967.2
923	162	Human Labor (Indirect)	MJ (Ind	0	19.4	17,906.2
2000	321	Roasted Soybeans	lb	0	1	2,000.0
3669	537	Electricity	kWh	3.6	0.4406	14,825.0
15944	585	Water	gallons	0	0.0348	554.9
68816	561	Water	gallons	0	0.0348	2,394.8

04 April

118,935 Monthly Direct MJ

235,766 Monthly Indirect MJ

354,701 Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	574	Water	gallons	0	0.0348	0.0
0	526	Electricity	kWh	3.6	0.4406	0.0
8	277	Poultry Feed	50 lb ba	0	158.4	1,267.2
11	64	Labor 2	hours	1.4115	0	15.5
15	279	Poultry Feed	50 lb ba	0	158.4	2,376.0
15	317	Fertilizer	lb	0	8.26	123.9
15.9	52	Labor 2	hours	1.4115	0	22.4
24	276	Poultry Feed	50 lb ba	0	158.4	3,801.6
27	37	Labor 2	hours	1.4115	0	38.1
29	278	Poultry Feed	50 lb ba	0	158.4	4,593.6
31.25	58	Labor 2	hours	1.4115	0	44.1
34.1	70	Labor 2	hours	1.4115	0	48.1
40.3	55	Labor 2	hours	1.4115	0	56.9
65	187	Gasoline	gallons	129	10.9	9,093.5
81	46	Labor 2	hours	1.4115	0	114.3
88.5	313	Vegetable Seed	lb	0	16.7	1,478.0
97.22	650	Machinery	kg	0	92	8,944.2
98.4	43	Labor 2	hours	1.4115	0	138.9

118.4	330	Shavings	ft^3	0	9.9	1,172.2
118.7	61	Labor 1.25	hours	0.901	0	106.9
120	307	Grain Seed	lb	0	16.7	2,004.0
141.3	49	Labor 2	hours	1.4115	0	199.4
150	342	Trace Mineral	lb	0	3.168	475.2
155	310	Grass Seed	lb	0	16.7	2,588.5
161	621	Plastic	lb	0	40.8	6,568.8
179	175	Gasoline	gallons	129	10.9	25,042.1
229.2	40	Labor 2.5	hours	1.5787	0	361.8
241	31	Labor 2	hours	1.4115	0	340.2
260	311	Grass Seed	lb	0	16.7	4,342.0
269	622	Plastic	lb	0	40.8	10,975.2
296.74	605	Machinery	kg	0	92	27,300.1
300	304	LP Gas	gallons	93.9	6.94	30,252.0
300	34	Labor 1.25	hours	0.901	0	270.3
362	620	Plastic	lb	0	40.8	14,769.6
375	303	LP Gas	gallons	93.9	6.94	37,815.0
425	597	Chicks (broilers)	each	0	0.89	378.3
459	550	Electricity	kWh	3.6	0.4406	1,854.6
600	306	Grain Seed	lb	0	16.7	10,020.0
1120	619	Plastic	lb	0	40.8	45,696.0
1187.25	67	Labor 3	hours	1.7459	0	2,072.8
2341	514	Electricity	kWh	3.6	0.4406	9,459.0
2824	538	Electricity	kWh	3.6	0.4406	11,410.7
3830	163	Human Labor (Indirect)	MJ (Ind	0	19.4	74,302.0
19684	586	Water	gallons	0	0.0348	685.0
59840	562	Water	gallons	0	0.0348	2,082.4

74,140 Monthly Direct MJ

235,793 Monthly Indirect MJ

309,933 Total Monthly MJ

05 May

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
1	280	Poultry Feed	50 lb ba	0	158.4	158.4

1.94	631	Pesticides	lb	0	56.2	109.0
11	65	Labor 2	hours	1.4115	0	15.5
15	630	Pesticides	lb	0	56.2	843.0
15.9	53	Labor 2	hours	1.4115	0	22.4
27	38	Labor 2	hours	1.4115	0	38.1
31.25	59	Labor 2	hours	1.4115	0	44.1
34.1	71	Labor 2	hours	1.4115	0	48.1
40.4	56	Labor 2	hours	1.4115	0	57.0
43	281	Poultry Feed	50 lb ba	0	158.4	6,811.2
53	198	Diesel	gallons	146	12.3	8,389.9
80.9	47	Labor 2	hours	1.4115	0	114.2
94	188	Gasoline	gallons	129	10.9	13,150.6
97.22	651	Machinery	kg	0	92	8,944.2
98.5	44	Labor 2	hours	1.4115	0	139.0
100	595	Poults (young turkeys)	each	0	0.89	89.0
118.7	62	Labor 1.25	hours	0.901	0	106.9
128	282	Poultry Feed	50 lb ba	0	158.4	20,275.2
134	283	Poultry Feed	50 lb ba	0	158.4	21,225.6
141.3	50	Labor 2	hours	1.4115	0	199.4
185.6	331	Shavings	ft^3	0	9.9	1,837.4
208	176	Gasoline	gallons	129	10.9	29,099.2
229.2	41	Labor 2.5	hours	1.5787	0	361.8
242	32	Labor 2	hours	1.4115	0	341.6
296.74	606	Machinery	kg	0	92	27,300.1
300	35	Labor 1.25	hours	0.901	0	270.3
510	601	Pullets (Young Hens)	each	0	115	58,650.0
746	527	Electricity	kWh	3.6	0.4406	3,014.3
824	515	Electricity	kWh	3.6	0.4406	3,329.5
850	598	Chicks (broilers)	each	0	0.89	756.5
954	551	Electricity	kWh	3.6	0.4406	3,854.7
1187.25	68	Labor 3	hours	1.7459	0	2,072.8
2000	322	Roasted Soybeans	lb	0	1	2,000.0
3832	164	Human Labor (Indirect)	MJ (Ind	0	19.4	74,340.8
4035	539	Electricity	kWh	3.6	0.4406	16,303.8

7716	587	Water	gallons	0	0.0348	268.5
14000	320	Ag Lime	lb	0	0.005625	78.8
53490	575	Water	gallons	0	0.0348	1,861.5
97988	563	Water	gallons	0	0.0348	3,410.0

06 June

206,664 Monthly Direct MJ

192,082 Monthly Indirect MJ

398,746 Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0.5	633	Pesticides	lb	0	56.2	28.1
1	634	Pesticides	lb	0	56.2	56.2
3.88	632	Pesticides	lb	0	56.2	218.1
6.3825	635	Pesticides	lb	0	56.2	358.7
11	66	Labor 2	hours	1.4115	0	15.5
15.9	54	Labor 2	hours	1.4115	0	22.4
27	39	Labor 2	hours	1.4115	0	38.1
31.25	60	Labor 2	hours	1.4115	0	44.1
34.1	72	Labor 2	hours	1.4115	0	48.1
40.3	57	Labor 2	hours	1.4115	0	56.9
80.9	48	Labor 2	hours	1.4115	0	114.2
90	285	Poultry Feed	50 lb ba	0	158.4	14,256.0
97.22	652	Machinery	kg	0	92	8,944.2
98.5	45	Labor 2	hours	1.4115	0	139.0
99	189	Gasoline	gallons	129	10.9	13,850.1
118.6	63	Labor 1.25	hours	0.901	0	106.9
135	284	Poultry Feed	50 lb ba	0	158.4	21,384.0
141.3	51	Labor 2	hours	1.4115	0	199.4
202	177	Gasoline	gallons	129	10.9	28,259.8
208	332	Shavings	ft^3	0	9.9	2,059.2
229.1	42	Labor 2.5	hours	1.5787	0	361.7
242	33	Labor 2	hours	1.4115	0	341.6
291	552	Electricity	kWh	3.6	0.4406	1,175.8
296.74	607	Machinery	kg	0	92	27,300.1

300	36	Labor 1.25	hours	0.901	0	270.3
744	516	Electricity	kWh	3.6	0.4406	3,006.2
946	199	Diesel	gallons	146	12.3	149,751.8
1187.25	69	Labor 3	hours	1.7459	0	2,072.8
1196	528	Electricity	kWh	3.6	0.4406	4,832.6
2000	318	Fertilizer	lb	0	8.26	16,520.0
3831	165	Human Labor (Indirect)	MJ (Ind	0	19.4	74,321.4
4960	540	Electricity	kWh	3.6	0.4406	20,041.4
11456	588	Water	gallons	0	0.0348	398.7
98873	576	Water	gallons	0	0.0348	3,440.8
135388	564	Water	gallons	0	0.0348	4,711.5

215,335 Monthly Direct MJ

266,284 Monthly Indirect MJ

481,619 Total Monthly MJ

07 July

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0.5625	637	Pesticides	lb	0	56.2	31.6
1.94	636	Pesticides	lb	0	56.2	109.0
1.975	639	Pesticides	lb	0	56.2	111.0
6.3825	638	Pesticides	lb	0	56.2	358.7
6.42	109	Labor 1.25	hours	0.901	0	5.8
27	79	Labor 2	hours	1.4115	0	38.1
28.75	115	Labor 2	hours	1.4115	0	40.6
34.8	103	Labor 2	hours	1.4115	0	49.1
39.58	118	Labor 2	hours	1.4115	0	55.9
63.08	100	Labor 1.25	hours	0.901	0	56.8
68.8	112	Labor 2	hours	1.4115	0	97.1
79.59	85	Labor 2	hours	1.4115	0	112.3
92.7	94	Labor 2	hours	1.4115	0	130.8
94	88	Labor 2	hours	1.4115	0	132.7
97.22	653	Machinery	kg	0	92	8,944.2
100	553	Electricity	kWh	3.6	0.4406	404.1
109	190	Gasoline	gallons	129	10.9	15,249.1

115	287	Poultry Feed	50 lb ba	0	158.4	18,216.0
155	286	Poultry Feed	50 lb ba	0	158.4	24,552.0
157.5	91	Labor 2	hours	1.4115	0	222.3
200	319	Fertilizer	lb	0	8.26	1,652.0
201.6	333	Shavings	ft^3	0	9.9	1,995.8
227.92	97	Labor 2	hours	1.4115	0	321.7
236	178	Gasoline	gallons	129	10.9	33,016.4
241	73	Labor 2	hours	1.4115	0	340.2
281.5	82	Labor 2.5	hours	1.5787	0	444.4
296.74	608	Machinery	kg	0	92	27,300.1
300	76	Labor 1.25	hours	0.901	0	270.3
425	599	Chicks (broilers)	each	0	0.89	378.3
607	517	Electricity	kWh	3.6	0.4406	2,452.6
946	200	Diesel	gallons	146	12.3	149,751.8
1417	529	Electricity	kWh	3.6	0.4406	5,725.5
2000	325	Trace Mineral	lb	0	3.168	6,336.0
2665	338	Egg Cartons	each	0	2.49	6,635.9
2823.25	106	Labor 3	hours	1.7459	0	4,929.1
4950	541	Electricity	kWh	3.6	0.4406	20,001.0
7247	166	Human Labor (Indirect)	MJ (Ind	0	19.4	140,591.8
7716	589	Water	gallons	0	0.0348	268.5
126412	565	Water	gallons	0	0.0348	4,399.1
169277	577	Water	gallons	0	0.0348	5,890.8

08 August

51,911 Monthly Direct MJ

246,550 Monthly Indirect MJ

298,461 Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0.3125	640	Pesticides	lb	0	56.2	17.6
1.48125	643	Pesticides	lb	0	56.2	83.2
4.5	641	Pesticides	lb	0	56.2	252.9
6.42	110	Labor 1.25	hours	0.901	0	5.8
27	80	Labor 2	hours	1.4115	0	38.1

28.75	116	Labor 2	hours	1.4115	0	40.6
34.8	104	Labor 2	hours	1.4115	0	49.1
39.58	119	Labor 2	hours	1.4115	0	55.9
63.08	101	Labor 1.25	hours	0.901	0	56.8
66	191	Gasoline	gallons	129	10.9	9,233.4
68.8	113	Labor 2	hours	1.4115	0	97.1
79.58	86	Labor 2	hours	1.4115	0	112.3
92.7	95	Labor 2	hours	1.4115	0	130.8
94	89	Labor 2	hours	1.4115	0	132.7
97.22	654	Machinery	kg	0	92	8,944.2
107	179	Gasoline	gallons	129	10.9	14,969.3
112	334	Shavings	ft^3	0	9.9	1,108.8
124	289	Poultry Feed	50 lb ba	0	158.4	19,641.6
141.8718	642	Pesticides	lb	0	56.2	7,973.2
154	554	Electricity	kWh	3.6	0.4406	622.3
157.5	92	Labor 2	hours	1.4115	0	222.3
191	288	Poultry Feed	50 lb ba	0	158.4	30,254.4
227.92	98	Labor 2	hours	1.4115	0	321.7
242	74	Labor 2	hours	1.4115	0	341.6
281.5	83	Labor 2.5	hours	1.5787	0	444.4
296.74	609	Machinery	kg	0	92	27,300.1
300	77	Labor 1.25	hours	0.901	0	270.3
425	600	Chicks (broilers)	each	0	0.89	378.3
509	530	Electricity	kWh	3.6	0.4406	2,056.7
805	518	Electricity	kWh	3.6	0.4406	3,252.7
2823.25	107	Labor 3	hours	1.7459	0	4,929.1
4739	542	Electricity	kWh	3.6	0.4406	19,148.4
7249	167	Human Labor (Indirect)	MJ (Ind	0	19.4	140,630.6
7716	590	Water	gallons	0	0.0348	268.5
68816	566	Water	gallons	0	0.0348	2,394.8
77044	578	Water	gallons	0	0.0348	2,681.1

88,362	Monthly Direct MJ
231,079	Monthly Indirect MJ
319,441	Total Monthly MJ

09 September

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	341	Labor 4	hours	2.069	0	0.0
0	615	Machinery	kg	0	92	0.0
0	555	Electricity	kWh	3.6	0.4406	0.0
0.08125	644	Pesticides	lb	0	56.2	4.6
2.1275	645	Pesticides	lb	0	56.2	119.6
6.41	111	Labor 1.25	hours	0.901	0	5.8
27	81	Labor 2	hours	1.4115	0	38.1
28.75	117	Labor 2	hours	1.4115	0	40.6
34.9	105	Labor 2	hours	1.4115	0	49.3
39.59	120	Labor 2	hours	1.4115	0	55.9
52.6	192	Gasoline	gallons	129	10.9	7,358.7
63.09	102	Labor 1.25	hours	0.901	0	56.8
68.7	114	Labor 2	hours	1.4115	0	97.0
71	291	Poultry Feed	50 lb ba	0	158.4	11,246.4
79.58	87	Labor 2	hours	1.4115	0	112.3
92.6	96	Labor 2	hours	1.4115	0	130.7
93	90	Labor 2	hours	1.4115	0	131.3
96	335	Shavings	ft^3	0	9.9	950.4
97.22	655	Machinery	kg	0	92	8,944.2
157.5	93	Labor 2	hours	1.4115	0	222.3
180	290	Poultry Feed	50 lb ba	0	158.4	28,512.0
227	180	Gasoline	gallons	129	10.9	31,757.3
227.91	99	Labor 2	hours	1.4115	0	321.7
242	75	Labor 2	hours	1.4115	0	341.6
276	305	LP Gas	gallons	93.9	6.94	27,831.8
281.5	84	Labor 2.5	hours	1.5787	0	444.4
296.74	610	Machinery	kg	0	92	27,300.1
300	78	Labor 1.25	hours	0.901	0	270.3

362	531	Electricity	kWh	3.6	0.4406	1,462.7
586	519	Electricity	kWh	3.6	0.4406	2,367.8
1000	339	Egg Cartons	each	0	2.49	2,490.0
2823.25	108	Labor 3	hours	1.7459	0	4,929.1
4366	543	Electricity	kWh	3.6	0.4406	17,641.3
7247	168	Human Labor (Indirect)	MJ (Ind	0	19.4	140,591.8
11456	591	Water	gallons	0	0.0348	398.7
13900	579	Water	gallons	0	0.0348	483.7
78540	567	Water	gallons	0	0.0348	2,733.2

10 October

63,884 Monthly Direct MJ

175,460 Monthly Indirect MJ

239,344 Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	556	Electricity	kWh	3.6	0.4406	0.0
0	532	Electricity	kWh	3.6	0.4406	0.0
0.25	646	Pesticides	lb	0	56.2	14.1
3.7	151	Labor 1.25	hours	0.901	0	3.3
20.58	133	Labor 2	hours	1.4115	0	29.0
22.5	142	Labor 2	hours	1.4115	0	31.8
26.7	127	Labor 2	hours	1.4115	0	37.7
32	336	Shavings	ft^3	0	9.9	316.8
41.17	136	Labor 2	hours	1.4115	0	58.1
52.8	139	Labor 2	hours	1.4115	0	74.5
56.5	193	Gasoline	gallons	129	10.9	7,904.4
59.9	157	Labor 2	hours	1.4115	0	84.5
85	293	Poultry Feed	50 lb ba	0	158.4	13,464.0
95	292	Poultry Feed	50 lb ba	0	158.4	15,048.0
97.22	656	Machinery	kg	0	92	8,944.2
99.5	145	Labor 2	hours	1.4115	0	140.4
133.7	130	Labor 2	hours	1.4115	0	188.7
162.42	154	Labor 1.50	hours	1.0711	0	174.0
170	312	Grass Seed	lb	0	16.7	2,839.0

200	121	Labor 2	hours	1.4115	0	282.3
234	124	Labor 1.25	hours	0.901	0	210.8
281	181	Gasoline	gallons	129	10.9	39,311.9
296.74	611	Machinery	kg	0	92	27,300.1
400	309	Grain Seed	lb	0	16.7	6,680.0
550	520	Electricity	kWh	3.6	0.4406	2,222.3
1145.5	148	Labor 3	hours	1.7459	0	1,999.9
1600	308	Grain Seed	lb	0	16.7	26,720.0
3315	169	Human Labor (Indirect)	MJ (Ind	0	19.4	64,311.0
4181	544	Electricity	kWh	3.6	0.4406	16,893.7
9212	592	Water	gallons	0	0.0348	320.6
10200	580	Water	gallons	0	0.0348	355.0
97240	568	Water	gallons	0	0.0348	3,384.0

48,494 Monthly Direct MJ

112,386 Monthly Indirect MJ

160,880 Total Monthly MJ

11 November

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	581	Water	gallons	0	0.0348	0.0
0	533	Electricity	kWh	3.6	0.4406	0.0
3.7	152	Labor 1.25	hours	0.901	0	3.3
15	294	Poultry Feed	50 lb ba	0	158.4	2,376.0
20.58	134	Labor 2	hours	1.4115	0	29.0
22.5	143	Labor 2	hours	1.4115	0	31.8
26.7	128	Labor 2	hours	1.4115	0	37.7
29	201	Diesel	gallons	146	12.3	4,590.7
41.17	137	Labor 2	hours	1.4115	0	58.1
52.8	140	Labor 2	hours	1.4115	0	74.5
59.8	158	Labor 2	hours	1.4115	0	84.4
70	616	Wheat Straw	bale	0	40.8	2,856.0
90	182	Gasoline	gallons	129	10.9	12,591.0
91	194	Gasoline	gallons	129	10.9	12,730.9
97.22	657	Machinery	kg	0	92	8,944.2

99.5	146	Labor 2	hours	1.4115	0	140.4
133.7	131	Labor 2	hours	1.4115	0	188.7
140	323	Whole Corn	lb	0	1.6	224.0
162.42	155	Labor 1.50	hours	1.0711	0	174.0
186	557	Electricity	kWh	3.6	0.4406	751.6
200	122	Labor 2	hours	1.4115	0	282.3
233	125	Labor 1.25	hours	0.901	0	209.9
296.74	612	Machinery	kg	0	92	27,300.1
1004	521	Electricity	kWh	3.6	0.4406	4,056.8
1145.5	149	Labor 3	hours	1.7459	0	1,999.9
3314	170	Human Labor (Indirect)	MJ (Ind	0	19.4	64,291.6
3698	545	Electricity	kWh	3.6	0.4406	14,942.1
5000	204	Gravel	lb	0	0.005625	28.1
9960	593	Water	gallons	0	0.0348	346.6
44132	569	Water	gallons	0	0.0348	1,535.8

12 December

79,332 Monthly Direct MJ

109,981 Monthly Indirect MJ

189,313 Total Monthly MJ

Quantity	ILN	Input Name	Units	Direct Energy/Unit	Indirect Energy/Unit	Total Energy MJ
0	582	Water	gallons	0	0.0348	0.0
0	594	Water	gallons	0	0.0348	0.0
0	534	Electricity	kWh	3.6	0.4406	0.0
3.6	153	Labor 1.25	hours	0.901	0	3.2
20.59	135	Labor 2	hours	1.4115	0	29.1
22.5	144	Labor 2	hours	1.4115	0	31.8
26.6	129	Labor 2	hours	1.4115	0	37.5
41.16	138	Labor 2	hours	1.4115	0	58.1
50	183	Gasoline	gallons	129	10.9	6,995.0
52.9	141	Labor 2	hours	1.4115	0	74.7
55.6	195	Gasoline	gallons	129	10.9	7,778.4
59.8	159	Labor 2	hours	1.4115	0	84.4
97.22	658	Machinery	kg	0	92	8,944.2

99.5	147	Labor 2	hours	1.4115	0	140.4
133.6	132	Labor 2	hours	1.4115	0	188.6
162.41	156	Labor 1.50	hours	1.0711	0	174.0
200	123	Labor 2	hours	1.4115	0	282.3
204	558	Electricity	kWh	3.6	0.4406	824.3
233	126	Labor 1.25	hours	0.901	0	209.9
288	202	Diesel	gallons	146	12.3	45,590.4
296.74	613	Machinery	kg	0	92	27,300.1
1145.5	150	Labor 3	hours	1.7459	0	1,999.9
1491	522	Electricity	kWh	3.6	0.4406	6,024.5
3314	171	Human Labor (Indirect)	MJ (Ind irect)/M	0	19.4	64,291.6
3957	546	Electricity	kWh	3.6	0.4406	15,988.7
55352	570	Water	gallons	0	0.0348	1,926.2
59600	205	Gravel	lb	0	0.005625	335.3

Model Output: ESF 2014 Growing Season

421,758	MJ Total 2014 Output
100,418,649	Kcal Total 2014 Output

01 January

10,140	MJ Monthly Total
2,414,397	Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
0.75	314	POPCORN	1,733	1,300
1	311	CORNMEAL	1,642	1,642
1.25	310	SALSA, MILD	132	165
2.5	648	DRIED PEPPERS	1,565	3,913
2.5	649	DRIED PEPPERS	1,565	3,913
3	312	ONIONS	181	543
5	308	KETCHUP	508	2,540
5	313	DRY BEANS	644	3,220
5.75	650	ARUGULA	113	650
5.75	651	TOMATOES, DICED	118	679
6.5	652	TOMATOES, DICED	118	767
10	653	CORNMEAL	1,642	16,420
10	654	CORNMEAL	1,642	16,420
11.5	655	KALE	209	2,404
12.5	657	SALSA, MILD	132	1,650
12.5	656	SALSA, MILD	132	1,650
16	305	KALE	209	3,344
16.5	658	DRY BEANS	644	10,626
18	659	DRY BEANS	644	11,592
20.25	309	MARINARA	222	4,496
22.5	661	MARINARA	222	4,995
22.5	660	MARINARA	222	4,995
23	662	POPCORN	1,733	39,859
26	663	POPCORN	1,733	45,058

69	664	LETTUCE	64	4,416
75	306	POTATOES	349	26,175
75	307	SWEET POTATOES	485	36,375
92	666	SWEET POTATOES	485	44,620
92	665	POTATOES	349	32,108
103.5	667	VARIOUS VEGETABLES	327	33,845
104	670	VARIOUS VEGETABLES	327	34,008
104	669	POTATOES	349	36,296
104	668	ONIONS	181	18,824
155	1043	Hens	730	113,150
198.94	1031	Eggs	649	129,112
312	671	SWEET POTATOES	485	151,320
1657.5	1072	Beef	948	1,571,310

02 February

3,801 MJ Monthly Total

904,953 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
0.25	323	POPCORN	1,733	433
1	317	KETCHUP	508	508
1	17	KETCHUP	508	508
1	14	SWEET POTATOES	485	485
2.25	19	MARINARA	222	500
2.25	318	MARINARA	222	500
3	321	ONIONS	181	543
3.25	266	KALE	209	679
4	320	CORNMEAL	1,642	6,568
4.5	673	ARUGULA	113	509
4.5	672	ARUGULA	113	509
6	268	DRY BEANS	644	3,864
6.25	674	TOMATOES, DICED	118	738
6.25	319	SALSA, MILD	132	825
9.5	322	DRY BEANS	644	6,118
10	675	CORNMEAL	1,642	16,420
10	676	CORNMEAL	1,642	16,420
12.5	679	SALSA, MILD	132	1,650
12.5	677	SALSA, MILD	132	1,650

12.5	678	CHARD	86	1,075
13.75	8	POTATOES	349	4,799
15	267	POTATOES	349	5,235
17.5	681	DRY BEANS	644	11,270
17.5	680	DRY BEANS	644	11,270
22.5	682	MARINARA	222	4,995
22.5	683	MARINARA	222	4,995
35	685	POPCORN	1,733	60,655
35	684	POPCORN	1,733	60,655
41.25	269	SALSA, MILD	132	5,445
51.5	316	SWEET POTATOES	485	24,978
74	315	POTATOES	349	25,826
100	686	VARIOUS VEGETABLES	327	32,700
106.25	687	VARIOUS VEGETABLES	327	34,744
112.5	688	LETTUCE	64	7,200
150	689	POTATOES	349	52,350
155	1044	Hens	730	113,150
175	690	POTATOES	349	61,075
198.94	1032	Eggs	649	129,112
200	692	SWEET POTATOES	485	97,000
200	691	SWEET POTATOES	485	97,000

03 March

10,988 MJ Monthly Total

2,616,078 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
0.25	330	DRIED PEPPERS	1,565	391
0.75	329	POPCORN	1,733	1,300
1.2	15	SWEET POTATOES	485	582
2.5	20	SALSA, MILD	132	330
2.5	10	POTATOES	349	873
3	327	ONIONS	181	543
3.75	9	POTATOES	349	1,309
3.75	326	SALSA, MILD	132	495
5.5	328	DRY BEANS	644	3,542
6.25	693	TOMATOES, DICED	118	738
10	81	SWEET POTATOES	485	4,850

10	694	CORNMEAL	1,642	16,420
12.5	696	SALSA, MILD	132	1,650
12.5	695	KALE	209	2,613
17.5	697	DRY BEANS	644	11,270
22.5	698	MARINARA	222	4,995
35	699	POPCORN	1,733	60,655
41	325	SWEET POTATOES	485	19,885
93.75	700	VARIOUS VEGETABLES	327	30,656
118	324	POTATOES	349	41,182
150	701	POTATOES	349	52,350
155	1045	Hens	730	113,150
198.94	1033	Eggs	649	129,112
200	702	SWEET POTATOES	485	97,000
2131	1073	Beef	948	2,020,188

04 April

22,533 MJ Monthly Total

5,365,044 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
5	336	CORNMEAL	1,642	8,210
5	331	CHARD	86	430
7.25	338	POPCORN	1,733	12,564
30	335	SALSA, MILD	132	3,960
30	333	SPINACH	104	3,120
31	337	DRY BEANS	644	19,964
38	171	POTATOES	349	13,262
154	334	SWEET POTATOES	485	74,690
155	1046	Hens	730	113,150
280	332	POTATOES	349	97,720
282.24	1034	Eggs	649	183,174
5100	1074	Beef	948	4,834,800

05 May

16,074 MJ Monthly Total

3,827,262 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal

1.75	349	CORNMEAL	1,642	2,874
2	263	TURNIPS	354	708
2	240	PEAS	367	734
3.25	352	POPCORN	1,733	5,632
4	176	SPINACH	104	416
7	237	LETTUCE	64	448
7	340	COLLARDS	145	1,015
8.5	351	DRY BEANS	644	5,474
8.75	83	SALSA, MILD	132	1,155
10	93	SPINACH	104	1,040
10	89	LETTUCE	64	640
15	259	SWEET POTATOES	485	7,275
17.5	339	CHARD	86	1,505
21	347	MUSTARD GREENS	122	2,562
21	82	Eggs	649	13,629
24	96	STRAWBERRIES	145	3,480
25	261	TOMATOES	82	2,050
26	250	SPINACH	104	2,704
33	258	STRAWBERRIES	145	4,785
36.5	703	DRY BEANS	644	23,506
42	341	KALE	209	8,778
48.5	704	SPINACH	104	5,044
50	348	TURNIPS	354	17,700
52.5	346	SALSA, MILD	132	6,930
52.5	354	SALAD MIX	77	4,043
55	705	STRAWBERRIES	145	7,975
60	137	SPINACH	104	6,240
72	55	SPINACH	104	7,488
73	706	RADISHES	73	5,329
105	353	BOK CHOH	59	6,195
155	1047	Hens	730	113,150
162	707	LETTUCE	64	10,368
177	708	CHARD	86	15,222
205	343	POTATOES	349	71,545
230	709	SPINACH	104	23,920
253.75	345	SWEET POTATOES	485	123,069
264	342	LETTUCE	64	16,896

270	710	SPINACH	104	28,080
270	344	SPINACH	104	28,080
339	350	STRAWBERRIES	145	49,155
382.2	1035	Eggs	649	248,048
618	711	STRAWBERRIES	145	89,610
1266	712	LETTUCE	64	81,024
1433.4	1055	Broilers	730	1,046,382
1820	1075	Beef	948	1,725,360

06 June

32,452 MJ Monthly Total

7,726,623 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
0.75	5	KALE	209	157
1	12	SPINACH	104	104
1.2	7	LETTUCE	64	77
1.5	162	KALE	209	314
2	241	PEAS	367	734
2	167	OKRA	100	200
2	204	GARLIC	676	1,352
2	168	PEAS	367	734
2	223	BEETS	195	390
2	78	SPINACH	104	208
2.25	187	TURNIPS	354	797
2.5	1	CABBAGE	113	283
2.5	161	FENNEL	141	353
2.5	202	FENNEL	141	353
3	127	FENNEL	141	423
3	146	KALE	209	627
3	156	BROCCOLI	405	1,215
5	177	SPINACH	104	520
5	143	CUCUMBER	54	270
5	70	FENNEL	141	705
5	215	PEAS	367	1,835
6	67	CHARD	86	516
6	75	MUSTARD GREENS	122	732
7	407	CORNMEAL	1,642	11,494

7.5	411	SALSA, HOT	132	990
7.5	165	KOHLRABI	122	915
7.5	205	KALE	209	1,568
9	46	FENNEL	141	1,269
10	74	KOHLRABI	122	1,220
10	194	BROCCOLI	405	4,050
10	153	BEETS	195	1,950
10	219	SQUASH, PATTY PAN	154	1,540
10.5	410	TURNIP GREENS	163	1,712
12	401	FENNEL	141	1,692
13	157	CHARD	86	1,118
13	414	DRY BEANS	644	8,372
15	80	TURNIPS	354	5,310
15	217	SPINACH	104	1,560
20	276	CABBAGE	113	2,260
20	139	TURNIPS	354	7,080
20	72	KALE	209	4,180
23	713	OKRA	100	2,300
25	51	KOHLRABI	122	3,050
27	41	COLLARDS	145	3,915
29.5	714	STRAWBERRIES	145	4,278
30	119	CABBAGE	113	3,390
30	418	GARLIC SCAPES	8	240
34	715	RADISHES	73	2,482
35	64	BEETS	195	6,825
36	48	KALE	209	7,524
36	279	CHARD	86	3,096
36	39	CHARD	86	3,096
36	283	COLLARDS	145	5,220
37.5	24	KOHLRABI	122	4,575
40	210	LETTUCE	64	2,560
41.25	402	OKRA	100	4,125
45	413	STRAWBERRIES	145	6,525
50	397	KOHLRABI	122	6,100
54	128	KALE	209	11,286
54.5	388	CHARD	86	4,687
54.5	716	SPINACH	104	5,668

58.75	394	SALSA, MILD	132	7,755
60	56	SPINACH	104	6,240
63	389	COLLARDS	145	9,135
65	192	BEETS	195	12,675
68	132	LETTUCE	64	4,352
70	396	CUCUMBER	54	3,780
75	412	SQUASH, PATTY PAN	154	11,550
80.5	403	MUSTARD GREENS	122	9,821
81.25	404	RADISHES	73	5,931
95	717	BROCCOLI	405	38,475
95	718	SQUASH, YELLOW	73	6,935
96	400	BEANS	513	49,248
96	417	CARROTS	186	17,856
96	270	BEETS	195	18,720
100	299	SQUASH, YELLOW	73	7,300
102	719	GARLIC SCAPES	8	816
110	406	SQUASH, BABY	77	8,470
120	21	BEETS	195	23,400
132	53	LETTUCE	64	8,448
137.5	393	SWEET POTATOES	485	66,688
138.75	416	SALAD MIX	77	10,684
140	398	SQUASH, GREEN	77	10,780
140	297	SQUASH, GREEN	77	10,780
144	295	LETTUCE	64	9,216
153	720	BEANS	513	78,489
155	1048	Hens	730	113,150
160	399	SQUASH, YELLOW	73	11,680
168	271	BEETS	195	32,760
175	415	BOK CHOH	59	10,325
180	274	LETTUCE	64	11,520
180	273	KALE	209	37,620
181	721	KALE	209	37,829
183	722	KALE, RED	209	38,247
198	289	KALE	209	41,382
201	723	BROCCOLI	405	81,405
202	724	RADISHES	73	14,746
204.5	725	GARLIC SCAPES	8	1,636

204.5	392	SPINACH	104	21,268
205	726	SPINACH	104	21,320
210	387	CABBAGE	113	23,730
217	727	SPINACH	104	22,568
225	30	SQUASH, YELLOW	73	16,425
225	27	SQUASH, GREEN	77	17,325
232.5	409	PEAS	367	85,328
242	728	KALE	209	50,578
247	729	PEPPERS	122	30,134
270	730	SPINACH	104	28,080
273.5	731	SPINACH	104	28,444
288	732	CUKES	54	15,552
301	390	KALE	209	62,909
356	733	BEANS	513	182,628
372	734	CHARD	86	31,992
381	735	BEETS	195	74,295
422	736	CUKES	54	22,788
437.5	405	TURNIPS	354	154,875
498.5	395	BEETS	195	97,208
500	737	CARROTS	186	93,000
512	738	BEETS	195	99,840
588	739	STRAWBERRIES	145	85,260
595	740	BROCCOLI	405	240,975
626	741	PEAS	367	229,742
630	408	BROCCOLI	405	255,150
631	742	LETTUCE	64	40,384
631	743	PEAS	367	231,577
636	744	CABBAGE	113	71,868
637	745	FENNEL	141	89,817
679	746	SWEET CORN	390	264,810
690	747	BROCCOLI	405	279,450
756	391	LETTUCE	64	48,384
764	748	BROCCOLI	405	309,420
815.85	1036	Eggs	649	529,487
818	749	PEAS	367	300,206
864	750	TURNIPS	354	305,856
951	751	LETTUCE	64	60,864

955.5	752	LETTUCE	64	61,152
955.5	753	LETTUCE	64	61,152
963	754	LETTUCE	64	61,632
1022.5	755	KOHLRABI	122	124,745
1221	756	BOK CHOH	59	72,039
1274	757	SQUASH, YELLOW	73	93,002
1329.5	758	SQUASH, YELLOW	73	97,054
1640	759	CABBAGE	113	185,320
1938.4	1056	Broilers	730	1,415,032

07 July

91,359 MJ Monthly Total

21,752,208 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
2	231	FENNEL	141	282
2	247	RADISHES	73	146
3	450	BLACKBERRIES	195	585
4	147	KALE	209	836
4.6	444	GARLIC	676	3,110
5	203	FENNEL	141	705
5	253	SQUASH, GREEN	77	385
5	135	OKRA	100	500
5	256	SQUASH, YELLOW	73	365
5.5	144	CUCUMBER	54	297
6.25	426	SALSA, MILD	132	825
7.5	251	SQUASH, BABY	77	578
8	224	BEETS	195	1,560
9	52	KOHLRABI	122	1,098
10	222	BEANS	513	5,130
10	264	TURNIPS	354	3,540
10	68	COLLARDS	145	1,450
10	201	CUCUMBER	54	540
10.5	254	SQUASH, PATTY PAN	154	1,617
10.5	293	KOHLRABI	122	1,281
12	441	CORNMEAL	1,642	19,704
12.5	436	RADISHES	73	913
13.5	443	PEPPER, HOT	122	1,647

14.25	124	COLLARDS	145	2,066
17	65	BEETS	195	3,315
17.25	199	COLLARDS	145	2,501
17.5	425	SPINACH	104	1,820
18	40	CHARD	86	1,548
18.75	25	KOHLRABI	122	2,288
20	211	LETTUCE	64	1,280
20	118	BEETS	195	3,900
20	213	OKRA	100	2,000
21	47	FENNEL	141	2,961
21.5	69	CUCUMBER	54	1,161
22.5	198	CHARD	86	1,935
24	133	LETTUCE	64	1,536
24	446	DRY BEANS	644	15,456
24	54	LETTUCE	64	1,536
25	36	CABBAGE	113	2,825
27	42	COLLARDS	145	3,915
27	284	COLLARDS	145	3,915
27.5	451	MELLONS	163	4,483
27.5	141	CABBAGE	113	3,108
27.75	206	KALE	209	5,800
28	422	COLLARDS	145	4,060
30	218	SQUASH, BABY	77	2,310
33.75	448	SALAD MIX	77	2,599
36	296	LETTUCE	64	2,304
36	34	BEETS	195	7,020
36	434	FENNEL	141	5,076
37.5	209	KOHLRABI	122	4,575
40	66	CABBAGE	113	4,520
42	430	PEPPER, BELL	91	3,822
44	760	OKRA	100	4,400
50	226	CABBAGE	113	5,650
51	122	CHARD	86	4,386
62	761	OKRA	100	6,200
70	73	KALE	209	14,630
70	126	CUCUMBER	54	3,780
77	195	CABBAGE	113	8,701

80	43	CUCUMBER	54	4,320
80	763	GARLIC	676	54,080
80	762	PEPPERS	122	9,760
90	280	CHARD	86	7,740
90	445	SQUASH, PATTY PAN	154	13,860
90	764	CUKES	54	4,860
96.25	421	CHARD	86	8,278
106.5	129	KALE	209	22,259
125	437	TURNIPS	354	44,250
126.1	1085	Turkey	630	79,443
128	193	BEETS	195	24,960
131	765	BROCCOLI	405	53,055
135	290	KALE	209	28,215
138	420	CELERY	73	10,074
138.75	435	OKRA	100	13,875
144	154	BEETS	195	28,080
145	120	CABBAGE	113	16,385
155	1049	Hens	730	113,150
156	424	LETTUCE	64	9,984
160	300	SQUASH, YELLOW	73	11,680
162.5	447	POPCORN	1,733	281,613
180	429	KOHLRABI	122	21,960
180	298	SQUASH, GREEN	77	13,860
186	766	BROCCOLI	405	75,330
192	272	BEETS	195	37,440
200.4	449	CARROTS	186	37,274
220	169	PEPPER, BELL	91	20,020
223	767	CUKES	54	12,042
225.75	423	KALE	209	47,182
230	768	FENNEL	141	32,430
238	49	KALE	209	49,742
247.5	419	CABBAGE	113	27,968
261	158	CHARD	86	22,446
275	183	SQUASH, YELLOW	73	20,075
292	769	KALE	209	61,028
309	770	LETTUCE	64	19,776
350	439	SQUASH, BABY	77	26,950

350	432	SQUASH, YELLOW	73	25,550
354	277	CABBAGE	113	40,002
360	431	SQUASH, GREEN	77	27,720
380.5	286	CUCUMBER	54	20,547
412	771	PEPPERS	122	50,264
421	772	TOMATOES	82	34,522
422	773	CELERY	73	30,806
424	774	CARROTS	186	78,864
435	438	TOMATOES	82	35,670
477	775	CABBAGE	113	53,901
478.5	776	CUKES	54	25,839
491	777	POTATOES	349	171,359
522	427	BEETS	195	101,790
555	778	WATERMELON	136	75,480
600	433	BEANS	513	307,800
630	779	MELLONS	163	102,690
632	780	BEANS	513	324,216
632	781	KOHLRABI	122	77,104
632	782	BEANS	513	324,216
643	783	BEANS	513	329,859
666	442	BROCCOLI	405	269,730
778.75	428	CUCUMBER	54	42,053
842	784	CELERY	73	61,466
866	785	CUKES	54	46,764
930	786	TURNIPS	354	329,220
940	787	MELLONS	163	153,220
948	788	SQUASH, YELLOW	73	69,204
1025	789	BROCCOLI	405	415,125
1032.5	790	CARROTS	186	192,045
1227.45	1037	Eggs	649	796,615
1238	182	SQUASH, GREEN	77	95,326
1264	791	SQUASH, YELLOW	73	92,272
1275	792	BROCCOLI	405	516,375
1360	160	CUCUMBER	54	73,440
1369	793	SQUASH, YELLOW	73	99,937
1476	58	CUCUMBER	54	79,704
1490	23	CUCUMBER	54	80,460

1505.5	1058	Broilers	730	1,099,015
1685	794	CABBAGE	113	190,405
1741.2	1057	Broilers	730	1,271,076
1830	31	SQUASH, YELLOW	73	133,590
1880	60	SQUASH, GREEN	77	144,760
1928	28	SQUASH, GREEN	77	148,456
1944	795	TOMATOES	82	159,408
2001	22	BEETS	195	390,195
2266.25	440	SWEET CORN	390	883,838
2320	62	SQUASH, YELLOW	73	169,360
2526	796	WATERMELON	136	343,536
2624	797	SWEET CORN	390	1,023,360
2624	798	SWEET CORN	390	1,023,360
2817	799	SWEET CORN	390	1,098,630
3422	800	SWEET CORN	390	1,334,580
5402.5	1076	Beef	948	5,121,570

08 August

50,016 MJ Monthly Total

11,908,535 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
1	136	OKRA	100	100
1.75	244	PEPPER, HOT	122	214
2	512	DRY BEANS	644	1,288
3.75	507	EGG PLANT	113	424
4	87	CUCUMBER	54	216
4	242	PEPPER, BELL	91	364
4	148	KALE	209	836
4	230	CUCUMBER	54	216
4	504	CORNMEAL	1,642	6,568
4	86	CELERY	73	292
4	92	PEPPER, BELL	91	364
4.5	294	KOHLRABI	122	549
5	98	BEANS	513	2,565
5	227	CABBAGE	113	565
5	216	PEPPER, BELL	91	455
6	178	SPINACH	104	624

6	140	CORNMEAL	1,642	9,852
7	152	TOMATOES	82	574
7.4	509	GARLIC	676	5,002
7.5	190	SALSA, HOT	132	990
7.5	207	KALE	209	1,568
10	257	SQUASH, YELLOW	73	730
10	508	SALSA, HOT	132	1,320
10	492	SALSA, MILD	132	1,320
10	97	TOMATOES	82	820
10	85	CABBAGE	113	1,130
11	94	SQUASH, BABY	77	847
11	90	OKRA	100	1,100
12	104	CUCUMBER	54	648
12	185	SWEET POTATOES	485	5,820
12	172	POTATOES	349	4,188
12	116	SWEET CORN	390	4,680
15	511	TOMATILLAS	145	2,175
15	262	TOMATOES	82	1,230
15	101	CHARD	86	1,290
15	110	SQUASH, BABY	77	1,155
15	105	KALE	209	3,135
19	145	CUCUMBER	54	1,026
20	214	OKRA	100	2,000
20	220	SQUASH, PATTY PAN	154	3,080
20	221	TOMATOES	82	1,640
22	801	DRIED PEPPERS	1,565	34,430
22	802	RASPBERRIES	236	5,192
24	84	BEANS	513	12,312
25	495	KOHLRABI	122	3,050
26	803	HERBS	8	208
26	804	HERBS	8	208
27	506	PEPPER, HOT	122	3,294
28	488	COLLARDS	145	4,060
30	57	SQUASH, YELLOW	73	2,190
30	130	KALE	209	6,270
30	514	CARROTS	186	5,580
35	117	BEANS	513	17,955

36	805	EGG PLANT	113	4,068
36	291	KALE	209	7,524
39	806	GARLIC	676	26,364
40	212	LETTUCE	64	2,560
40	121	CABBAGE	113	4,520
43.5	515	BLACKBERRIES	195	8,483
43.5	142	CABBAGE	113	4,916
45	516	MELLONS	163	7,335
53	808	GARLIC	676	35,828
53	807	GARLIC	676	35,828
54	281	CHARD	86	4,644
60	196	CELERY	73	4,380
63	505	BROCCOLI	405	25,515
69	809	KOHLRABI	122	8,418
80	44	CUCUMBER	54	4,320
80	45	CUCUMBER	54	4,320
80	134	LETTUCE	64	5,120
99	810	PEPPERS	122	12,078
106	812	OKRA	100	10,600
106	813	ONIONS	181	19,186
106	811	OKRA	100	10,600
106.5	493	BEETS	195	20,768
115	510	SQUASH, PATTY PAN	154	17,710
120	35	BEETS	195	23,400
129.5	513	SALAD MIX	77	9,972
140	59	OKRA	100	14,000
140	37	CABBAGE	113	15,820
145.25	487	CHARD	86	12,492
155	1050	Hens	730	113,150
159	814	OKRA	100	15,900
182.5	490	LETTUCE	64	11,680
187.5	500	OKRA	100	18,750
190	815	KALE	209	39,710
210	496	PEPPER, BELL	91	19,110
210	816	CUKES	54	11,340
212	817	KALE	209	44,308
220	301	SQUASH, YELLOW	73	16,060

225	485	CABBAGE	113	25,425
269	486	CELERY	73	19,637
294	489	KALE	209	61,446
345	502	SQUASH, BABY	77	26,565
353	287	CUCUMBER	54	19,062
379	818	CUKES	54	20,466
395	498	SQUASH, YELLOW	73	28,835
405	819	CUKES	54	21,870
422	820	CELERY	73	30,806
433	821	PEPPERS	122	52,826
439	822	PEPPERS	122	53,558
455	497	SQUASH, GREEN	77	35,035
470	823	SQUASH, YELLOW	73	34,310
472.7	278	CABBAGE	113	53,415
500	491	POTATOES	349	174,500
527	824	POTATOES	349	183,923
529	825	BEANS	513	271,377
530	61	SQUASH, GREEN	77	40,810
534	499	BEANS	513	273,942
541	826	PEPPERS	122	66,002
600	29	SQUASH, GREEN	77	46,200
600	32	SQUASH, YELLOW	73	43,800
632	827	BEANS	513	324,216
632	828	POTATOES	349	220,568
634	829	POTATOES	349	221,266
656	830	BEANS	513	336,528
708	831	MELLONS	163	115,404
822	832	TURNIPS	354	290,988
848.75	494	CUCUMBER	54	45,833
892	833	SQUASH, YELLOW	73	65,116
894	834	SQUASH, YELLOW	73	65,262
948	836	SQUASH, YELLOW	73	69,204
948	835	LETTUCE	64	60,672
984	837	LETTUCE	64	62,976
1100	1077	Beef	948	1,042,800
1270.08	1038	Eggs	649	824,282
1304	838	LETTUCE	64	83,456

1312	839	CABBAGE	113	148,256
1322.8	1059	Broilers	730	965,644
1484	840	TOMATOES	82	121,688
1715	503	SWEET CORN	390	668,850
1750	63	SQUASH, YELLOW	73	127,750
2154	841	TOMATOES	82	176,628
2246	842	SWEET CORN	390	875,940
2414	843	SWEET CORN	390	941,460
2535	844	SWEET CORN	390	988,650
2588	501	TOMATOES	82	212,216
2747	845	TOMATOES	82	225,254
2748	846	TOMATOES	82	225,336

09 September

60,432 MJ Monthly Total

14,388,598 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
1	151	PEPPER, BELL	91	91
1	174	SAGE	1,429	1,429
1	248	RADISHES	73	73
1	229	COLLARDS	145	145
1.45	232	GARLIC	676	980
3	540	BASIL	104	312
4	149	KALE	209	836
5	99	BEANS	513	2,565
6	534	CORNMEAL	1,642	9,852
6	528	PEPPER, BELL	91	546
6	847	RASPBERRIES	236	1,416
7.5	200	COLLARDS	145	1,088
9	535	PEPPER, HOT	122	1,098
10	106	KALE	209	2,090
10	102	CHARD	86	860
10	115	SQUASH, YELLOW	73	730
10	113	SQUASH, GREEN	77	770
12	538	DRY BEANS	644	7,728
13	848	HERBS	8	104
15	155	BEETS	195	2,925

15	163	KALE	209	3,135
16.5	125	COLLARDS	145	2,393
17	849	OKRA	100	1,700
17	524	KETCHUP	508	8,636
17.5	236	KOHLRABI	122	2,135
18	50	KALE	209	3,762
18	123	CHARD	86	1,548
20	536	SALSA, HOT	132	2,640
20	850	HERBS	8	160
20	138	SQUASH, YELLOW	73	1,460
22.5	525	MARINARA	222	4,995
27	851	GARLIC	676	18,252
27	852	GARLIC	676	18,252
28.75	539	SALAD MIX	77	2,214
30	853	PEPPERS	122	3,660
31	854	KALE, BLACK	209	6,479
35	519	COLLARDS	145	5,075
36	282	CHARD	86	3,096
37.5	208	KALE	209	7,838
38.75	526	SALSA, MILD	132	5,115
39	855	BRUSSELL SPROUTS	195	7,605
39.5	541	RASPBERRIES	236	9,322
40	197	CELERY	73	2,920
42	111	SQUASH, BABY	77	3,234
44	533	SQUASH, BABY	77	3,388
46	856	EGG PLANT	113	5,198
50	537	SQUASH, PATTY PAN	154	7,700
51	857	BEETS	195	9,945
53	858	GARLIC	676	35,828
53	859	GARLIC	676	35,828
54	860	EGG PLANT	113	6,102
56	861	GARLIC	676	37,856
58.5	131	KALE	209	12,227
60	38	CELERY	73	4,380
60	862	KALE	209	12,540
69	863	BEETS	195	13,455
69	864	KALE, BLACK	209	14,421

70	866	CHARD	86	6,020
70	865	KALE, RED	209	14,630
72	285	COLLARDS	145	10,440
74.05	531	OKRA	100	7,405
80	33	BEANS	513	41,040
88	867	KALE, RED	209	18,392
88	868	COLLARDS	145	12,760
89	869	KALE, RED	209	18,601
90	530	BEANS	513	46,170
93	870	COLLARDS	145	13,485
99	288	CUCUMBER	54	5,346
114.25	518	CHARD	86	9,826
118	871	OKRA	100	11,800
120	521	LETTUCE	64	7,680
131	872	KALE	209	27,379
139	873	CHARD	86	11,954
150	523	SWEET POTATOES	485	72,750
151.8	1082	Lamb	1,324	200,983
155	1051	Hens	730	113,150
161	874	KALE	209	33,649
168	875	EGG PLANT	113	18,984
180	876	KALE, RED	209	37,620
180	302	SQUASH, YELLOW	73	13,140
190	877	KALE	209	39,710
212	879	DRY BEANS	644	136,528
212	878	CUKES	54	11,448
220	880	CHARD	86	18,920
223	881	BEANS	513	114,399
224	882	CUKES	54	12,096
224	883	OKRA	100	22,400
224	884	LETTUCE	64	14,336
227	885	CUKES	54	12,258
292.25	520	KALE	209	61,080
297	886	PEPPERS	122	36,234
300	887	PEPPERS	122	36,600
304	888	SQUASH, YELLOW	73	22,192
317	889	LEEKS	277	87,809

317	890	LEEKS	277	87,809
317	891	RADISHES	73	23,141
318	892	PEPPERS	122	38,796
326	893	RADISHES	73	23,798
329	529	SQUASH, YELLOW	73	24,017
330	894	PEPPERS	122	40,260
378	292	KALE	209	79,002
386.5	522	POTATOES	349	134,889
423	895	CORNMEAL	1,642	694,566
446.25	527	CUCUMBER	54	24,098
451.5	517	CELERY	73	32,960
541	896	BEANS	513	277,533
592	897	SWEET CORN	390	230,880
634	898	POTATOES	349	221,266
658	899	SWEET POTATOES	485	319,130
682	901	POTATOES	349	238,018
682	902	POTATOES	349	238,018
682	900	POTATOES	349	238,018
705	903	TOMATOES	82	57,810
752	904	SQUASH, YELLOW	73	54,896
769	905	TOMATOES	82	63,058
787	906	TOMATOES	82	64,534
846	907	CELERY	73	61,758
846	908	CELERY	73	61,758
846	909	CELERY	73	61,758
894	910	SQUASH, YELLOW	73	65,262
962	911	SQUASH, YELLOW	73	70,226
991	912	SWEET CORN	390	386,490
995.19	1039	Eggs	649	645,878
1023	913	LETTUCE	64	65,472
1788	914	WINTER SQUASH	154	275,352
1980	532	TOMATOES	82	162,360
2340	915	TOMATOES	82	191,880
3246.8	1060	Broilers	730	2,370,164
5300	1078	Beef	948	5,024,400

10 October

51,955 MJ Monthly Total

12,370,267 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
0.5	234	HERBS	8	4
0.5	239	ONIONS	181	91
0.5	304	HERBS	8	4
0.5	3	CHARD	86	43
0.8	233	GARLIC	676	541
1	18	KETCHUP	508	508
1	103	CHARD	86	86
1.2	13	SQUASH, SPAGHETTI	122	146
1.35	245	PEPPER, HOT	122	165
1.5	88	KALE	209	314
2	265	TURNIPS	354	708
2	249	RADISHES	73	146
2	175	RADISHES	73	146
2	243	PEPPER, BELL	91	182
2.25	95	SQUASH, BABY	77	173
4	558	CORNMEAL	1,642	6,568
4	228	CELERY	73	292
4	225	BEETS	195	780
4	255	SQUASH, PATTY PAN	154	616
5	91	OKRA	100	500
5	252	SQUASH, FALL	154	770
5	100	BEETS	195	975
5	184	SQUASH, YELLOW	73	365
5	170	PEPPER, HOT	122	610
6	235	KALE	209	1,254
6.5	916	TOMATOES, DICED	118	767
7	150	KALE	209	1,463
7	917	HERBS	8	56
8	246	POTATOES	349	2,792
8.5	260	SWEET POTATOES	485	4,123
9	238	LETTUCE	64	576
11.5	562	DRY BEANS	644	7,406

12	188	KETCHUP	508	6,096
12	112	SQUASH, DELICATTA	154	1,848
13	919	DRY BEANS	644	8,372
13	918	CORNMEAL	1,642	21,346
15	191	SALSA, HOT	132	1,980
15	107	KALE	209	3,135
18	114	RED KURI	1,016	18,288
20.5	564	RASPBERRIES	236	4,838
22	920	LETTUCE	64	1,408
22.5	559	PEPPER, HOT	122	2,745
24	552	PEPPER, BELL	91	2,184
27	921	LETTUCE	64	1,728
30	166	LETTUCE	64	1,920
30	922	GARLIC	676	20,280
30	923	GARLIC	676	20,280
31	924	CHARD	86	2,666
32	549	KETCHUP	508	16,256
32.5	925	SALSA, MILD	132	4,290
35	926	KALE	209	7,315
40.25	544	COLLARDS	145	5,836
41.5	554	OKRA	100	4,150
43.75	550	SALSA, MILD	132	5,775
50	561	SQUASH, PATTY PAN	154	7,700
51.25	560	SALSA, HOT	132	6,765
52	557	SQUASH, BABY	77	4,004
52	927	OKRA	100	5,200
58.5	928	MARINARA	222	12,987
60	181	SQUASH, SPAGHETTI	122	7,320
63	543	CHARD	86	5,418
65	108	LETTUCE	64	4,160
69	929	KALE, RED	209	14,421
70	179	SQUASH, BUTTERNUT	154	10,780
75	303	TURNIP GREENS	163	12,225
75	159	COLLARDS	145	10,875
84	551	BEETS	195	16,380
88	931	KALE, WHITE	209	18,392
88	930	KALE, WHITE	209	18,392

93	932	KALE, BLACK	209	19,437
93	933	KALE, RED	209	19,437
99.75	563	SALAD MIX	77	7,681
101	934	BEETS	195	19,695
112	935	CHARD	86	9,632
115	76	POTATOES	349	40,135
117	565	TOMATOES, DICED	118	13,806
120	164	KALE	209	25,080
131	936	KALE	209	27,379
131	937	KALE, BLACK	209	27,379
152	938	RADISHES	73	11,096
155	1052	Hens	730	113,150
168	546	LETTUCE	64	10,752
198	939	BOK CHOH	59	11,682
202	941	ONIONS	181	36,562
202	942	POTATOES	349	70,498
202	940	CELERY	73	14,746
206	1083	Lamb	1,324	272,744
210	173	POTATOES	349	73,290
212.5	555	TURNIPS	354	75,225
233.25	545	KALE	209	48,749
247.5	556	TOMATOES	82	20,295
250	553	SQUASH, YELLOW	73	18,250
276	542	CELERY	73	20,148
303	943	TURNIPS	354	107,262
317	944	ONIONS	181	57,377
318.75	547	POTATOES	349	111,244
325	275	PUMPKIN	195	63,375
332	945	ONIONS	181	60,092
339	946	LETTUCE	64	21,696
404	947	PEPPERS	122	49,288
404	948	WINTER SQUASH	154	62,216
418	26	PEPPER, BELL	91	38,038
422	949	CELERY	73	30,806
562.5	548	SWEET POTATOES	485	272,813
606	950	SWEET POTATOES	485	293,910
658	953	SWEET POTATOES	485	319,130

658	952	PEPPERS	122	80,276
658	951	SWEET POTATOES	485	319,130
682	954	POTATOES	349	238,018
707	955	PUMPKIN	195	137,865
846	956	TURNIPS	354	299,484
864.36	1040	Eggs	649	560,970
890	957	PEPPERS	122	108,580
894	958	SQUASH, YELLOW	73	65,262
987	959	WINTER SQUASH	154	151,998
1424.9	1086	Turkey	630	897,687
1645	1061	Broilers	730	1,200,850
1705	960	POTATOES	349	595,045
2446	961	WINTER SQUASH	154	376,684
4640	1079	Beef	948	4,398,720
11835	1088	Tobacco	8	94,680

11 November

28,075 MJ Monthly Total

6,684,495 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
0.5	6	KALE	209	105
0.5	4	COLLARDS	145	73
3	71	GINGER	363	1,089
3	578	PEPPER, BELL	91	273
5	180	SQUASH, BUTTERNUT	154	770
6	2	CELERY	73	438
6	77	RADISHES	73	438
6	586	RASPBERRIES	236	1,416
6.5	963	DRIED PEPPERS	1,565	10,173
6.5	962	DRIED PEPPERS	1,565	10,173
7	964	HERBS	8	56
10	16	SWEET POTATOES	485	4,850
11	965	GARLIC	676	7,436
11	966	GARLIC	676	7,436
13	970	DRY BEANS	644	8,372
13	968	DRY BEANS	644	8,372
13	584	DRY BEANS	644	8,372

13	971	POPCORN	1,733	22,529
13	969	CORNMEAL	1,642	21,346
13	967	CORNMEAL	1,642	21,346
15	109	LETTUCE	64	960
16.25	583	SALSA, HOT	132	2,145
17.5	576	SALSA, MILD	132	2,310
21	972	GINGER	363	7,623
23	574	KETCHUP	508	11,684
23.75	11	POTATOES	349	8,289
25	186	SWEET POTATOES	485	12,125
26	973	KETCHUP	508	13,208
27	582	CORNMEAL	1,642	44,334
27	575	MARINARA	222	5,994
27	189	MARINARA	222	5,994
31.5	568	CHARD	86	2,709
32.5	974	SALSA, MILD	132	4,290
32.5	975	SALSA, MILD	132	4,290
33.75	587	TOMATOES, DICED	118	3,983
38.5	569	COLLARDS	145	5,583
40	579	SQUASH, YELLOW	73	2,920
48	571	LETTUCE	64	3,072
48.75	585	SALAD MIX	77	3,754
53	976	ONIONS	181	9,593
53	977	ONIONS	181	9,593
58.5	978	MARINARA	222	12,987
72	577	BEETS	195	14,040
75	580	GINGER	363	27,225
79	979	BRUSSELL SPROUTS	195	15,405
79	980	KALE	209	16,511
105	981	PEPPERS	122	12,810
105	982	RADISHES	73	7,665
112.5	581	TURNIPS	354	39,825
120	566	CABBAGE	113	13,560
130	79	SWEET POTATOES	485	63,050
132	567	CELERY	73	9,636
132	983	LETTUCE	64	8,448
155	1053	Hens	730	113,150

158	985	KALE	209	33,022
158	984	BEETS	195	30,810
176.25	588	WINTER RADISH	73	12,866
196	570	KALE	209	40,964
210	986	CELERY	73	15,330
210	988	CELERY	73	15,330
210	989	POTATOES	349	73,290
210	987	POTATOES	349	73,290
262.5	572	POTATOES	349	91,613
315	991	RADISHES	73	22,995
315	992	CABBAGE	113	35,595
315	990	CABBAGE	113	35,595
420	993	WINTER SQUASH	154	64,680
473	994	LETTUCE	64	30,272
475	573	SWEET POTATOES	485	230,375
504	995	SWEET POTATOES	485	244,440
577.71	1041	Eggs	649	374,934
840	998	WINTER SQUASH	154	129,360
840	997	SWEET POTATOES	485	407,400
840	996	SQUASH, YELLOW	73	61,320
1188	1087	Turkey	630	748,440
3437.5	1080	Beef	948	3,258,750

12 December

43,933 MJ Monthly Total

10,460,190 Kcal Monthly Total

Quantity (lb)	OLN	Output Name	Kcal/lb	Kcal
2.5	644	SALSA, HOT	132	330
3	643	CORNMEAL	1,642	4,926
6.5	999	TOMATOES, DICED	118	767
6.5	1000	DRIED PEPPERS	1,565	10,173
9	639	KETCHUP	508	4,572
11	1001	GARLIC	676	7,436
11	1002	GARLIC	676	7,436
11.25	641	SALSA, MILD	132	1,485
13	1003	CORNMEAL	1,642	21,346
13	1004	CORNMEAL	1,642	21,346

21	1005	GINGER	363	7,623
21.5	645	DRY BEANS	644	13,846
25	642	TURNIPS	354	8,850
26	1006	KALE	209	5,434
26	1008	SPINACH	104	2,704
26	1010	POPCORN	1,733	45,058
26	1007	LETTUCE	64	1,664
26	1009	LETTUCE	64	1,664
27	640	MARINARA	222	5,994
29.25	646	TOMATOES, DICED	118	3,452
32.5	1012	SALSA, MILD	132	4,290
32.5	1011	SALSA, MILD	132	4,290
37	1013	SPINACH	104	3,848
37.5	637	SPINACH	104	3,900
41.16	1042	Eggs	649	26,713
48	1014	HERBS	8	384
53	1015	ONIONS	181	9,593
53	1016	ONIONS	181	9,593
58.5	1018	MARINARA	222	12,987
58.5	1017	MARINARA	222	12,987
62.5	647	WINTER RADISH	73	4,563
66	1019	DRY BEANS	644	42,504
87.5	636	POTATOES	349	30,538
119	1020	DRY BEANS	644	76,636
155	1054	Hens	730	113,150
158	1021	BEETS	195	30,810
162.5	638	SWEET POTATOES	485	78,813
210	1023	RADISHES	73	15,330
210	1022	CABBAGE	113	23,730
259.7	1084	Lamb	1,324	343,843
315	1025	RADISHES	73	22,995
315	1024	CABBAGE	113	35,595
420	1027	WINTER SQUASH	154	64,680
420	1026	POTATOES	349	146,580
420	1028	POTATOES	349	146,580
525	1029	SWEET POTATOES	485	254,625
714	1030	SWEET POTATOES	485	346,290

8880	1081	Beef	948	8,418,240