ASSESSMENT OF ENERGY USAGE PATTERNS AND IMPROVEMENT OPPORTUNITIES FOR SMALL-SCALE FARMS IN THE WESTERN NORTH CAROLINA LOCAL FOOD SYSTEM

A Thesis
by
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Abstract

ASSESSMENT OF ENERGY USAGE PATTERNS AND IMPROVEMENT OPPORTUNITIES FOR SMALL-SCALE FARMS IN THE WESTERN NORTH CAROLINA LOCAL FOOD SYSTEM

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The localization of food production is considered by many to be an important step toward a more resilient agriculture system. USDA has acknowledged the social, environmental, and economic benefits of locally grown food, and has shown a commitment to supporting local food systems through a host of programs. USDA has also recognized the important role that energy plays in the security of the national food system with the Rural Energy for America Program (REAP) and the Environmental Quality Incentives Program (EQIP). However, the small farms that are the most common participants in local food systems are not participating in these energy programs in numbers that represent their share of the distribution of U.S. farms. If the U.S. government wishes to create policies that support local food movements, a comprehensive approach for assessing the energy uses and needs of small farms of a given local food system is needed. Such a profile could better equip USDA and local food advocacy organizations to identify and pursue funding opportunities for appropriate energy interventions that benefit small farms in local food systems.

This pilot study used a self-reported survey to create energy use profiles (electricity, propane, natural gas, heating oil, diesel, gasoline, and wood) and identify energy use improvement opportunities for seven types of small farms that serve local markets in western North Carolina (cattle, culinary and medicinal herbs, field crops, fruits and nuts, goats and sheep, horticultural and nursery products, and vegetables). Energy efficiencies per unit of land (in GJ/ha) for each farm type were compared with those observed in national agricultural statistics. Higher proportions of the system-level energy use across all study farm types, as compared to the centralized agricultural system, came from gasoline and electricity, with high variability in energy usage mixes between and within farm types. Opportunities for on-farm energy improvement (mostly in tractor use and irrigation), as well as system-wide energy improvement (mostly in transportation and storage), were available and farmer interest levels were high. Solar energy resources were available on 94% of study farms and, due to the mountain terrain, micro-hydro and passive pump development were possible for an estimated 40% of farms. However, only 7-10% of the farms were eligible for USDA energy grant funding programs.

Preliminary comparisons of energy usage efficiency (in GJ/ha) were made between the study farms and large, centralized farms from literature data, but the low response rate and lack of data about indirect energy usage and agricultural output per hectare suggested further study is needed. Shortcomings of the survey were highlighted and recommendations for attaining a more representative sample were developed. Ultimately, a more focused survey with clarifying follow-up phone interviews could provide a more thorough portrayal of small farm energy usage, needs, and improvement opportunities.

Acknowledgments

This study would not have been completed without the help of a number of individuals to whom I am most grateful. First, I would like to thank my committee chairperson, Dr. Susan Doll, for her continued support of the project and thoughtful advice and comments throughout the course of the study. This study would not have fully materialized without her enthusiasm and patience. Many thanks also to my committee members, Dr. Jeremy Ferrell and Dr. Jeff Ramsdell, for their guidance, engagement, and suggestions for improvement along the way. I would also like to express my appreciation for the department's Graduate Program Director, Dr. Marie Hoepfl, for her regular mentorship and counsel throughout my graduate program.

I would like to extend my gratitude to the five farmers who offered their time to beta-test the survey instrument and provide thoughtful comments when they very well could have been working on any of the myriad other things that come with a busy growing season.

I must also contribute my thanks to the Office of Student Research, the Cratis D. Williams Graduate School, and Logic Springs Technologies, all of which contributed financially to my graduate studies and made this study's conclusion possible.

Finally, and foremost, I would like to thank my wife and partner, Lauren, for her unfailing love and encouragement during the ups and downs of my graduate program. Thank you for pushing me forward, and for helping me see the world in ever new and fascinating ways.

Dedication

This thesis work is dedicated to my parents, who first showed me how to ask questions, and how to move toward answers with patience and levity.

> Give your approval to all you cannot
> understand. Praise ignorance, for what man
> has not encountered he has not destroyed.
> Ask the questions that have no answers.
> Invest in the millennium. Plant sequoias.
> Say that your main crop is the forest
> that you did not plant,
> that you will not live to harvest.
>
> —Wendell Berry, “Manifesto: The Mad Farmer Liberation Front”

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CHAPTER 1: INTRODUCTION

The localization of food production is considered by many to be an important step toward a more resilient agriculture system. The United States Department of Agriculture (USDA) has established a number of programs designed to support the local food sector, a sector that is currently comprised mostly of small farms. While local food production provides numerous benefits to local economies and communities, the viability of local food systems from an energy-use efficiency standpoint hinges on more than just the distance food travels to end-consumers. In addition to energy used in transportation, processing and production energy also have an impact.

There is considerable debate and ambiguity about the energy used on small farms in the emerging sector of local food. If the U.S. government wishes to create policies that support local food movements, a more nuanced look into the energy uses, needs, and improvement opportunities on the small farms predominating the sector is necessary.

Statement of the Problem

The USDA has acknowledged the value of fresh, nutritious, locally grown food and has shown a commitment to supporting local food systems through a host of programs in the past two decades. These programs include the Community Food Service Initiative, which works with communities to "build local food systems, increase food access, and improve nutrition" (Kaplin, 2012, p. 3); the Farmer's Market Promotion Program, which provides promotional support for the sale of locally grown food through farmers' markets; the Community Food Project Grants Program, which supports low-income community food projects; the Women, Infants, and Children (WIC) Farmers' Market Nutrition Program and the Senior Farmer's Market Nutrition Program, which expands access to farmers' markets, CSAs, and roadside stands to low-income seniors; and the National School Lunch or Breakfast Program, through which the USDA provides grants to create farm-to-school programs (Kaplin, 2012).

The USDA has also recognized the important role that energy plays in the security of the national food system. The On-Farm Energy Initiative, through the Natural Resource Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP), assists farmers through cost-share payments for energy efficiency upgrades. Its purpose is to benefit "a farmer's bottom line and help lead the country toward energy independence" (USDA, n.d., p. 1). Through its Rural Energy for America Program (REAP), USDA Rural Development aims to "increase American energy independence" and "lower the costs of energy…for agricultural producers" (USDA, 2015, p. 2) through cost-share grants for renewable energy systems and energy efficiency measures.

However, the smaller farms that are the more common participants in local food systems and concomitant USDA local food programs are not participating in these programs in numbers that represent their share of the distribution of farms in the U.S. agricultural economy. Possible reasons for low small farm participation rates in on-farm energy programs offered by USDA-RD and USDA-NRCS include (1) requirements for expensive audits to identify energy efficiency measures to be made, (2) requirements of current high energy use (3) grant award scoring systems that favor projects with greater economies of scale and are therefore larger projects, (4) project minimums that are higher than a small farm may require for REAP grants, (5) requirements that the improvements not apply to a residence, and (6) the requirement that old infrastructure may be improved, but awards may not be used to build new infrastructure to higher energy standards.

These barriers for small farms serving local food markets could be counterproductive toward the USDA's efforts to support local food systems. Because small farms supporting local food markets typically have a lower per-farm energy use profile than the larger farms that commonly participate in USDA's energy programs, the financial resources necessary to capture their whole-farm energy profile have not been leveraged, and small farm energy assessments on a regional local food system scale have not been performed.

Purpose of the Study

The purpose of this study is to create a profile of the current energy use, energy conservation opportunities, and renewable energy generation opportunities that exist on small farms serving local markets in Western North Carolina. Such a profile is a critical step toward the USDA's various farm energy initiatives being better matched to its local food initiatives.

Research Questions

1. What is the energy use profile (in dollars by fuel type and by farm type, and in Gigajoules per hectare by farm type) of different types of small farms (cattle, culinary and medicinal herbs, field crops, fruits and nuts, horticultural and nursery crops, goats and sheep, and vegetables) in Western North Carolina selling in local food markets?
2. For each farm type, how does the resulting energy use profile compare to the energy use found in the literature for similar farm types in the centralized agriculture system?
3. Based on the energy needs for each farm type, what areas of the farms' total operation present the greatest opportunities and availability of resources for renewable energy and energy efficiency measures to be undertaken?

Limitations of the Study

This study only focuses on one sub-region of one state's local food system. While the energy profile of this region's small farms is likely to differ from that of other regions' small farms, the study itself is replicable, and may be of interest to economic development agencies and local food advocacy organizations in various localities throughout the United States.

Another major limitation of this study is that the data are self-reported by farmers. Exact measurements of energy use, fuel purchases, and operational areas of the farm's energy use were encouraged, but not expected. Instead, estimations from a broadly disseminated survey and case studies with more details from a number of farmers were used.

Only small farms serving local markets in Western North Carolina were surveyed, so results will not be directly applicable to other sizes of farms or other regions of the country necessarily, though the general methodology is adaptable to other survey and assessment applications in other regions.

Energy expenditures were only included if they were direct energy uses. This means that energy used in the manufacture of farm inputs like fertilizers and pesticides, or indirect energy use, is not included.

Data for only one year (2015) was collected, meaning that any changes in farm production practices from growing season to growing season by individual farms, and any events unique to the year 2015 affecting the use of energy on small farms as a whole, were not captured.

While the survey used in this study was distributed in hard copy and digital forms, only digital forms were completed, suggesting a segment of the farming population who may be decidedly less comfortable with computers was missing from the responses.

Significance of the Study

By demonstrating the energy profile of smaller farms that are actively selling in local food systems, local food advocacy organizations and regional economic development agencies can be better equipped to identify and pursue funding for appropriate energy interventions that benefit these farms. The USDA can also be a beneficiary of such a study, as a fuller picture of small farm energy needs can constructively shape future policy and funding decisions as pertains to the pursuit of resilient agriculture systems and the promotion of local food systems.

CHAPTER 2: REVIEW OF LITERATURE

Local Food Movements

There is no standard definition of what makes an agricultural food product "local." The Oxford American Dictionary defines a "locavore" as a resident who tries to eat food grown within a 100-mile radius (Matson, Sullins, & Cook, 2013). The definition adopted by the U.S. Congress in the 2011 Food Safety Modernization Act (FMCA) states that a product can be considered "local" or "regional" if it is purchased within 275 miles of its origin, or within the state where it was produced (Matson et al., 2013).

According to Johnson, Aussenberg, and Cowan (2013) local food activities are varied and numerous, including "direct-to-consumer marketing, farmers' markets, farm-to-school programs, community-supported agriculture, community gardens, school gardens, food hubs and market aggregators, kitchen incubators and mobile slaughter units, on-farm sales/stores, internet marketing, food cooperatives and buying clubs, pick-your-own or 'U-Pick' operations, roadside farm stands, urban farms (and rooftop farms and gardens), community kitchens, small- scale food processing and decentralized root cellars, and some agri-tourism or other types of on- farm recreational activities" (p. ii).

Local food systems are experiencing a surge in popularity and economic activity, and offer a number of benefits to communities and regional economies. Understanding these elements of the local food movement helps to put the movement into context within the larger U.S. agricultural system.

Growth in Local Food Economies

According to the U.S. Economic Research Service, the local food movement is growing. From 2007 to 2012, the number of farms selling in local markets rose from 107,000 to 163,675, with a total of $6.1 billion in sales reported in 2012 (Low et al., 2015). By 2011, more than 2,000 schools nationwide had developed farm-to-school initiatives, and over 7,000 cities and towns had developed farmers' markets. Further, in a poll conducted by the National Grocers Association, over 85 percent of people said that the availability of food from local growers was a part of their decision of where they buy groceries (USDA, 2013).

Benefits of the Localization of Food

Local food advocates proffer a number of different benefits to communities that develop local food systems, including climate change mitigation, economic and ecological improvement, and social benefits.

Climate change mitigation. Many of the benefits offered by the localization of food systems can be viewed through the lens of climate change mitigation. The global food system is a major component of global warming due to its use of fossil fuels and the associated release of greenhouse gases. An estimated 29% of the global warming potential in the activities of modern industrial economies can be attributed to their food systems (Brodt, Kramer, Kendall, & Feenstra, 2013). As the nations of the world develop plans to decarbonize their economies to avoid the worst effects of a changing climate, addressing the carbon footprint of the food system will be an essential component of meeting that challenge.

Proponents of local food systems often emphasize the environmental benefits of reduced transportation distance from farm to consumer, as well as the smaller total farm energy use inherent to small farms, which are often presented as the face of the local food movement. But comparing small farms in local food systems with larger farms in centralized production in terms of greenhouse gas emissions becomes complicated and potentially misleading. Significant variation exists within as well as between these two categories in terms of production methods, pest management techniques, soil conservation strategies, and the ultimate yield per acre in agricultural output that results from these differing farming practices. These nuances are often overlooked in the course of promoting the environmental benefits of local food.

Economic, ecological, and community benefits. There are a number of monetary and non-monetary benefits to the localization of food systems. Local food systems keep money circulating in local economies and keep local land in production. Contamination risks are also lessened when food production is decentralized, since excess agricultural inputs and wastes are less geographically concentrated. Preventing contamination through decentralized production is one reason the U.S. Congress passed the FMCA, in order to ensure higher levels of food safety (Low et al., 2015).

Local food systems strengthen ties within communities, and often present a high-visibility platform for "sustainable agricultural practices," such as crop and insect diversity (for disease prevention and nutrient cycling), cover cropping (for soil health and erosion prevention), and organic production (for reduced use of fossil fuel production inputs) (Cho, 2012).

Another major benefit of local food production is in the ecological localization of nutrient cycling. For example, the phosphorus needed for plants to grow, present in fertilizers and agricultural waste, can travel thousands of miles in conventional food systems. Phosphorus originally found in the soils of Iowa may become incorporated into the grain that is fed to cows in Wisconsin, where it goes into manure that is spread on fields in the Northeast, where it eventually runs off into streams, lakes, and finally the ocean. This imbalance through mass transport of nutrients could be restored through the cycling of such nutrients within a localized food system (Cho, 2012).

Understanding Local Food Systems in Context

Understanding the current state of local food systems requires a closer examination of the U.S. food system as a whole in terms of the types of farms it has, the agricultural goods it produces, and the energy use profile of its farms. Within that context it is then possible to assess similarities and differences in energy use of various farm types and methods in U.S. centralized and local food systems.

The U.S. Food System

The U.S. food system is large and multifaceted. In 2015, the output of U.S. farms contributed $136.7 billion to the U.S. economy, or about 1 percent of gross domestic product (Economic Research Service [ERS], 2017). To better understand the makeup of this network of farms and its relationship to local food systems, this section profiles U.S. farms by size and type, describes the types of farms participating in local food systems, and provides an overview of USDA programs supporting local food programs.

U.S. Farm Profiles

Size. The large majority (90%) of farms in the United States are small, family-operated farms, yet this group produces only 21% of the U.S. food system's output (Center for Sustainable Systems, 2016). Farm size classification is given by the U.S. Census of Agriculture farm typology report, and was revised in 2013 to show an increased upper limit on the sales level that constitutes a "small family farm," from less than $250,000 gross cash farm income (GFCI) to $350,000, and for "large-scale" farms from greater than $250,000 to greater than $1,000,000. Revisions to the typology can be observed in Table 1.

Table 1

USDA Farm Typology Revisions to Income Brackets

	Original Typology	Revised Typology
Small family farms	<$250,000	<$350,000
Retirement farms	<$250,000	<$350,000
Off-farm occupation farms	<$250,000	<$350,000
Farming-occupation farms:		
Low-sales	<$100,000	<$150,000
Moderate-sales	$100,000-$249,999	$150,000-$349,999
Midsize family farms	Category not used	$350,000-$999,999
Large-scale family farms	>$250,000	>$1,000,000
Large farms	$250,000-$500,000	$1,000,000-$4,999,999
Very large farms	>$500,000	>$5,000,000
Nonfamily farms	Not a criterion	Not a criterion

Note. Adapted from *Updating the ERS Farm Typology,* by R.A. Hoppe and J.M. MacDonald, 2013, p. iii.

Even with the expanded upper limits for small farms, the decades-long trend of consolidation of production into midsize and large-scale farms continues. Although the large majority of farms are still small, 79% of production coming from the 10% of U.S. farms that have greater than $350,000 in sales. Remarkably, the 2% of farms with greater than $1,000,000 in sales produce 41% of the nation's agricultural output, as shown in Table 2 (Hoppe & MacDonald, 2013).

Another interesting demographic statistic is that 33% of farms have primary operators 65 years of age or older. Only 6% are under 35 years old, 61% are 35 to 64 years (USDA, 2014a).

Table 2

Distribution of U.S. Farms by Type and Value of Production

	Distribution of farms	Distribution of value of production
Small farms:		
Retirement	16.6%	1.3%
Off-farm occupation	43.5%	4.9%
Farming occupation:		
Low-sales	25.4%	6.3%
Medium-sales	4.6%	8.5%
Midsize	5.6%	25.8%
Large-scale farms:		
Large	1.8%	28.2%
Very large	0.2%	12.7%
Nonfamily	2.3%	12.3%
	100%	100%

Note. Adapted from *Updating the ERS Farm Typology*, by R.A. Hoppe and J.M. MacDonald, 2013, p. 10.

Agricultural products categories. In addition to being subdivided by farmer occupation or size based on gross cash farm income, U.S. farms are also subdivided by the types of agricultural products they produce. In the 2012 Census of Agriculture, the following categories were used to subdivide farmers by agricultural product: grains, oilseeds, dry beans and dry peas (includes corn, wheat, soybeans, sorghum, barley, rice, and other); tobacco; cotton and cottonseed; vegetables, melons, potatoes, and sweet potatoes; fruits, tree nuts, and berries; nursery, greenhouse, floriculture, and sod; cut Christmas trees and short-rotation woody crops; other crops and hay; cattle and calves; milk from cows; hogs and pigs; sheep and goat products; horses, ponies, mules, burros, and donkeys; poultry and eggs; aquaculture; and other animals and other animal products (USDA, 2014a).

In Figure 1, two heat maps—graphical representations of data where the individual values contained in a matrix are represented as colors—show the intensity of production for various crops and animals across the U.S. and their different centers of production. Fruits and vegetables are grown in greatest intensity in the central valley of California, with wheat, soybeans, and corn predominating in the Midwest and Great Plains regions (Rankin, 2009a, 2009b). In North Carolina, the Coastal Plains show some concentration of high cropland usage, and the crops with highest sales in the state in 2012 were tobacco (number one producer in the country), soybeans, corn, sweet potatoes, and hay. North Carolina, the location of this study, dominates with several animal production industries. The state is first in the country in poultry and egg production, and second in the country in both hogs and turkeys (NASS, 2017). More specifically, the western 23 counties of North Carolina are largely comprised of the southern range of the Appalachian Mountains, and thus the utilization of land for crops and animals is low relative to the rest of the state, and especially in relation to the U.S. at large. This is an important feature of this study when considering its potential for generalizability.

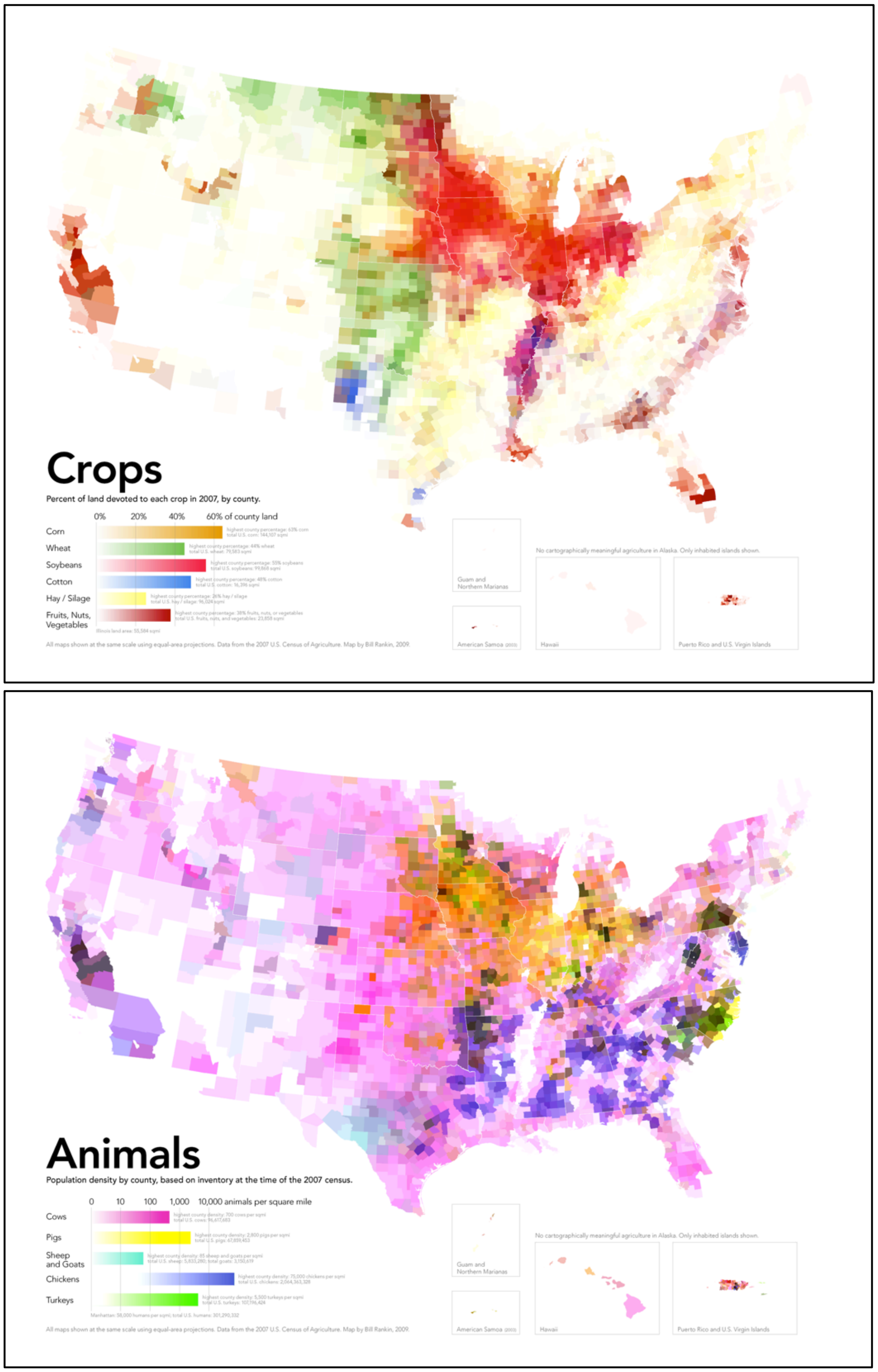

Figure 1. Two heat maps generated with 2007 Census of Agriculture data by B. Rankin (2009a, 2009b).

Farms Participating in Local Food Systems

Size of local food farms. Only 7.8% of all U.S. farms in 2012 were engaged in local food sales (Johnson et al., 2013). The distribution of farm sizes within the local food sales subset leans more toward small farms than the U.S. food system as a whole does, with 95% of local food sales farms being from small farms, as seen in Figure 2. It can also be seen that small farms serving local markets account for 33% of local food sales, as compared to 21% of food sales in the U.S. food system at large. Further, 86% of local food farms have less than $75,000 in sales (Low et al., 2015). This shows that local food systems have a larger rate of participation by small—and especially low-sales—farms than is shown in the U.S. food system as a whole.

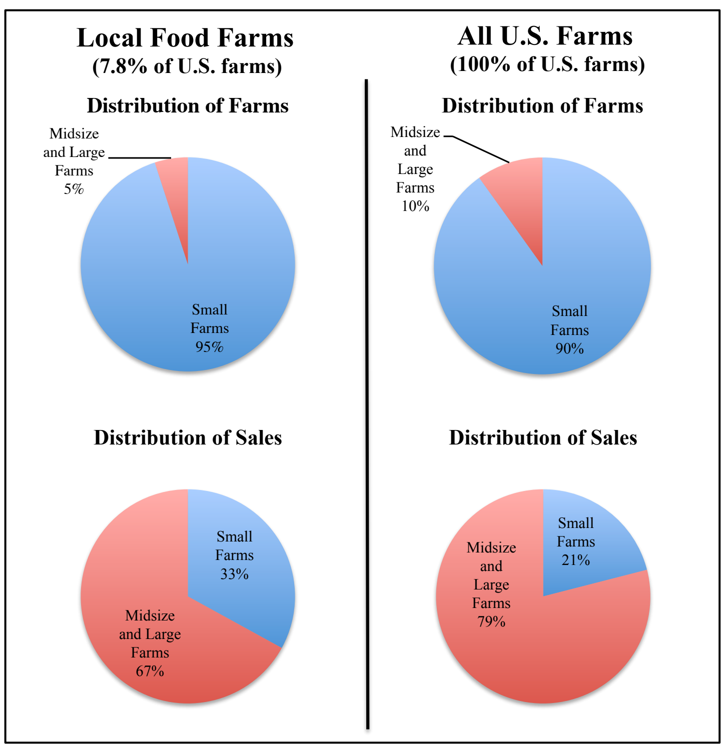

Figure 2. Comparison of small farm distribution in the local food system and the U.S. food system as a whole Adapted from *Trends in Local and Regional Food Systems*, by S.A. Low et al., 2015, p. 11, and *Updating the ERS Farm Typology*, by R.A. Hoppe and J.M. MacDonald, 2013, p. 10.

Agricultural products of local food farms. The distribution of farm types participating in local food systems differs further still from the overall U.S. food economy's farm type distribution. For example, twenty-nine percent of all farms serving local markets are vegetable, fruit, and nut producers, and account for 51% of all sales in local food systems. Further, only 3% of all other crop farms and only 8% of livestock and livestock product farmers in the national agricultural farm system sold their products through local food marketing channels (Low et al., 2015).

USDA Programs Supporting Local Food Systems

In 2010, when the USDA laid out its five-year strategic plan, Secretary of Agriculture Tom Vilsack acknowledged the important role of local farms, saying, "an increased emphasis on regional food systems will have direct and significant benefits to rural communities. Increased economic activity in food-related sectors of the economy helps communities build and maintain prosperity. USDA will work closely with all its strategic partners... to develop and revitalize the critical infrastructure necessary for vibrant regional food systems" (USDA, 2013, p. 6). Accordingly, various USDA programs supporting the development of local food systems have emerged. These programs can be grouped into six general categories: marketing and promotion, business assistance, rural and community development, nutrition and education, agricultural research and cooperative extension, and farmland conservation (Johnson, Aussenberg, & Cowan, 2013). The reasons stated by USDA for supporting local food, according to the Agricultural Marketing Service (McFadden et al., 2017), include the opportunities for entrepreneurship, improved negotiating power of local producers, revitalization of rural communities, and the protection of severe economic shocks through the decentralization of food production.

The USDA programs specifically supporting local food include the Local Food Promotion Program (LFPP), Women, Infants, and Children (WIC) Farmers' Market Nutrition Program, Community Food Project Grants, the Senior Farmers' Market Nutrition Program, the Federal State Marketing Improvement Program, the National Farmers' Market Promotion Program, the Specialty Crop Block Grant Program, Community Food Services Initiative, and the Community Facilities Program (Martinez et al., 2010). Examples of projects funded through these programs include rural cooperative grants, selected child nutrition programs, new enterprise business loans, and the creation of local food policy councils.

Because smaller farms rely more heavily on direct-to-consumer sales through farmers' markets and other such community food avenues that are supported by these USDA programs, they are inherently beneficiaries of programs that bring more consumers and institutions into business with local farms.

Energy Use in U.S. Agriculture

U.S. farms make use of various sources of energy in activities across all steps of the value chain. This section provides an overview of national statistics regarding energy use in the agricultural sector, a description of the major farm activities that require the use of energy, and USDA programs supporting on-farm energy improvement projects.

National Agricultural Energy Use Statistics

Types of energy used. The USDA classifies agricultural energy use into two categories: direct and indirect energy use. The scope of this study is limited to direct energy use, but an overview of both is important to include here to provide context for the study.

Direct energy use. Direct use includes diesel and gasoline to run machinery for field operations such as planting, tilling, and harvesting, as well as for drying, livestock use, and transportation of goods. Direct use also includes electricity for heating and cooling in livestock or dairy production and for irrigation (Beckman, Borchers, & Jones, 2013). In 2011, 63 percent of the total energy consumption of U.S. agricultural operations came from direct energy uses, with the dominant share going toward liquid fuels for field equipment, as seen in Figure 3.

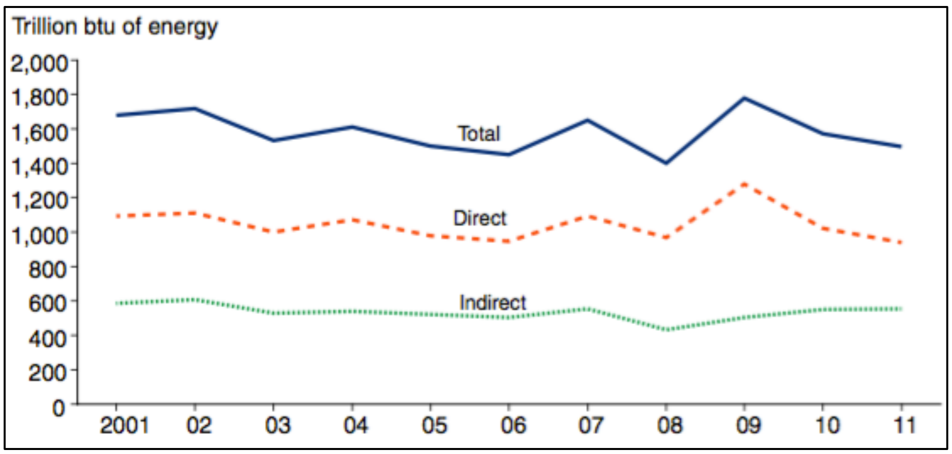

Figure 3. Share of direct and indirect energy consumed on U.S. farms from 2001-2011 (Beckman et al., 2013, p. 9)

Indirect energy use. Indirect use of energy refers to the embodied energy (i.e. the energy used to produce goods) in energy-intensive farm inputs such as fertilizers, pesticides, herbicides, and fungicides. According to the USDA (Beckman et al., 2013), over half of the indirect energy use in U.S. agriculture comes from fertilizers. Fifty-nine percent of the fertilizer consumption in 2010 was from nitrogen-based fertilizers, with potash and phosphate making up 21 and 20 percent, respectively. Slightly less than half of the indirect energy use of U.S. agricultural production comes from pesticides, herbicides, and fungicides.

A detailed breakdown of energy used by each of these specific energy types is seen in Figure 4.

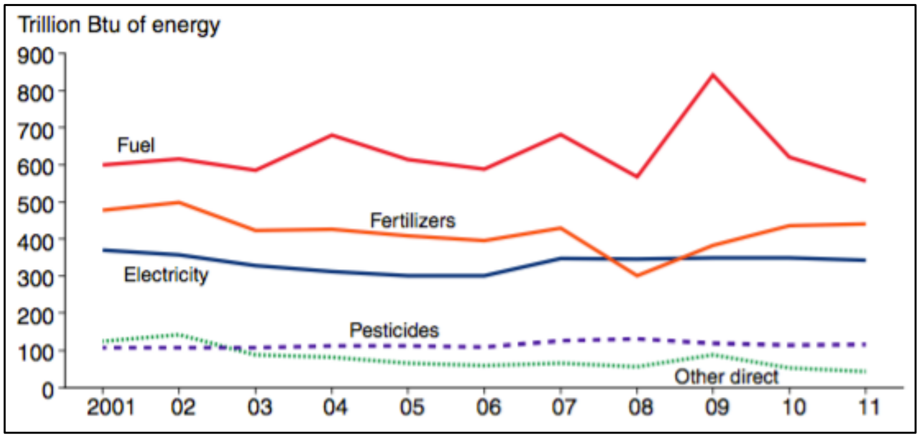

Figure 4. Energy inputs consumed on U.S. farms by component (Beckman et al., 2013, p. 10)

A detailed view of the percentages of energy use by source in U.S. agriculture is seen in Figure 5. In this depiction, pesticides and fertilizers represent the indirect uses, while the remaining are direct uses. See "On-Farm Energy Use Activities" below for a description of the different farm activities that use these energy sources.

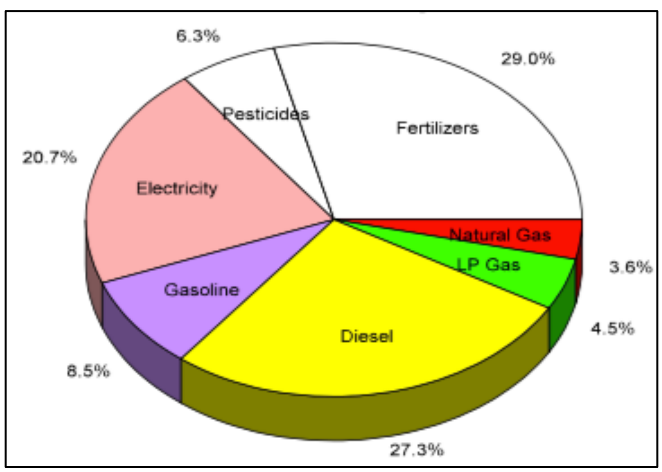

Figure 5. Total direct and indirect energy used on farms in 2002, by source. Adapted from *Energy Use in Agriculture* by R. Schnepf, p. 5.

The total amount spent and the share of expenses dedicated to direct and indirect energy uses varies widely across different farm categories. The relative expenses of four major categories of farm expenses, fuel and lubricant, pesticides, fertilizer, and electricity, are shown in Figure 6. The cotton and rice category has by far the highest total expenditures with beef cattle having the lowest.

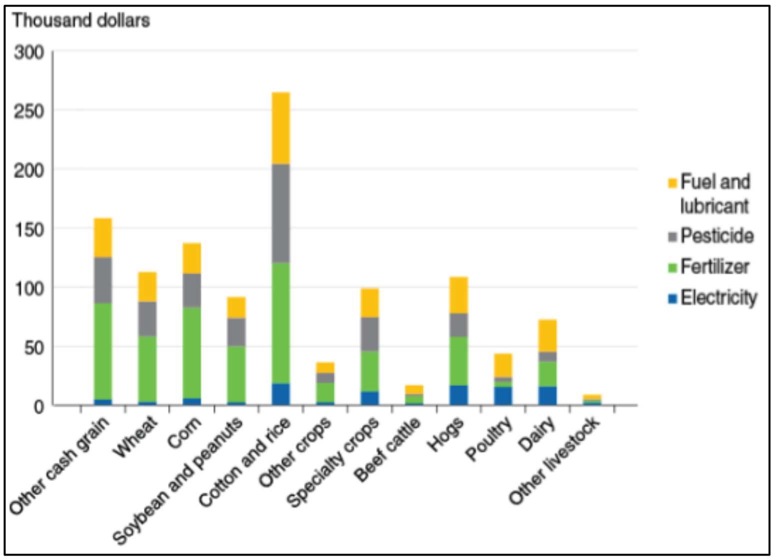

Figure 6. Average energy-based expenses by U.S. farm type (Suttles, 2014).

Renewable energy use on farms. According to the 2012 US Census of Agriculture, 2.7% of the nation's farms use renewable energy of some kind. The majority (1.7%) have solar panels, while wind turbines and geothermal systems each claim 0.4% (National Agricultural Statistics Service [NASS], 2012, Table 52).

Organic vs. conventional farming. The use of energy can vary widely between conventional farms and organic farms due to the former's regular use of energy-intensive indirect inputs from the manufacture, shipping, and application of fossil fuel-derived pesticides and fertilizers. While organic agriculture uses less of these inputs, it is not always the least energy intensive mode of production (Hill, 2009).

Some organic production farms are designed for ecological health, with production practices designed to build soil and decrease pest pressure through integrated management of on-site resources. Others behave similarly to conventional systems of mono-cropping or intensive animal operations, with the exception of not using synthetic inputs. For this reason, it is difficult to characterize a “typical” organic farm. When comparing energy intensities with conventional systems, though, the major factor in need of consideration is the energy use per unit of farm output. While organic operations almost always use less fossil fuel energy per unit of land area in production, the results can be more variable when considering the energy use per unit of farm output, and results depend largely on the type of farming being investigated (Smith, Williams, & Pearce, 2014).

Geographical variations in energy use. Intensity of energy use varies widely across different areas of the U.S., with the highest energy uses coming from the Corn Belt and Mountain States regions, as seen in Figure 7. A strong correlation exists between energy use and production levels (USDA, 2008), which can be confirmed visually by comparing Figure 7 with Figure 1. North Carolina, home to the local food region observed in this study, has a relatively low level of energy use compared to other areas of the country.

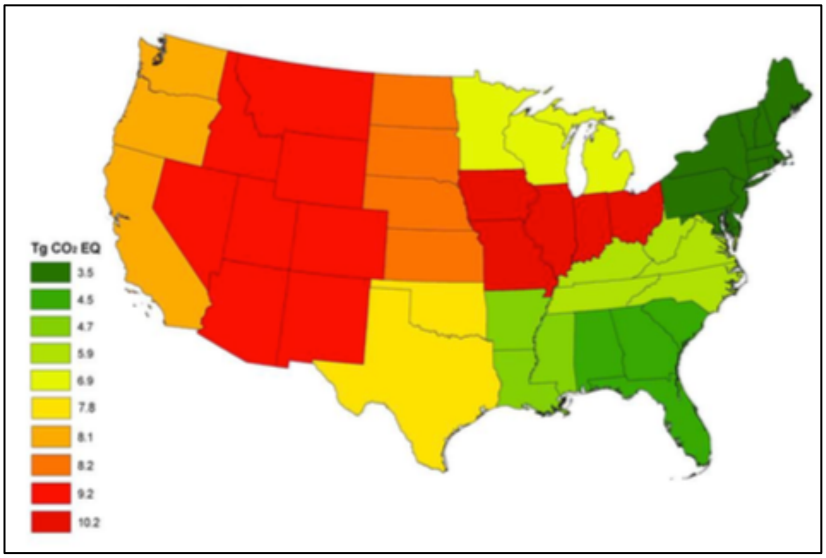

Figure 7. Farm energy use by region in 2005. Adapted from USDA's *U.S. Agriculture and Forestry Greenhouse Gas Inventory 1990-2005*, 2008, p. 81.

Other factors affecting on-farm energy use and impacts. Beyond fossil fuel use and energy use improvements through renewables and energy efficiency measures, there are other important factors that have less direct but certainly impactful effects on the future environmental stability of the U.S. agriculture system. Examples include reducing tillage in field management for carbon sequestration and water retention and agro-forestry techniques that integrate woody biomass materials for agriculture, fuel, or material use within traditional agricultural operations (Woods, Williams, Hughes, Black, & Murphy, 2010). Such considerations are outside the scope of this study but should not be excluded from the larger conversation about a resilient farm future.

On-Farm Energy Use Activities

Different studies choose different boundaries for assessing the energy use of the food system. Some look at the food system as a whole and include retail, commercial, and residential activities, as seen in the Figure 8. This study, however, focused on the energy use of activities relating specifically to the farm and its operators. These energy use activities can be divided into four major stages of the supply chain: production, processing, packaging, and transport. The production stage in particular is where direct and indirect energy uses are often subdivided. In Figure 8, farm fuels and farm irrigation are considered direct energy uses, and farm chemicals and farm machinery are considered indirect uses. This study focuses only on the direct energy use within the four major stages of farm energy use, which are shown in Figure 9. Farm types vary in their typical distribution of energy use activities across these stages.

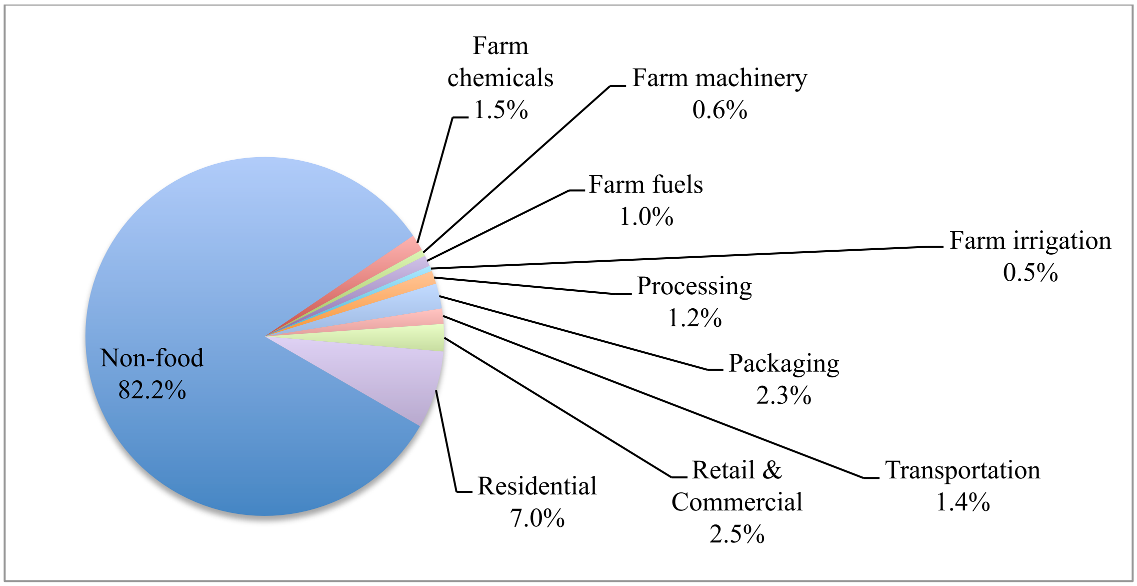

Figure 8. Distribution of U.S. direct and indirect energy uses, shown in detail by food sector activities and consolidated in the non-food sector. Adapted from *Energy Use in American Food Production* by M. Minn, 2009, p. 7.

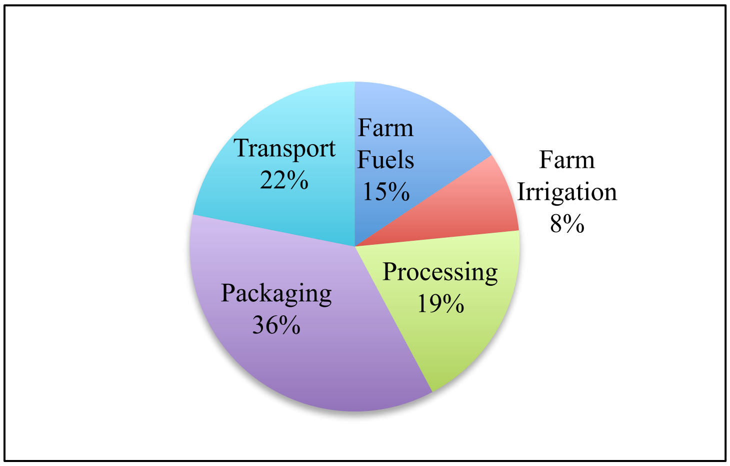

Figure 9. Distribution of U.S. direct energy uses in the food sector from production to transport. Adapted from *Energy Use in American Food Production* by M. Minn, 2009, p. 7.

Production. Energy use activities in the production stage include tilling, planting, cultivating, disking, harvesting, and applying fertilizers and pesticides. These activities are typically performed by diesel-powered machinery for larger farms and gasoline-powered equipment on smaller farms. Irrigation is also a production activity. While electricity is the primary power source for irrigation on U.S. farms (24.1 million acres in 2005), diesel (12 million acres) and natural gas (5 million acres) are also used. The other major energy use activity in the production phase is the use of thermal fuels like propane and natural gas to dry crops such as grain and tobacco and to heat greenhouses (USDA, 2008).

Processing. Processing steps vary widely based on agricultural commodity and the end product involved. Examples include corn milling, cheese making, and fruit and vegetable canning. Dairies rely heavily on electricity for the processing of their products (USDA, 2008).

Packaging. As with processing, the energy use at this stage is largely dependent on the food product in question.

Transport. Energy use activities in the transport stage involve moving products to off-site locations, which may be retail and commercial venues like restaurants grocery stores, or directly to end-consumers through local food marketing venues like farmers' markets and CSAs.

USDA Programs Supporting On-Farm Energy Projects

The USDA has also recognized the important role that energy plays in the security of the national food system. The On-Farm Energy Initiative, through the Natural Resource Conservation Service's (NRCS) Environmental Quality Incentives Program (EQIP), assists farmers through cost-share payments for energy efficiency upgrades. Its purpose is to benefit "a farmer's bottom line and help lead the country toward energy independence" (USDA, n.d., p. 1). Through its Rural Energy for America Program (REAP), USDA Rural Development aims to "increase American energy independence" and "lower the costs of energy…for agricultural producers" (USDA, 2015, p. 2) through cost-share grants for renewable energy systems and energy efficiency measures.

Energy Use in Local Food Systems

As mentioned previously, making an accurate assessment of local food farms' energy use can be complicated because of their smaller size. Often, local food farms are diversified, and have multiple agricultural products being produced over time on land that has a rotation of different agricultural uses or is shared with other agricultural products. These small, local food farms can also vary widely within a given region in terms of what mix of activities they are engaged in across the supply chain. Further, the integration of energy used for residential and personal activities that often occurs on a small local food farm creates difficulty in assessing energy use specifically associated with food production, in comparison to large, conventional farms with large, dedicated purchases of fuels and farm inputs.

"Food miles," or the distance food travels from its place of production to its place of consumption, is a concept used frequently in the promotion of local food systems, with the suggestion that fewer miles from farm to plate necessarily equates to lower greenhouse gas emissions. However, this can often be a misleading indicator. For example, economies of scale in the transport of large quantities of agricultural products may result in a lower carbon footprint when compared with very small producers bringing small quantities of fresh products to a market 100 miles away from the farm in inefficient farm vehicles. Further, transportation accounts for only 11-15% of the food system's total global warming potential (Kaplin, 2012), and Weber and Matthews (2008) show that only a 5% reduction occurs by localizing an individual's food choices. Perhaps most importantly, supply chains of different lengths are almost never identical. Load sizes, methods of transport, fuel types, and frequency of trips are likely to vary, and thus will result in a wide variation of energy use and emissions per unit of food produced (Martinez et al., 2010). One study even found no statistically significant difference in the impact from transportation between local and conventional models for 10 different foods, though the wide variations in load sizes in the local model suggested greater room for improvement than in the conventional system (Glettner, 2008). In any event, "both the supply-chain and life-cycle analyses suggest that the local food movement, in emphasizing food miles at the expense of other components of the food system, misses the mark if its goal is to reduce GHG emissions" (Kaplin, 2012, p. 154).

A complete assessment of local food system energy use and GHG emissions requires the consideration of all stages of food production and distribution. Other contributions to energy use and emissions—particularly related to production, processing, storage, and preparation—may be as important as transportation in assessing the overall impact of local food systems. Ultimately, a full accounting of not just energy use, but energy use per some unit of production measure, becomes necessary; and such a measure, if it is to be designed to draw a comparison with the energy efficiency of non-local food systems, needs to include all steps in the value chain.

Comparing Energy Use

Comparing the energy use of small farms participating in local food systems with that of larger farms in the more centralized U.S. agricultural economy requires some standard unit to serve as a basis of comparison. Energy use per unit of production (e.g. Gigajoules per ton of tomatoes) may be the best way to establish a fair comparison, while energy use per unit of land area (e.g. BTUs per acre, Gigajoules per hectare) leaves unanswered questions about the production efficiency of the land, the farm operation, and the production strategies under consideration for each unique farm. However, because local food systems—when viewed through the lens of regional resilience in the face of food security risks—contain many different farm types with a multitude of production practices affecting their per-hectare production efficiencies, and because record-keeping standards about volume of products sold varies for the low-sales small farms participating in this study, this study drew comparisons between local food farms and non-local food farms using the measure energy use per unit of land area.

Energy Efficiencies of Various Farm Types

Some efforts have been made in the literature to assess the energy use per unit of farmland area for many farm types. The unit of measure commonly seen is Gigajoules per hectare (GJ/ha). This measurement of energy use on farms includes on-farm diesel and gasoline use, irrigation energy, electricity, and fuel for transportation of products. It does not include the indirect uses of energy from fertilizers and pesticides, unless otherwise noted. The studies from Pimentel & Pimentel (2007) encapsulate the entirety of U.S. food production, while other studies are derived from case studies. Pimentel & Pimentel have a tendency to use old data that has been aggregated across the economy as a whole, possibly not accounting for the recent decades' improvements in farm sector energy efficiencies, but they are widely cited in the literature and provide a clear framework for distributing energy use across the different areas of farm operations (Minn, 2009; Schnepf, 2004). Figure 10 shows a summary of the energy efficiencies recorded for each farm type that will be further detailed below.

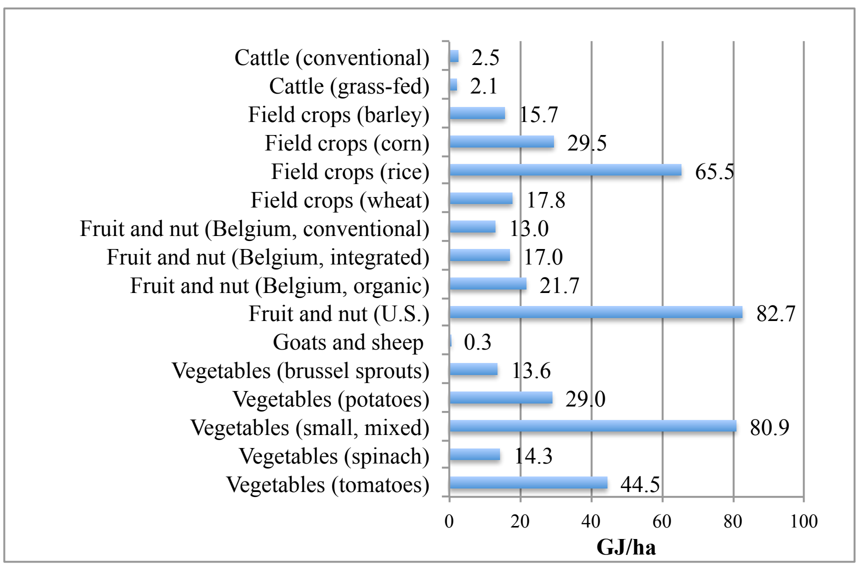

Figure 10. Energy efficiency of different agricultural products measured in direct energy use (GJ) per unit of land area (ha) (Pimentel & Pimentel, 2007; Annaert et al., 2015; Schramski et al., 2014).

Cattle. The direct fossil fuel energy use per hectare observed in beef cattle operations is 2.5 GJ (Pimentel & Pimentel, 2007). If grass-fed, the figure drops to 2.1 GJ/ha due to reductions in fossil fuel use related to feed production.

Field crops. Field crops represent a broad category that includes crops of varying energy use requirements, including barley, wheat, corn, and rice. These crops, respectively, are listed as requiring 15.7 GJ/ha, 17.8 GJ/ha, 29.5 GJ/ha, 65.5 GJ/ha **(**Pimentel & Pimentel, 2007).

Fruit and nut growers. Pimentel and Pimentel (2007) list US apple growers as requiring 82.7 GJ/ha, while a similar study done on Belgian apple producers from 2015 showed much lower numbers. That study (Annaert, Vranken, & Mathijs, 2015) showed that conventional apple growers used an average of 13 GJ/ha, integrated producers used an average of 17 GJ/ha, and organic producers used 21.7 GJ/ha. The estimates in this study did not include product cooling and storage, but did include indirect energy use from fertilizers and pesticides. A wide variation of greater than 40% was reported for these indirect energy uses across and even within each of the three apple-growing methods observed in the study.

Goats and sheep. Pimentel and Pimentel (2007) list grass-fed sheep operations as requiring 0.3 GJ/ha in fossil fuel energy use, the lowest figure of all farm types reported here. Data for factory-farmed sheep operations and goat operations of all kinds could not be found, nor could figures for goat and sheep dairy operations.

Horticultural and nursery producers. No data could be found regarding the energy use per unit of land area for horticultural and nursery operations, likely due to the intensive nature of these operations and the extent to which energy use would be more closely linked to geographical location than to levels of production or footprint of growing area.

Vegetable growers. The energy use per unit of farmland for vegetable operations varies widely across different vegetables (Pimentel and Pimentel, 2007). Low fossil fuel energy users include spinach (14.3 GJ/ha) and brussel sprouts (13.6) while potatoes (29.0 GJ/ha) and tomatoes (44.5 GJ/ha) are relatively higher in their usage. Most small-scale producers participating in local food sales and marketing are mixed vegetable operations. An equally weighted average of these four vegetable types yields 25.3 GJ/ha.

A more recent study performed at the University of Kentucky's 2.5 hectare organic farm analyzed the direct and indirect fossil fuel inputs for a season of production. The direct use of fossil fuels from production to market totaling 80.9 GJ/ha was observed for their small scale mixed vegetable production (Schramski, Jacobsen, Smith, Williams, & Thompson, 2014).

It is difficult to discern the reasons for the apparent large difference between the two styles of vegetable farming. The likeliest explanation is the efficiencies of scale inherent to the Pimentel & Pimentel studies. Those studies, too, were not focused on organic production as is the case with the Schramski et al. study. The greatest reduction in fossil fuel use from organic production is through the decreased use of synthetic pesticides and mineral fertilizers, which account for 25-68% of total energy use in conventional farms, depending on the farm type (Ziesemer, 2007). However, because these inputs are indirect energy use, they are not included in either of the numbers listed here for the Pimentel & Pimentel or the Schramski, et al. studies. Because they are only concerned with direct energy use, the benefits of decreased indirect energy inputs in the Schramski et al. study are not seen.

A graphical summary of the farm types listed above and the respective ranges of direct energy use per unit of land area can be seen in Figure 11. Note that the reported figure for goats and sheep from Pimentel (0.3 GJ/ha) is too low to appear on the graph.

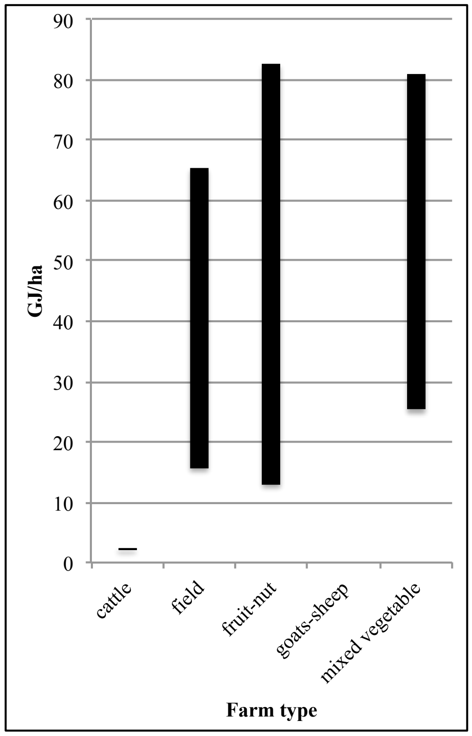

Figure 11. Energy use per unit of land area of different farm types, expressed as the range reported in prior studies.

Difficulties in Small Local Farm Energy Assessments

The energy use of large-scale agricultural operations is more frequently studied in the academic literature as compared to small-scale farms participating in local food systems. Even in studies comparing local and non-local foods, the farms under consideration are always large farms with production levels that would suggest that they would fall somewhere in the “midsize” to “large” farm size categories in the U.S. Such studies have been done for apples in the UK (Jones, 2002), Switzerland (Mouron Nemecek, Scholz, & Weber, 2006), New Zealand (Milá i Canals, Burnip, & Cowell, 2006); potatoes in Sweden (Mattsson &

Wallen, 2003); sugar beets in the UK (Tzilivakis, Jaggard, Lewis, May, & Warner, 2005); field crops in Switzerland (Nemecek & Erzinger, 2005); and greenhouse tomatoes in Spain (Anton, Montero, Munoz, & Castells, 2005) and the Netherlands (Nienhuis & de Vreede, 1996). Discerning the greenhouse gas emissions of the small farms engaged in farmers' market sales and community supported agriculture programs—programs supported by the USDA—is apparently not attempted in the literature.

Comparing energy use of agricultural systems requires a comprehensive look at a great number of variables. The task is made all the more difficult when there are insufficient datasets for equal representation of all categories of farm units. In particular, small farms serving localized food systems require a framework for assessing their energy use across all stages of agricultural production.

Assessing Local Food System Energy Use

Agricultural energy assessments are a common method of identifying opportunities for farms to reduce energy consumption and expense through improved energy practices, behaviors, and the use of energy-efficient equipment. Such assessments often take the form of a farm energy audit and follow the standards outlined by the American Association of Agricultural and Biological Engineers (ASABE) (Framel, 2009). These audits are a required step in the pursuit of cost-share funding for energy efficiency improvements on farms offered by two federal programs, USDA Rural Development's Rural Energy for America Program (REAP) and NRCS's Environmental Quality Incentives Program (EQIP). The payment for audits themselves can be eligible for cost-share funding through these programs as well.

Hurdles to Energy Assessments for Small Farms

Due to the high cost of an audit performed by a professional engineer, a farm generally must be consuming a large amount of energy to justify the time and money involved in having an audit performed on their operation, usually on the order of $10,000 per year or more, according to the North Carolina NRCS technical assessment office (S. Smith, personal communication, January 18, 2016). Gasoline and diesel use for transportation do not count toward this benchmark. Further, if a farm is producing livestock as well as vegetables or field crops, those operations are seen as distinct and separate enterprises and would not be permitted on the same application (Framel, 2009) For these reasons, it is not common to see small or diversified farms that participate in local food economies applying for energy efficiency improvements through these programs. This assessment structure instead tends to only provide knowledge of farm energy use on large, centralized, non-diversified, capital-rich enterprises. In addition, the scoring system for these programs favors such larger farms, according to the North Carolina state administrator for USDA-REAP funds (D. Nesbitt, personal communication, November 14, 2015). As a result, these are the farms most commonly awarded cost-share funding for energy efficient infrastructure improvements.

To summarize, the main reasons that small farms participating in local food systems often turn up ineligible for USDA on-farm energy improvement grant programs are (1) requirements for expensive audits to identify energy efficiency measures to be made, (2) requirements of current high energy use, which is not always the case for small—especially new and beginning—farmers, (3) grant award scoring systems that favor projects with greater economies of scale and are therefore larger projects, (4) project minimums that are higher than a small farm may require for a project that could benefit from a REAP, (5) requirements that the improvements not apply to a residence, which is often a space of shared energy use for the farm business, and (6) the requirement that old infrastructure may be improved, but awards may not be used to build new infrastructure to higher energy standards (D. Nesbitt, personal communication, November 14, 2015).

Conclusion

The U.S. food system is comprised of a wide range of farm types and sizes, from large, conventional operations with hundreds of thousands of dollars in sales per year to small operations making supplemental income selling agricultural products in local farmers markets. Energy audits and assessments are commonly and readily performed for large operations that have a high enough energy use to justify the investment in such professional assessments in the pursuit of cost-saving energy efficiency upgrades or renewable energy generation. Less is known about the carbon footprint of small, diversified farms serving local markets, and a comprehensive model for assessing the energy uses and needs of small farms of a particular locality does not exist.

If a resilient and robust future food system is to include the small, decentralized farms currently serving localized food markets, having a framework for assessing the current energy use and opportunities for renewable energy systems and energy efficiency improvements for these small farms is a critical step toward that future. Such a framework could provide small, local farms and their community development advocates with the tools and knowledge to improve their operations both in economic and environmental terms. It could also help to communicate to USDA the specific energy improvement needs of a particular local food system as USDA continues to strengthen small farms and local economies through its local food support programs.

CHAPTER 3: RESEARCH METHODOLOGY

Overview of Research Design

The aims of this research are to (1) observe the patterns in energy use for small farms participating in local food systems, (2) compare those energy use patterns to those observed in the literature for larger scale, centralized farms, and (3) identify potentially beneficial energy-efficiency and renewable energy strategies and the barriers to achieving those with USDA grant funding. The study utilized a descriptive research design, observing subjects in a natural and unchanged environment with no variables being manipulated and no hypothesis being proven or disproven. The study data provide a general overview of the types, amounts, and end uses of energy being used by small farmers in western North Carolina. Information was collected through two research instruments: a quantitative survey and qualitative follow-up interviews. This chapter describes the participants in the study, the research instruments used for the study, data collection strategies, and data analysis procedures.

Study Participants

The participants in this study were a group of small farmers in western North Carolina participating in local food markets. Respondents were confirmed as members of the intended demographic for the study on the basis of their location, their farm size, and their reported degree of activity in the local food system; they were organized primarily by their farm type.

Location

The subjects of this study are small farms in western counties of North Carolina serving local markets. The state of North Carolina is commonly divided into three major geographic regions: the Coastal Plains to the east, the Piedmont in the center, and the

Mountains to the west. Figure 12 shows the western 23 mountain counties from which data was gathered from farm operations. These counties include Alleghany, Ashe, Avery, Buncombe, Burke, Caldwell, Cherokee, Clay, Graham, Haywood, Henderson, Jackson, Macon, Madison, McDowell, Mitchell, Polk, Rutherford, Swain, Transylvania, Watauga, Wilkes, and Yancey. Focusing on the mountain counties helped to minimize differences in energy use caused by large differences in climate and topography.

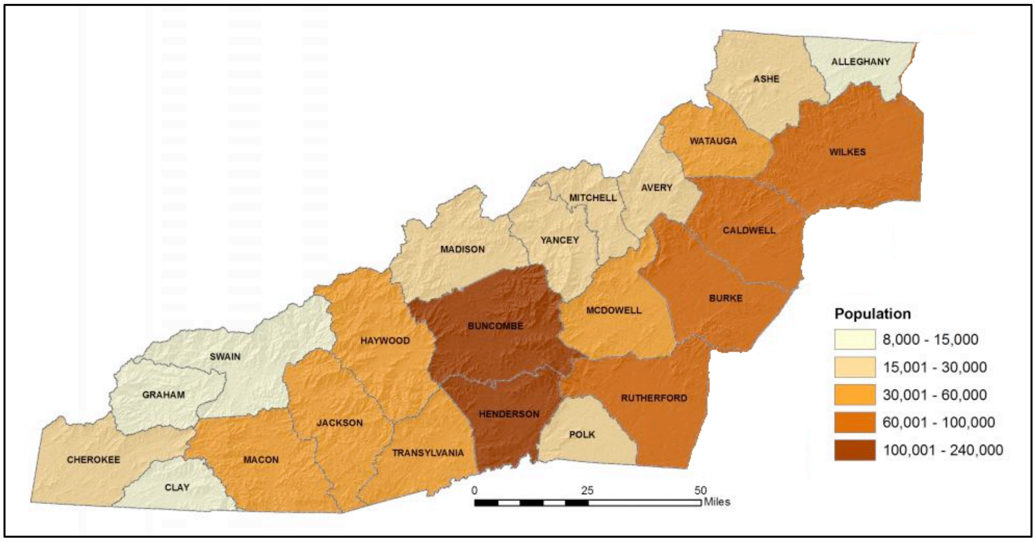

Figure 12. The 23 counties of Western North Carolina and their populations. Adapted from the Western North Carolina Vitality Index webpage ("Current Population," n.d.).

This region is part of the Appalachian Mountains and contains the highest mountains east of the Mississippi River. The region contains few major urban centers. Asheville, located in Buncombe County, lies roughly in the center of the region, is home to about thirty percent of the region's population as of 2010, and is the main commercial hub. Population density in the region at large is a sparse 121 people per square mile, which is lower than the state average of 196. Eighty-eight percent of people in the region are considered white, a higher percentage than the national average of around sixty-five percent ("Current Population," n.d.).

Farm Size

The subjects of this research are small farms as classified by the USDA Economic Research Service (ERS) typology described earlier in Table 1 as "Original Typology." By this definition, it can be seen that small farms in the U.S. represent 88% of all U.S. farms (Young, 2015). Further, farms with $100,000 or less in gross sales represent of 81% of all farms nationally.

Based on these same thresholds and information from the National Agricultural Statistics Service (NASS), it can be estimated that 96% of the farms in the 23 western counties of North Carolina (10,466 farms out of 10,912) are classified as small farms (less than $250,000 in gross sales), and of those, 93% had less than $100,000 in gross sales (low sales). This indicates that the region's farms are substantively smaller with lower sales than national averages. Further, if the revised typology thresholds of $350,000 for small farms and $150,000 for low-sales small farms were used, these percentages would be even higher. Therefore, it is evident that an overwhelming majority of farms in western North Carolina are small farms, over and above the national average. In addition, the Appalachian Sustainable Agriculture Project (ASAP) reports that more than half of all farms in the region operate on fewer than 50 acres (Kirby, Jackson, & Perrett, 2007). Nationally, 39% of farms operate on fewer than 50 acres (USDA, 2014b). Therefore, while the distribution of farm types and sizes in the study area are not representative of national averages, the focus of the research on small farms is highly relevant to the vast majority of farms in the NC mountain counties.

Local Food Producers

Participants in this study had a variety of market distances from their origins of production, and were classified according to the distances to market: less than 100 miles, less than 275 miles, and greater than 275 miles as shown in Figure 13. Farmers marketing their products below the 275-mile threshold were considered "local" for this study, in keeping with the previously described definition prescribed by USDA.

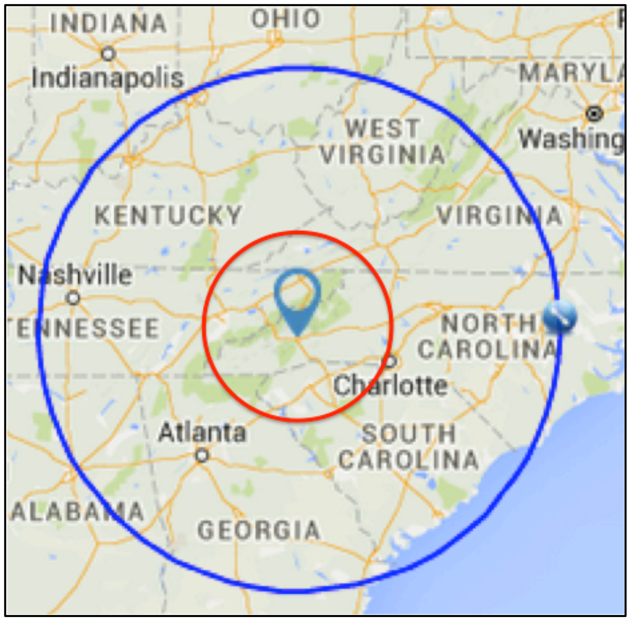

Figure 13. Example map of local food radii around Asheville, NC. The outer blue circle represents a 275-mile radius, and the inner red circle represents a 100-mile radius (Generated using "Radius Around Point" from Free Map Tools).

Of the estimated 10,466 small farms in the 23 western counties of North Carolina, the percentage with agricultural food products reaching end-consumers fewer than 275 miles away is unknown. However, the national average of farms marketing food locally (such as direct-to-consumer sales, farmers' markets, and CSAs) or using intermediated marketing channels (such as sales to institutions of regional distributors) has been estimated to be 7.8% (Low et al., 2015). Due to the high percentage of small farms in the study area, and the finding that 95% of agricultural producers participating in local food markets are small farms (Low et al., 2015), this estimate is likely somewhat low as a representation of western North Carolina farms engaged in local food marketing. Therefore, using the national average as a the low end estimate, the sampling pool of small farms in the 23-county region study area that market their food locally is between 800 and 1,000 farms.

The goal of this study is to analyze the data from at least 80 (10% of the estimated number) small farms serving local markets in the 23 western North Carolina counties. Participants were recruited through several channels, including County Extension office farmer lists, Soil and Water Conservation District farmer lists, and local food advocacy group email lists. Because a vast majority of area farmers were in the small farm target group, recruitment efforts invited all farmers (including medium- and large-scale) in these counties to further validate the data; however, the analysis of energy use, energy system improvement opportunities, and cost-share funding suitability were limited to small farms as defined above.

Farm Type

All farm types (including field crops, vegetables, fruits and nuts, horticultural/nursery, cattle, goats and sheep, culinary or medicinal herbs, forest products, and other) were included in the participant recruitment effort. Study participants were classified according to those types, or identified as “mixed.” For purposes of statistical analysis, classification categories were consolidated where secondary farm operations on the same farm are clearly minimal.

Research Instruments

This study utilized two research instruments. The primary instrument was a self-reported survey, meaning that data collected from farmers participating in the survey came from their own accounts and may or may not be informed by complete records of their energy use and farm production characteristics. Semi-structured interviews were used as a secondary instrument and were conducted at a subset of farms that represented major farm types to collect information about the farm and its energy use that the survey may not have captured.

Self-reported Survey

A survey was designed to generate quantitative data reflecting the study research questions related to energy use on the farm, types of renewable energy and energy efficiency practices currently present on the farm, and what kind of experiences farmers have had with federal grant programs for energy projects. The survey has three main categories: farm information, current energy use, and renewable energy and energy efficiency information.

The first category includes demographic and econometric data to allow proper categorization of the farm's survey answers. This includes economic information about the farm's gross income bracket, what the farm produces, by what means the farm markets its products, and the farm's average distance to market. In order to establish comparability between USDA reports and this study's findings, many of the questions in this section are derived primarily from USDA reporting figures listed in the 2012 Census of Agriculture. This section also asks for contact information in the event that the farmer is interested in a follow-up interview.

The second current energy use category assesses the farm's energy use profile. This includes questions about what types of fuel are being used on the farm, in what areas of the operation those fuels are being used, the kind of farm infrastructure using energy, and the annual energy costs of the farm. These questions were derived in part from the University of Wisconsin's Energy Self Assessment online energy calculators ("Energy Self Assessment Tool," n.d.).

The third category on renewable energy and energy efficiency information, asks questions about the farmers' interest in energy use improvement, basic access to renewable resources (solar, wind, hydro, biomass), relationship to federal grant programs, and potential perceived obstacles to the implementation of energy use improvement projects. These questions were modeled loosely on a farm energy survey conducted by the Connecticut Farm Energy Program, a nonprofit program assisting farmers with federal grant applications for energy projects (Fargo-Johnson, 2015).

The survey design was validated by beta-testing it with five farmer volunteers, and their recommendations were largely incorporated into the final survey to improve the relevance, content, and user-friendliness of the survey for area farmers before recruitment began. The Appalachian State University Institutional Review Board (IRB) approved the final questions and proposed survey process to protect the privacy and safety of participants. A hard copy version of the survey questions can be found in Appendix A.

Semi-structured Interviews

A subset of farmers who completed surveys and indicated an interest in a follow-up discussion participated in on-site, semi-structured interviews. The interview questions were designed to complement the survey with qualitative data about the farms' operational practices that were not readily apparent from the survey results. In particular, these interviews helped to identify potential differences between types of farms that may lead to fundamentally different energy use profiles. This interview instrument also includes questions about farmer sentiments toward energy use, renewable energy and energy efficiency measures, and federal grant programs supporting energy projects. A guided tour of the farms' operations was also part of the interview. The semi-structured interview questions can be seen in Appendix A.

Data Collection Strategies

Self-reported Survey

The survey was administered by two pathways: hard copy written surveys were mailed to county extension offices for dissemination through their office, and a digital survey was designed and made available using the Qualtrics survey platform. Qualtrics is a survey software tool that provides advanced data collection, including the ability to create questions with matrix-style responses with multiple answers and the ability to use conditional logic that can base some of the questions a participant sees on their answers to other survey questions. Small farmers vary in their comfort and familiarity with digital technology, so the two pathways were used in conjunction in an effort to represent the largest number of farmers.

The Appalachian Sustainable Agriculture Project (ASAP), a western North Carolina nonprofit that provides farmer training and marketing support for local growers, lists 545 North Carolina farmers in their "Appalachian Grown" network. These farmers were mailed a hard copy postcard inviting them to participate in the online survey. The farmers on this list were also emailed directly with the same invitation letter that can be found in Appendix A.

The online survey was promoted concurrently through recruitment efforts made through County Extension Office newsletters, Soil and Water Conservation District newsletters, WNC Energy Cost-share Assistance Program (WNC energyCAP) web and Facebook pages, as well as at in-person events and conferences where attendees could sign up to participate. After arriving on a landing page for the online survey, participants were asked to authorize their consent and continue to the survey, which Qualtrics estimated would take an average of 22 minutes to complete.

Because significant overlap exists across the recruitment pools, care was taken to request only one response per participant in the opening text of the survey. Survey participation was motivated by the possibility of having a whole-farm energy assessment performed on the participant's farm, and a free report and resource guide to be delivered to farmers who completed the survey.

Semi-structured Interviews

The survey asked respondents to indicate their willingness to be contacted for a follow-up survey. Based on the results of the survey, a typical farm from each farm production category (cattle, vegetables, etc.) who had expressed willingness was selected and contacted to schedule a follow-up interview. Consent forms were signed prior to the interview, which was audio-recorded. Photos were taken during the farm tour segment of the interview.

Survey Data

Survey questions were designed to be easy to understand and as succinct as possible to minimize participant fatigue and maximize response completion rates. The overall objectives were to gather pertinent information to discern patterns in small farm energy use and identify potential funding needs and obstacles.

Patterns in Small Farm Energy Use

Energy use profiles were developed based on the responses in the energy use section of the survey. These profiles were categorized based on the information about farm type and size given in the farm information section of the survey. For each farm type, an analysis was conducted on the amount of energy used by fuel type, and the portion of the farm's operation where the energy was used. The data from farms within a given farm type were analyzed for commonality, and farm types were compared to one another to identify major patterns and sources of differentiation. Descriptive data were graphically represented in pie or bar charts for farm size and type classification and energy use information. Comparisons were made between the survey data and national data cited in the literature review.

Farm size and type classification. Farm size was determined by a question asking for the farm's gross sales in 2015. This year was used because the survey was conducted in the final three months of 2016, so complete records for that year were not yet available at the time of the survey. Checkbox questions also determined if farms were retirement farms or off-farm occupation farms. The type of farm was determined by a question asking the farm's primary source of farm income, which was simply the financially highest-yielding aspect of their operation. This put the farmer into their "primary farm type" category, with options including field crops, vegetables, fruits and nuts, horticultural/nursery, cattle, goats/sheep, poultry, culinary/medicinal herbs, forest products, honey, and other. If any additional sources of farm income generated 20% or more of a farm's total income, that respondent was directed to describe that income source as well, and again such that the maximum number of income sources described was three, with each comprising greater than 20% of total farm income. For each source of income, the respondent was asked to quantify how many acres were devoted to production of that product.

The extent to which the farm served local markets was determined by two questions asking the percentage of the farm's products reaching end-consumers within 100 and 275 miles from the farm.

The primary constituency of the study was comprised of all farmers whose responses indicated less than $100,000 in gross sales that had some portion of their products reaching end-consumers within 100 miles of the farm. Farm type (field crops, vegetables, cattle, goats/sheep, fruits and nuts, horticultural/nursery, culinary or medicinal herbs, and other) was used to subdivide the study population for further analysis.

Energy use. Energy use was determined by questions that asked participants to identify which energy types they used on their farm, to estimate their use of those selected energy types, and to identify the on-farm activities that required the use of those energy types. Energy use was quantified in dollars, as it was determined more likely that a farmer would be able to better estimate that figure before they could the number of kilowatt-hours of electricity or gallons of propane they used in a year,

An estimate of residential use of energy, extrapolated from survey questions about the number of occupants in the residences and the size of the residences, was subtracted from each energy type total in those cases where the participant indicated that their energy use estimates included residential use.

Use of the energy for specific applications was further described by farm activity and trends were identified (such as “81% of fruit and nut growers use electricity to freeze their product.”). Activities were organized by the four farm direct energy use stages: production, processing, packaging, and transport, as described in Chapter 2.

Renewable energy. Questions concerning renewable energy use on farms asked respondents to report the size and types of their renewable energy generation systems, as well as estimates of annual savings provided by the systems.

Funding Needs and Obstacles

Questions related to the criteria used by USDA-REAP and NRCS-EQIP to determine eligibility for cost-share payments on energy improvements are found throughout the survey. Measures such as energy use, farm size, and farm income are found in the first two sections, and the availability of renewable resource and level of interest and experience in implementing energy improvement projects are found in the third section. The interview instrument also draws out criteria about the participants that either support or rule out program eligibility. Obstacles to the pursuit of funding or the awarding of funding were also recorded in the third section and through the interviews. The percentages of farms projected to qualify and not qualify for these programs was calculated, and the primary reasons for ineligibility were identified.

Survey Data Analysis Procedures

While Qualtrics was the digital platform that managed the survey process, data analysis was performed through Microsoft Excel. A multi-tab Excel workbook was developed to make the data suitable for analysis through cleaning and sorting, and allow the data to be integrated with external data. A basic export-to-Excel feature is available on the Qualtrics platform to transfer the raw data between the two software applications.

Excel Format

Questions in the Qualtrics systems are numbered in order of their generation by the survey builder. They are not numbered according to the final order that is seen by the respondents. Thus, a new number-ordering was created manually in the Excel file, turning Qualtrics question orders (QID) as directly imported, into study question order (SQ), as seen in Figure 14. Each row of the spreadsheet is a complete chronological set of answers for each individual respondent.

	SQ>>	1	2	3	4	5	…
		QID4	QID13_TEXT	QID16	QID14	QID20	…
RESPONSE #		Q4 - County:	Q13 - Year farm started: (YYYY)	Q16 - How would you describe your farm work? (select ALL that apply)	Q14 - Do you have a Farm Number with the Farm Service Agency (FSA)? (You might h...	Q20 - In 2015, what was the FIRST month of your farm's active production season?	…
1							
2							
…							

Figure 14. Cut-off image of Microsoft Excel workbook used to import survey data and re-number survey questions from Qualtrics.

Cleaning and Sorting the Data

After the data were exported into Excel, several cleaning and sorting steps needed to be performed before analysis could take place. Because no survey questions were mandatory, incomplete surveys needed to be identified. After the last completed answer (chronologically) of an incomplete survey, the questions that followed were identified as not having been seen by that respondent with the word “QSincomplete.”

Because answers with multiple responses were exported from Qualtrics as comma-separated values in a single Excel cell, a separate tab was used to separate the values using Excel’s Text to Columns feature in a way that allowed each of the multiple answers available to have its own response column in subsequent iterations (tabs) of the cleaning and sorting process.

A logic sequence for cleaning survey responses was developed to allow the responses and nonresponses of questions through the Qualtrics platform to be suitable for analysis. Using logic formulas in Excel and multiple tabs to represent sequential layers of cleaning, responses were converted to show a readout that was regular and consistent (excepting fill-in-the-blank responses). As an example, a multiple answer question in a completed survey may have two of the available answer boxes checked. Each of the checked answers was given a value of 1 and the rest were assigned a value of 0. However, if no checkboxes were checked, and the rest of the survey was completed, the logic generates an answer of "skipQ," to indicate that the question was skipped. If that multiple-answer question was part of the trail of unanswered questions at the end of an incomplete survey, the logic generated an answer of "QSincomplete." That logic can be seen in Table 3.

Table 3

Logical System for Survey Data Cleaning

		Response given	Readout
Multiple answer	Primary logic	filled choice	1
		blank = choose "no"	0
		blank = skipped question	skipQ
		blank = didn't see question	noseeQ
	Additional logic for incomplete surveys	blank = unfinished survey portion	QSincomplete
Multiple choice	Primary logic	filled choice	choice
		blank = skipped question	skipQ
		blank = didn't see question	noseeQ
	Additional logic for incomplete surveys	blank = unfinished survey portion	QSincomplete
Fill-in-the-blank		filled in answer	filled in answer
		blank = skipped question	skipQ
		blank = didn't see question	noseeQ
	Additional logic for incomplete surveys	blank = unfinished survey portion	QSincomplete

Note. *Formulas were used in Excel to generate cell values seen in the "Readout" column that corresponded with the logical realities presented by the survey respondents' answers exported from the Qualtrics survey platform, as seen in the "Response given" column.*

Conditional logic was used within the Qualtrics platform, meaning that some questions appeared only if a previous question was answered in a certain way. For example, if a respondent answered only "Electricity, Propane" in a multiple-answer question about what types of energy they used on the farm, they would see the follow-up questions for those energy types, but would not see the follow-up questions for natural gas, biomass, gasoline, diesel, heating oil, renewables which were also offered as answers. For the followup questions of the latter energy types in this example case, the logic would deliver a "noseeQ" for those answers to indicate that those questions were not seen by the respondent. The purpose of this is to avoid unseen questions being marked as skipped questions or in some way incomplete or neglected.

Some fill-in-the-blank answers intended to include only numbers had qualifying words like "about 15 or so" instead of "15." In these cases, answers were manually hard coded to read "15."

Major outliers in the responses were identified through an answer-by-answer scan for typos and likely numerical errors for cases where the response suggested an astronomical amount or was otherwise out of line with the internal logic of survey respondent's answers taken as a whole. For example, one respondent claimed they had a 4 megawatt solar system providing what appeared to be the amount of energy savings to be expected from a 4 kilowatt system. Follow-up clarification from the respondent directly was sought in some cases where contact information was provided.

Conversions of Energy Use Data

There were several questions pertaining to residential energy use and energy costs that required further processing to covert the survey responses to the data that was used for analysis.

Responses about the amount of electricity and the amount of propane used on the farm included a question about whether the farmer's reported estimate included residential use of that energy. This could be the case if a farmer only had one electricity meter for both the farm and the residence, or if a single propane tank was used for residential heating as well as farm activities. If a respondent indicated that residential use was included in the estimate for that energy type, a pre-determined value for residential use was subtracted out of that estimate in order to reflect only the farm's energy use. This was done using the average residential electricity use and the average residential propane use reported for North Carolina in the 2015 U.S. Energy Information Administration's (EIA) reports on those residential energy types, which were 13,356 kilowatt-hours per year of electricity (2015a) and 360.2 gallons per year of propane (2015c). While individual farms' residential energy usage will vary in reality, this approach at least provided a corrected value for farm energy use.

Questions about the amount of energy used on the farm were answered in dollar amounts for all energy types except wood or pellet wood, which were estimated in cords and bags, respectively. However, because this study requires a consistent unit of energy across all types (in BTUs or in Gigajoules), conversions were necessary. Conversion rates used can be seen in Table 4.

Table 4

Conversion Units for Describing Energy Use in BTUs

Price per energy volume			
Energy type			(Source)
Electricity	$0.1128	/kWh	EIA, 2015a
Propane	$2.54	/gallon	EIA, 2015c
Heating oil	$2.58	/gallon	EIA, 2015c
Gasoline	$2.291	/gallon	EIA, 2015b
Diesel	$2.668	/gallon	EIA, 2015b
Firewood	$150	/cord	area companies*
Pellet wood	$5.29	/bag	"Wood fuel pellets," n.d.
*average determined from conversations with WNC area sellers			
BTU content per energy volume			
Energy type			(Source)
Electricity	3,412.14	BTU/kWh	EIA, 2015d
Propane	91,333	BTU/gallon	EIA, 2015d
Heating oil	138,500	BTU/gallon	EIA, 2015d
Gasoline	120,405	BTU/gallon	EIA, 2015d
Diesel	137,381	BTU/gallon	EIA, 2015d
Firewood	23,260,000	BTU/cord	Kuhns & Schmidt, 2013
Pellet wood	33,000	BTU/bag	Reeb, 2009

Electricity. Because there are roughly seven utilities represented in the 23 counties of the survey area, and not all respondents would answer the question about what utility provided their electricity, a standard rate was adopted from the EIA’s 2015 report on annual monthly bills for residential electricity users. The North Carolina rate in price per kilowatt hour was $0.1128 (2015a). Assumed monthly charges of $17.20 (an average of the residential monthly charges of the four most commonly reported utility companies in the responses: Duke Energy, Blue Ridge Energy, French Broad EMC, and Rutherford EMC) were subtracted from the respondents’ self-reported dollar estimates of their total annual energy use for 2015. For respondents who claimed that their residential energy use was included in this self-reported estimate, there was a lack of certainty as to whether monthly charges were rolled into the EIA residential use estimates in some way, as their residential electricity report shows a column for Average Monthly Bill which is in fact simply the product of Average Monthly Consumption (kWhs) and Average Price ($/kWh). Therefore, consideration of monthly charges, or proxy values for monthly charges, was not given in these instances where residential energy use was subtracted from a self-reported response. Since BTUs for electricity were calculated using the common conversion rate of 3,412.142 BTU/kWh for all farms, this uncertainty would affect comparison to national averages but not comparison across farm types.

Direct fossil fuels. Propane, heating oil, gasoline, and diesel use were converted from dollars to gallons using EIA's 2015 report on the average cost and usage of those fuels (2015c, 2015b). The average rate of $/gallon in North Carolina for the year and BTU/gallon conversion values for each fuel type were used to calculate the BTU value of the fuels used. Additional questions were asked about the percentage of heating oil use that was fulfilled with renewable BioHeat and the percentage of diesel fuel use that was fulfilled with renewable biodiesel. Farmers were instructed in the survey to not include personal use of gasoline or diesel in their estimate.

Wood. Wood use questions were answered in cords. Inconsistency exists amongst buyers and sellers in perceptions of how much wood is in a cord, and it is not uncommon for a truckload to be called a cord when it would more accurately be called half a cord. Thus, the price for a cord of firewood (for considerations of operating expenses) is subject to some debate. Based on calls to five local firewood sales operations, an estimate of $150/cord was determined. An additional question was asked as to whether a farm's firewood was produced onsite (at no apparent cost), offsite (at a cost), or some combination of the two. Based on the answer to this question, a farm's cost for the cords of wood used on their farm was multiplied by zero (produced onsite), one (produced offsite), or 50% (some combination of the two). The BTU value of a cord of wood was derived from the average of five common species—cherry, green ash, white oak, red oak, black walnut—as reported by Utah State, which is 23,260,000 BTU/cord (Kuhns & Schmidt, 2013).

Pellet wood is a less common form of heat, though the pellet industry is growing in North Carolina. Pellet questions were answered in bags of pellets. 40-pound bags of pellets contain 330,000 BTU/bag (Reeb, 2009) and cost $5.29 per bag ("Wood Fuel Pellets," n.d.).

Synthesis of Data

Secondary farm types. In instances where the farm operation was diversified across several types of farming (e.g. a vegetable operation that also raises poultry), reporting of energy use does not distinguish which of the two operations on the farm is using that energy type, or what amount it is using. An attempt was made to create a per-acre proxy value of each energy type used by the secondary farm operation. Then, that value multiplied by the number of acres devoted to that secondary operation was subtracted from the total BTUs reported for each energy type used on the farm as a whole.

Labor hours. On-farm labor questions were answered in hours of total labor. Some difficulty emerged in accurately depicting on-farm labor hours, as asking for dollar amounts would present confusion about unreported wage rate for paid laborers, representation of unpaid labor (farm interns or community help), and the question of whether the farmers themselves were reporting their time and at what rate. For simplicity, the question only asked for all man-hours spent on farm activities, paid and unpaid alike. Consideration of labor as an operating cost would use the minimum wage rate of $7.25/hour as a conversion.

Presentation of Data

Due to the small sample size of respondents in this study, a test for statistical significance was not conducted. Instead, basic descriptive statistics were generated, including average, standard deviation, maximum, minimum, and median values of the reported energy use estimates for the different farm type categories.

Comparisons to Large, Non-local Agriculture

As described in Chapter 2, there are two major ways to compare the efficiency of energy use between different farm systems. Due to the difficulty in establishing a clear and reliable method of self-reporting the agricultural production levels of a farm operation, this study instead conducted a comparison of direct energy use per unit of land area between the small farms in the study and their large-scale agriculture counterparts for each farm type, which can be found in Table 5.

Table 5

Direct energy (GJ) use per land area (ha) for various farm types, large-scale

Farm type	GJ/ha	Source
Cattle (conventional)	2.5	Pimentel & Pimentel, 2007
Cattle (grass-fed)	2.1	Pimentel & Pimentel, 2007
Field crops (barley)	15.7	Pimentel & Pimentel, 2007
Field crops (corn)	29.5	Pimentel & Pimentel, 2007
Field crops (rice)	65.5	Pimentel & Pimentel, 2007
Field crops (wheat)	17.8	Pimentel & Pimentel, 2007
Fruit and nut (Belgium, conventional)	13.0	Annaert et al., 2015
Fruit and nut (Belgium, integrated)	17.0	Annaert et al., 2015
Fruit and nut (Belgium, organic)	21.7	Annaert et al., 2015
Fruit and nut (U.S.)	82.7	Pimentel & Pimentel, 2007
Goats and sheep	0.3	Pimentel & Pimentel, 2007
Vegetables (brussel sprouts)	13.6	Pimentel & Pimentel, 2007
Vegetables (potatoes)	29.0	Pimentel & Pimentel, 2007
Vegetables (spinach)	14.3	Pimentel & Pimentel, 2007
Vegetables (tomatoes)	44.5	Pimentel & Pimentel, 2007

In order to compare study data with energy use per land area values found in the literature, a summation of these converted and synthesized BTU values for the farms' reported energy use was made, and the sum was converted to Gigajoules using the conversion rate of 1.055 Gigajoules/1,000,000 BTU. Reported acres were converted to hectares using the rate of 0.404686 hectares/acre.

Energy Improvement Opportunities and Barriers

Respondents were asked to describe their sentiments toward adopting renewable energy, undergoing energy audits, implementing energy efficiency measures, and major reasons for doing so or not doing so. They were also asked to make an assessment of their access to renewable resources, including access to full sun from 9 AM to 3 PM, flow and head estimations for on-farm surface water available, amounts of crop waste and animal waste available. Major on-farm activities for each farm type were then matched to available resources to make recommendations toward renewable energy adoption and energy efficiency implementation for each farm type. Barriers to securing grant funding for these energy improvements were assessed through questions that determined eligibility for grant programs, such as total energy use levels, farming occupational status, and relationship between farm and residential energy use.

Interview Analysis

Audio recordings from interviews were transcribed and assessed for discrepancies between in-person interviews and survey responses for those farmers interviewed. This was done to provide clarity regarding the degree to which survey responses were to be considered valid and accurate. A better understanding of the rough percentages of each energy type going toward different farming activities was also sought during the interview, as this level of granularity was not provided by the survey itself. Further elaboration was sought and recorded on issues of perspective and opinion that the survey's format did not allow to be fully expressed.

CHAPTER 4: RESEARCH FINDINGS

Overview of Survey Responses

While hard copies of the survey were disseminated to each of the 23 counties' agricultural extension offices, the only responses that were obtained were through the online version of the survey. No information was collected regarding how respondents found out about the online survey opportunity or whether they also received a hard copy.

Demographics Dataset

While the eighty-one online surveys that were submitted met the 10% target of the approximately 800 small farms in the designated NC counties, the final dataset contained 58 respondents. Exclusion criteria included incomplete data, location and farm income. This dataset is referred to as the demographics dataset and is used for analysis of the study population.

Of the 81 original surveys, 20 were classified as incomplete. Sixteen were excluded on the basis of not having completed basic questions about energy usage, while the other four were considered salvageable for having included those answers before leaving the survey. Subsequent answers regarding energy efficiency, gross sales, and farm operating costs were not given for these latter four respondents.

From the 65 surveys considered complete enough to include, seven more were excluded from the group based on location and farm income criteria. One survey response was excluded for reporting a location outside the 23 counties in the sample area, and two survey responses were removed due to unknown locations. Four additional farms were removed for reporting gross sales in excess of $250,000, making them outside the intended sample of small-scale farms. This brought the total number of viable survey responses within the sample group down to 58, all of which had some portion of their agricultural products reaching end-consumers within 100 miles of the farm. This breakdown can be observed in Figure 15.

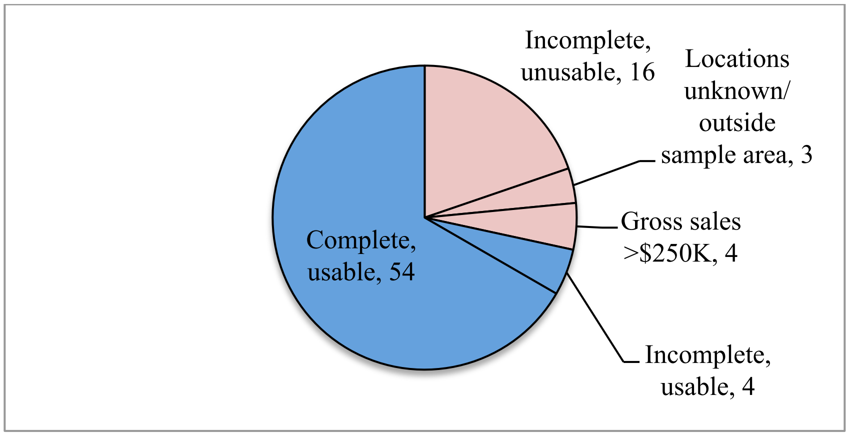

Figure 15. Breakdown of survey responses showing viable demographics dataset of 58 respondents.

Because no individual question in the survey was mandatory, and individual responses guided which questions were skipped, a full set of 58 responses was rarely available for a given question. Also, because the survey contained conditional logic, some questions were seen by fewer than the full 58 respondents in the demographics dataset. Table 6 shows the response rates for the 20 questions in the survey seen by all respondents.

Table 6

Response Rates for Questions Seen by All Demographics Dataset Respondents

Survey question	Responses (n=58)	Question	Response rate
1	58	County of operation	100%
2	56	Year that farm started	97%
3	48	Farm occupation status (retired, primary income, non-primary)	83%
4	57	Do you have an FSA farm number?	98%
5	58	What was the first month of your production season?	100%
6	57	What was the last month of your production season?	98%
7	42	Where are your products sold?	72%
8	57	What percentage of your products reaches end-consumers within 100 miles of the farm?	98%
10	53	Are your products "certified locally grown" through ASAP?	91%
11	58	What is your primary source of farm income? (farm type)	100%
22	57	Do you keep complete records of energy expenses?	98%
23	57	What types of energy do you use on your farm operation?	98%
77	58	Would you be willing/interested in a follow-up interview or energy assessment?	100%
99	50	Do you have an area in an unused field or on a roof that gets full sunlight from 9 AM to 3 PM?	86%
100	38	How many cubic yards of crop waste does your operation produce?	66%
102	54	Do you have a running stream or river on your property?	93%
105	53	Would you apply for grant funding for a renewable energy system if the grant required that the system not be tied to your residence?	91%
106	37	What energy-saving devices and procedures have you done on your farm in the last 5-10 years?	64%
114	53	Gross sales level	91%
115	41	Operating expenses	71%
		AVERAGE	90%

There were six questions with response rates below 90%. Survey questions #99, #100, #106 and #115 were all near the end of the survey, which suggests that survey fatigue, in combination with no questions being mandatory, resulted in low response rates. Figure 16 shows possible survey fatigue effect with a dropoff in response rates over time. The other two survey questions with low response (#3 and #7) were in the introductory section of the survey, and were “select all that apply”-style questions. Question three in particular may have been relatively cumbersome to answer, as a farmer’s occupation status, or whether the farm is the primary income in a household, can be a gray area.

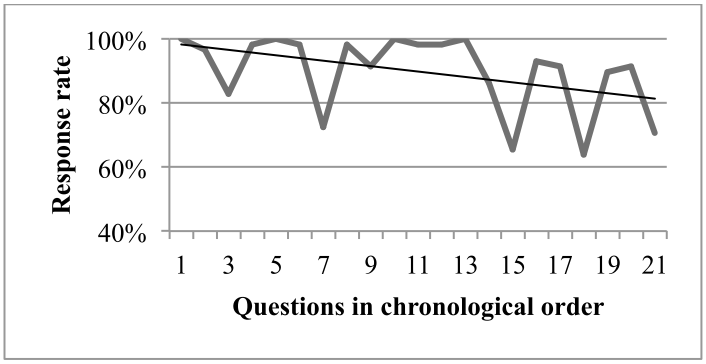

Figure 16. Drop-off in survey response rates over time, as a percentage of those questions seen by all 58 survey respondents (see Table 6) in the demographics dataset.

The average time needed to complete the survey by the respondents included in the demographics dataset was 25.2 minutes. This calculation excludes one outlier with a reported 482 minutes for completion, which suggested that browser was left open and the survey was not completed in a single session at the computer. Such activities as leaving the survey temporarily or multitasking with concurrent activities during the completion of the survey are not monitored by the online survey platform.

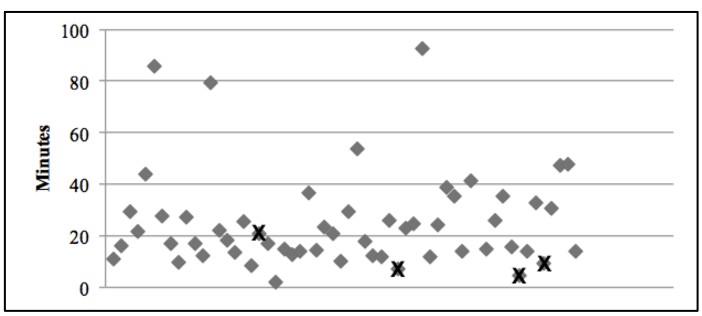

Figure 17. Response times of the demographics dataset (n=58), excluding one outlier. Average time to complete the survey was 25.2 minutes. The four partial surveys are indicated with an “X.”

In summary, the 58 surveys included in the demographics dataset were those responses that were sufficiently complete and met the criteria for small farms reporting gross sales of less than $250,000 per year, operating in a county within the sample territory, with some portion of their goods reaching end-consumers within 100 miles of the farm. This dataset of mixed primary farm types was analyzed for geographical diversity of response, farmer occupation, farm type, and degree of involvement in local food marketing and sales, and income level.

Geographic diversity. Twenty of the 23 counties in the sample territory are represented in the survey responses. A map showing the distribution of survey response across the 23-county area is shown in Figure 18. The biggest clusters are around Asheville (Buncombe County) and Boone (Watauga County), two of the largest cities in the sample area. Also, Boone is home to Appalachian State University.

Figure 18. A map of the 23-county sample area showing representative clusters of 58 viable survey responses coming from 20 counties. Counties within the sample area with no recorded respondents are shown with an 'X.'

An analysis of which counties were over- and under-represented in the survey results was performed by comparing the number of respondents from each county as a percentage of the 58 survey responses and as a percentage of the total number of farms in the counties where the study farms are located. The latter provides a baseline expectation for the percentage of survey responses from each county that would make up a representative sample. Table 7 summarizes the location information for the study participants in the final dataset and the percentage deviation from a representative sample.

All but six counties were within +/-5% of the distribution percentages for the sample geographic region with three counties each being over- and under-represented. Buncombe County was the most over-represented county with 14.3% more of the survey response than what the county's number of respondents as a percent of all farms would suggest. Madison County and Clay County were over-represented by 7.0% and 5.5%, respectively. Farms in Buncombe and Madison Counties are nearest to the partner organization administering the survey (WNC energyCAP), and are therefore most likely to be familiar with that organization, making them more likely to volunteer their time to complete a survey. Buncombe County is also home to Asheville, the largest city in the region, which may have been a relatively more effective geographic area for targeting potential online survey respondents. The reason Clay County was overrepresented is likely due to its low number of small farms to begin with, making its threshold for overrepresentation easily crossed.

Table 7

Distribution of Survey Responses by County and Degree of Sample Representation

County	Survey Responses (n=58)	Percent of Study total	Number of Farms in County	Percent of County total	Sample representation	
Buncombe	14	24.1%	1,031	9.9%	over represented by	14.3%
Madison	8	13.8%	716	6.8%	over represented by	7.0%
Clay	4	6.9%	150	1.4%	over represented by	5.5%
Watauga	6	10.3%	590	5.6%	over represented by	4.7%
Transylvania	3	5.2%	212	2.0%	over represented by	3.1%
Cherokee	2	3.4%	245	2.3%	over represented by	1.1%
Graham	1	1.7%	105	1.0%	over represented by	0.7%
Mitchell	2	3.4%	286	2.7%	over represented by	0.7%
McDowell	2	3.4%	318	3.0%	over represented by	0.4%
Henderson	2	3.4%	435	4.2%	under represented by	-0.7%
Yancey	2	3.4%	448	4.3%	under represented by	-0.8%
Swain	0	0.0%	94	0.9%	under represented by	-0.9%
Polk	1	1.7%	287	2.7%	under represented by	-1.0%
Macon	1	1.7%	323	3.1%	under represented by	-1.4%
Caldwell	1	1.7%	395	3.8%	under represented by	-2.0%
Haywood	2	3.4%	584	5.6%	under represented by	-2.1%
Jackson	0	0.0%	240	2.3%	under represented by	-2.3%
Rutherford	2	3.4%	622	5.9%	under represented by	-2.5%
Burke	1	1.7%	457	4.4%	under represented by	-2.6%
Avery	1	1.7%	476	4.5%	under represented by	-2.8%
Alleghany	0	0.0%	538	5.1%	under represented by	-5.1%
Ashe	3	5.2%	1,103	10.5%	under represented by	-5.4%
Wilkes	0	0.0%	811	7.7%	under represented by	-7.7%

Wilkes County, Ashe County, Alleghany County, three rural counties the farthest away from the partner organization's territory, were underrepresented by 7.7%, 5.4%, and 5.1%. This region experiences generally higher elevations compared to the rest of the 23-county area, which may affect the type of farming operations present, and therefore the profile of potential respondents. Wilkes and Alleghany, along with Swain and Jackson, two counties west of Asheville with a relatively low number of farms to begin with, had zero responses.

While all extension offices were contacted and solicited for support for the survey, individual extension offices' level of promotion of the survey likely varied, and may have been one of the causes for these standouts in the otherwise even geographic distribution of responses.

Occupation. Survey Question #3 (n=48): "How would you describe your farm work?" Of these respondents, only 33% reported making 50% or more of their household income through the farm 29% reported retired or semi-retired status, and 31% reported that their primary employment was something other than the farm operation. Only 42% of respondents to this question reported that farming was their primary occupation.

Income level. Survey Question #114 (n=53): "In the year 2015, the farm's total gross sales (i.e. total receipts) from all farm products were roughly:" Three quarters of the respondents reported annual gross sales under $50,000. None were in the upper range of the small farms category ($150,000-$250,000). Sales for the five respondents who did not answer this question is unknown. A breakdown of the respondents' income ranges can be seen in Figure 19.

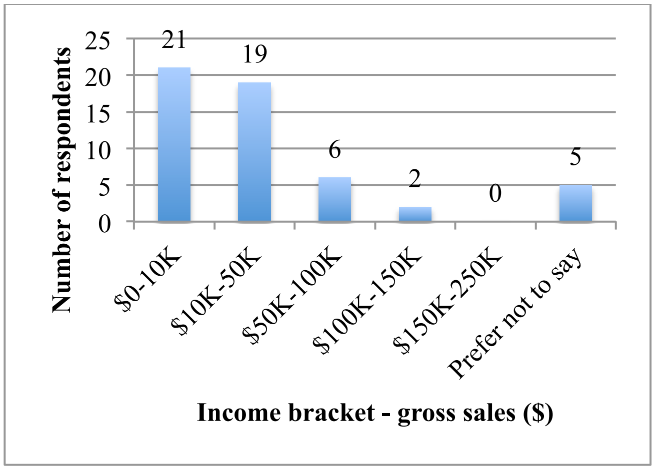

Figure 19. Breakdown of income brackets for the 53 respondents who answered Survey Question #114.

Local food marketing and sales. Survey Question #8 (n=57): "Roughly what percentage of your product reaches end-consumers (people who eat it) within 100 miles from the farm?" A majority of the respondents (62%) reported that 100% of their products reached consumers within 100 miles of the farm, while the overall average was 84% of products, and "10% of products" was the minimum.

Survey Question #9 (n=23): "Roughly what percentage of your product reaches end-consumers (people who eat it) within 275 miles from the farm?" This question did not appear if respondents answered "100%" to Survey Question #8 so was presented to only 38% of the respondents. This question apparently caused confusion in its placement directly after the 100-mile question which may have been alleviated if it had been placed first. Some respondents failed to consider the percentage of their products reaching consumers within 100 miles as an implied subset of the 275-mile percentage, providing an answer that was less than the total for the smaller radius and causing too much inconsistency in interpretation of the question. It can be said, though, that 100% of these respondents report that a portion of their products reach end-consumers within a 100-mile radius of the farm. Future studies should choose only one radius, or otherwise put the higher 275-mile radius first in the question order.

Energy Usage Dataset (Subset for Energy Analysis)

Although not originally anticipated, further winnowing of the demographics dataset was necessary before conducting deeper analysis of energy types used and farm activities using each energy type. Exclusion criteria used to establish the dataset for energy use analysis were incomplete responses to energy type questions, farm type with only one viable respondent, farms with mixed type farm income, and major outliers.

Energy type responses. The survey asked farmers to report their farm operation's use for seven energy types: electricity, propane, natural gas, heating oil, gasoline, diesel, and wood. If a farmer provided a response for fewer than four of these categories, their energy use responses were not considered for second-level analysis. All respondents were either highly responsive (six or seven) or highly incomplete (three or fewer), making for a clear divide. This criterion eliminated only one of the 58 farms from the demographics dataset.

Farm type groupings. Farms were then grouped by the following primary farm types: cattle, culinary and medicinal herbs, field crops, forest products, fruits and nuts, honey, goats and sheep, horticultural and nursery, poultry, vegetables, and other. If a farm type category only had one survey response it was not considered in the analysis due to the difficulty in establishing generalizability with a single response for that category. Only one farm responded in each of five farm type categories (dairy, forest products, grapes, honey, pigs) that were therefore excluded. Three fill-in "other" responses that listed agri-tourism as their primary farm type, which has no comparable equivalents in the conventional, centralized food production industry, were also not included. A total of 8 additional farms were excluded based on primary farm type criterion.

Diversified farm data. Diversified farms with income from two or three reported farm products (15 farms within the demographics dataset) were excluded, leaving only those reporting a single farm type. While these respondents were diverse in terms of their primary farm type and county of operation, over half of them had $10,000 or less in gross sales, suggesting that diversification may be more common on homestead-scale farms that are selling the excess. An effort was made to include data from these farms by creating a proxy value to subtract out the second and third farm type's energy uses, but results were not reliable. Because diversified farms here represent 26% of the demographics dataset and had to be excluded, future studies should find ways to accurately apportion the energy used toward the multiple operations occurring on diversified farms so that these farms can be included in the data analysis.

Major outliers. Finally, outliers in terms of energy use per energy type and calculated energy use per acre were removed. This was done by looking at the maximum and minimum response for the amount of each energy type used, and investigating those farms individually. The only major outlier discovered in this way was one hydroponic vegetable grower who was using a very high amount of energy on a very small footprint of land. Because this study was assessing energy use per land area and did not include production volumes in its analysis, this unique farm was deemed too dissimilar to other vegetable farms to allow for comparability within this farm type group and with the large, centralized farms studied in the literature.

The resulting subset of responses suitable for energy use analysis after applying the above-mentioned exclusion criteria, called the energy usage dataset, consisted of a total of 33 responses (see Figure 20). This energy usage dataset was used to analyze farm characteristics and energy use profiles for each farm type, and to compare energy use per land area results with literature values. The 58 responses of the demographics dataset were used to analyze attitudes and positions relating to the use of renewable energy and energy efficiency measures.

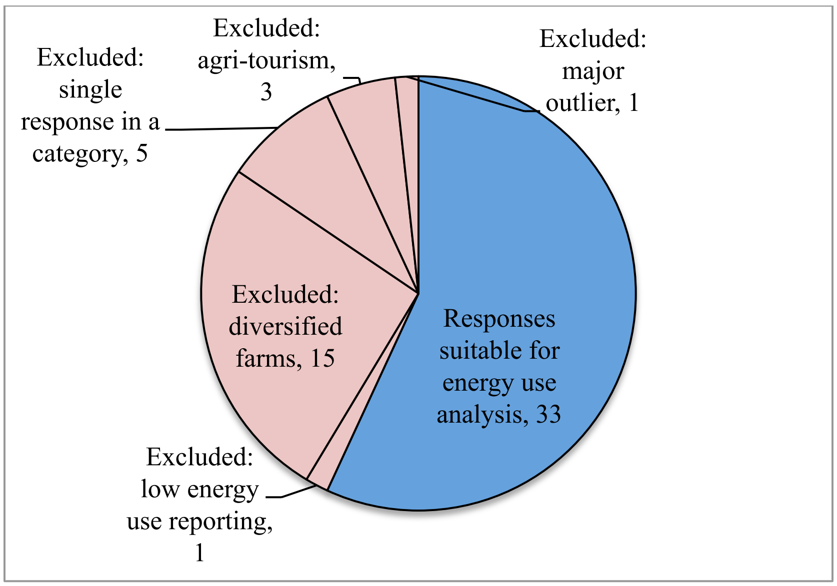

Figure 20. Breakdown of survey responses showing viable energy usage dataset of 33 respondents (whole represents the demographics dataset of 58 respondents).

Farm Type Profiles

Farm characteristics and energy use profiles were established for the 33 respondents in the energy usage dataset, grouped by primary farm type. Seven farm types were represented in this analysis, with the number of respondents in each farm type category shown in Figure 21.

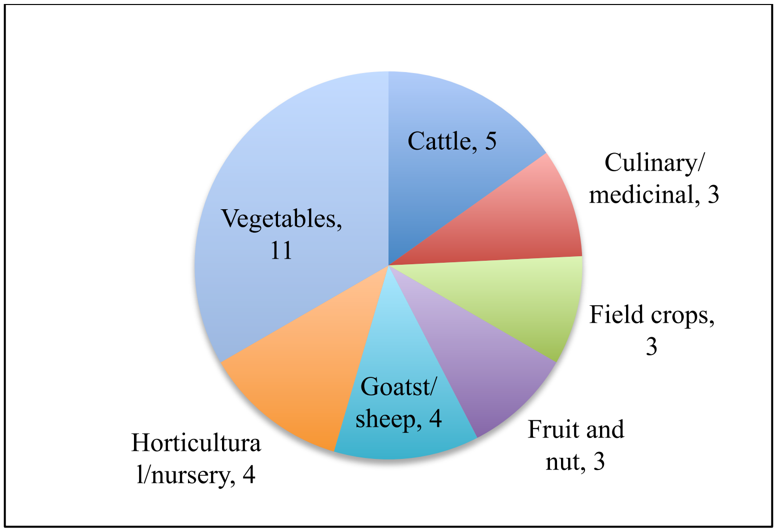

Figure 21. Number of responses in each viable farm type grouping used for energy profile analysis (33 total respondents).

Profiles for these farm types were created to compare farm characteristics, including occupational status, participation in local marketing and sales, and farm acreages, as well as patterns in energy use within each farm type. A summary of results for all farm type categories is shown here first, followed by detailed analysis of each farm type and how its energy use compares with the same farm type in large-scale, centralized agriculture.

Farm Characteristics

Twenty-eight of the 33 farms in the energy usage dataset reported their occupational status. Ten farms (36%) reported that 50% or more of household income came from the farm operation in 2015. Ten farms (36%) also reported that the primary operator was retired. "Horticultural and nursery products" and "Vegetable" were the only two farm types reporting their work with the farm as their primary occupation (75% and 36%, respectively). Three farm types, including horticulture and nursery products, cattle farmers and goat and sheep farmers, reported no operators as retired. A detailed breakdown of reported occupational status of farm types can be seen in Table 8.

Table 8

Occupational Status, by Farm Type

	Occupation				
Farm type	Number reporting	50% or more of household income is from farm	Farming is primary occupation	Primary occupation is something other than farming	Retired
cattle	4	2		2	
cul-med	2	1		1	1
field	2				1
fruit-nut	3	1		1	2
goats-sheep	2	2			
hort-nurs	4	1	3	1	
veg	11	3	4		6
TOTAL	28				

All farms sold some portion of their products through local food marketing and sales channels, with details for each farm type provided in Table 9. The average percentage of all reported products reaching end-consumers within 100 miles of the farm was 81%. Vegetable growers and cattle farmers had the highest rate of reports of a full 100% of products reaching end-consumers within this radius, followed by goat and sheep farmers. This relatively higher reliance on sales within a smaller radius may have to do with the higher perishability of vegetables and animal products, in comparison to herbs, field crops, fruits, nuts, and horticultural and nursery plants. It may also have to do with customer demand variations between different types of agricultural products. The most consistent findings for percentage of product sold within 100 miles, as measured by standard deviation of 9-10%, were for cattle, fruit & nuts, and vegetable farm types.

Table 9

Local Food Sales Participation Levels, by Farm Type

	Survey Responses		% of products sold in <100 mile radius				
Farm type	**Number reporting**	**Individual Farm responses**	**Mean**	**Median**	**Maximum**	**Minimum**	**Standard Deviation**
cattle	5	(100%, 100%, 100%, 100%, 80%)	96%	100%	100%	80%	9%
cul-med	3	(100%, 50%, 20%)	56%	50%	100%	20%	40%
field	3	(100%, 90%, 10%)	67%	90%	100%	10%	49%
fruit-nut	3	(80%, 70%, 60%)	70%	70%	80%	60%	10%
goats-sheep	4	(100%, 100%, 100%, 10%)	78%	100%	100%	10%	45%
hort-nurs	4	(90%, 80%, 40%, 20%)	58%	60%	90%	20%	33%
veg	11	(100% [X 10 responses], 70%)	97%	100%	100%	10%	9%
TOTAL	33	(equally weighted)>	81%				

Table 10 shows the average acreages within each farm type category. The animal categories, followed by the field crops category, show the highest acreage per farm, at 53.6 acres (cattle), 28.2 acres (goats and sheep), and 19.3 acres (field crops). Culinary and medicinal herbs (1.3 acres), fruit and nut (2.4 acres), and vegetables (3.2 acres) had the lowest. Horticultural and nursery plants represented the intermediate value of average per-farm acreage at 11.3 acres.

Table 10

Average Farm Acres in Production, by Farm Type

	Acreage			
Farm type	Average acres	Median	Max	Min
cattle	53.6	42.0	100.0	26.0

cul-med	1.3	1.0	2.0	1.0
field	19.3	4.0	53.0	1.0
fruit-nut	2.4	3.0	4.0	0.2
goats-sheep	28.2	13.0	77.0	10.0
hort-nurs	11.3	2.1	40.0	1.0
veg	3.2	2.0	8.0	1.5

Energy Usage Profiles

Data for six types of energy were analyzed for each farm type: electricity, propane, heating oil, gasoline, diesel and wood. The usage of different energy types was measured in two ways: on a cost basis and on a BTU basis.

Cost basis. Estimates for each energy type were analyzed from costs reported by respondents in each farm type category. A summary of average energy cost values can be seen in Table 11. As the table shows, a large variation was observed in the energy types used even within each farm type, and it was rare to observe a full 100% of farms in a given farm type using a given energy type. The average values include the zero-use instances and therefore have high standard deviations, suggesting that future studies would benefit from larger sample sizes.

The three farm types with the highest average total energy costs were horticultural and nursery products ($5,658), goats and sheep ($3,218), and vegetables ($2,866). Each of these farm types had a different single energy type responsible for greater than 50% of their total energy costs. Horticultural and nursery plant producers had a large share of total energy costs going toward propane (54%), goat and sheep farmers had 56% of their total energy costs going toward gasoline, and vegetable growers had 55% of their total energy costs going toward electricity. The dominant forms of energy used by the other farm types were diesel for cattle farms (39%), heating oil for culinary and medicinal herbs (76%), diesel for field crop farmers (49%), and electricity for fruit and nut growers (44%). However, the large standard deviations present in the small sample sizes prevent these results from being delivered with certainty, and further studies should aim for larger sample sizes.

Electricity was a top-two energy cost for five of the seven farm type categories, the other two farm types being culinary and medicinal herbs and horticultural and nursery crops. These two types were unique among all farm types in their relatively high demand for thermal applications of liquid fossil fuels (heating oil for the former, and propane for the latter). Diesel was also a top-two energy cost for five farm types. Gasoline was the only fuel type seen in the top three energy costs for all farm types. Wood and heating oil were consistently the least used fuels by farm type as well as on a cost-basis, with the exception of heating oil's higher use in culinary and medicinal herb farms. Diesel and gasoline were the only energy sources used by all farm types, and all but culinary and medicinal farms also used electricity and propane. It should be noted that wood energy, when used, was reported as being fully or partially provided at no cost with on-site resources. Of the eight farms reporting wood energy use, none bought all wood from off-site, three provided all wood energy with on-site resources, and five had some combination of on- and off-site resources.

Table 11

Average, Maximum, and Minimum Costs ($) of Different Energy Types, by Farm Type

		ELECTRICITY				PROPANE			
Farm type	Total #	AVG	MAX	MIN	users	AVG	MAX	MIN	users
cattle	5	$ 609	$ 1,800	$ 0	4	$ 140	$ 700	$ 0	2
cul-med	3	$ 0	$ 0	$ 0	0	$ 0.00	$ 0	$ 0	0
field	3	$ 731	$ 1,493	$ 0	2	$ 0.00	$ 50	$ 0	2
fruit-nut	3	***$ 417***	$ 750	$ 0	2	$ 0	$ 0	$ 0	0
goats-sheep	4	$ 1,213	$ 2,293	$ 0	4	$ 140	$ 560	$ 0	1
hort-nurs	4	$ 300	$ 1,200	$ 0	2	***$ 3,075***	$ 12,000	$ 0	2
veg	11	***$ 1,563***	$ 4,187	$ 0	11	$ 287	$ 2,500	$ 0	4
		HEATING OIL				GASOLINE			
(continued)		AVG	MAX	MIN	users	AVG	MAX	MIN	users
cattle		$ 0	$ 0	$ 0	0	$ 285	$ 400	$ 0	4
cul-med		***$ 1,067***	$ 3,200	$ 0	1	$ 100	$ 200	$ 0	2
field		$ 0	$ 0	$ 0	0	$ 182	$ 300	$ 120	3
fruit-nut		$ 0	$ 0	$ 0	0	$ 200	$ 600	$ 0	1
goats-sheep		$ 0	$ 0	$ 0	0	***$ 1,800***	$ 4,800	$ 0	2
hort-nurs		$ 200	$ 800	$ 0	1	$ 324	$ 1,000	$ 0	3
veg		$ 74	$ 319	$ 0	4	$ 828	$ 3,000	$ 0	8
		DIESEL				WOOD			
(continued)		AVG	MAX	MIN	users	AVG	MAX	MIN	users
cattle		***$ 740***	$ 2,200	$ 0	4	$ 105	$ 450	$ 0	2
cul-med		$ 233	$ 700	$ 0	1	$ 0	$ 0	$ 0	1
field		***$ 900***	$ 1,500	$ 500	3	$ 0	$ 0	$ 0	0
fruit-nut		$ 333	$ 1,000	$ 0	1	$ 0	$ 0	$ 0	0
goats-sheep		$ 65	$ 260	$ 0	1	$ 0	$ 0	$ 0	0
hort-nurs		$ 1,759	$ 3,637	$ 0	3	$ 0	$ 0	$ 0	0
veg		$ 106	$ 500	$ 0	6	$ 8	$ 75	$ 0	2
(continued)		TOTAL (AVG)							
cattle		$ 1,879							
cul-med		$ 1,400							
field		$ 1,830							
fruit-nut		$ 950							
goats-sheep		$ 3,218							
hort-nurs		$ 5,658							
veg		$ 2,866							

Note. The highest-cost energy type for each farm type is indicated with bold and italicized text.

A visual comparison of the cost basis of energy use of different energy types across all farm types can be seen in Figure 22.

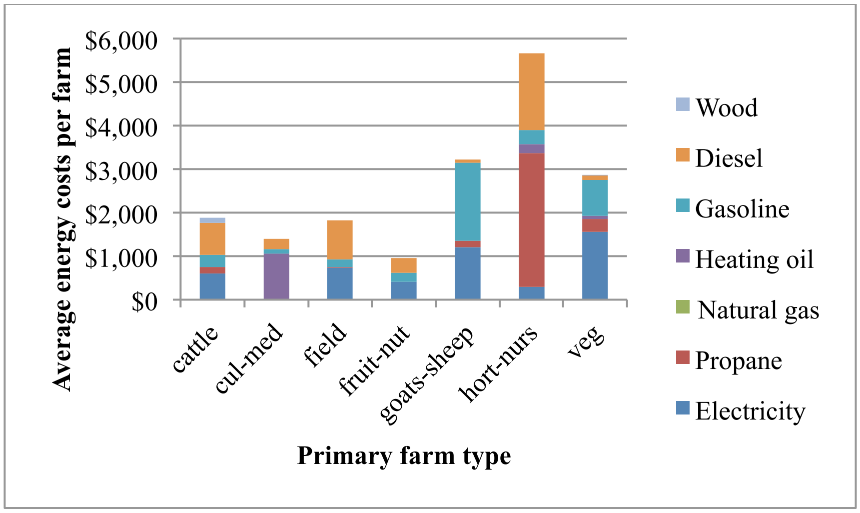

Figure 22. Totals of average costs of all energy types for each farm type.

Additional descriptive analysis data for each farm type category, including average, standard deviation, maximum, minimum, and median values for all energy costs, can be found in Appendix B.

BTU basis. Viewing the energy use of farm types from a BTU basis yields similar distributions of energy use for each farm type, with the exception of wood, as seen in Table 12. Bolded values indicate the largest BTU energy usage for each farm type and highlighted values show the major differences from the cost basis table.

The BTU value of on-farm firewood used at no cost to the farmer changes the energy use rankings in a few categories. This additional fuel usage, unaccounted for in the cost-basis analysis, brings “culinary and medicinal herbs” ahead of “vegetables” as the third highest energy user, largely due to one respondent claiming five times the use of the next highest wood user in that category, using wood for water heating, heating a greenhouse, and heating another farm building.

Table 12

Average, Maximum, and Minimum Use (MMBtu) of Different Energy Types, by Farm Type

		ELECTRICITY				PROPANE			
Farm type	Total #	AVG	MAX	MIN	users	AVG	MAX	MIN	users
cattle	5	13.9	48.2	0.0	4	5.0	25.2	0.0	2
cul-med	3	0.0	0.0	0.0	0	0.0	0.0	0.0	0
field	3	18.0	38.9	0.0	2	0.6	1.8	0.0	2
fruit-nut	3	***17.4***	33.3	2.4	2	0.0	0.0	0.0	0
goats-sheep	4	31.6	63.1	0.0	4	5.0	20.2	0.0	1
hort-nurs	4	7.5	30.1	0.0	2	***110.7***	432.2	0.0	2
veg	11	43.4	120.4	0.0	11	10.3	90.0	0.0	4

	HEATING OIL				GASOLINE			
(continued)	AVG	MAX	MIN	users	AVG	MAX	MIN	users
cattle	0.0	0.0	0.0	0	14.9	21.0	0.0	4
cul-med	57.2	171.5	0.0	1	5.2	10.5	0.0	2
field	0.0	0.0	0.0	0	9.5	15.8	0.0	3
fruit-nut	0.0	0.0	0.0	0	10.5	31.5	0.0	1
goats-sheep	0.0	0.0	0.0	0	***94.6***	252.3	0.0	2
hort-nurs	10.7	42.3	0.0	1	17.0	52.6	0.0	3
veg	4.0	17.1	0.0	4	***43.5***	157.7	0.0	8

	DIESEL				WOOD			
(continued)	AVG	MAX	MIN	users	AVG	MAX	MIN	users
cattle	***38.1***	113.3	0.0	4	32.6	139.6	0.0	2
cul-med	12.0	36.0	0.0	1	***100.8***	255.9	0.0	1
field	***46.3***	77.2	0.0	3	0.0	0.0	0.0	0
fruit-nut	17.2	51.5	0.0	1	0.0	0.0	0.0	0
goats-sheep	3.3	13.4	0.0	1	0.0	0.0	0.0	0
hort-nurs	90.6	187.3	0.0	3	0.0	0.0	0.0	0
veg	5.4	25.7	0.0	6	6.3	38.2	0.0	2

(continued)	TOTAL (AVG)
cattle	104.5
cul-med	175.2
field	74.4
fruit-nut	45.1
goats-sheep	134.6
hort-nurs	236.6
veg	113.0

Note. The highest-use energy type for each farm type is indicated with bold and italicized text.

Additional descriptive analysis data for each farm type category, including average, standard deviation, maximum, minimum, and median values for all MMBtu values, can be found in Appendix B.

Horticultural and nursery plant producers still had its largest share of total energy use going toward propane (47%), goat and sheep farmers had 70% of their total energy costs going toward gasoline, and culinary and medicinal herb farmers had 58% of their total BTU usage going toward firewood. The dominant forms of energy used by the other farm types were diesel for cattle farms (36%), diesel for field crop farmers (62%), electricity for fruit and nut growers (39%), and gasoline for vegetable growers (38%). Horticulture and nursery plants, fruit & nut, and vegetable farm types had a 2nd high BTU usage for diesel (38%), diesel (38%), and electricity (38%), respectively.

The effect of wood on the BTU energy basis can be seen clearly in Figure 23, as compared to the cost basis hat was presented in Figure 22, particularly for cattle and culinary and medicinal herbs.

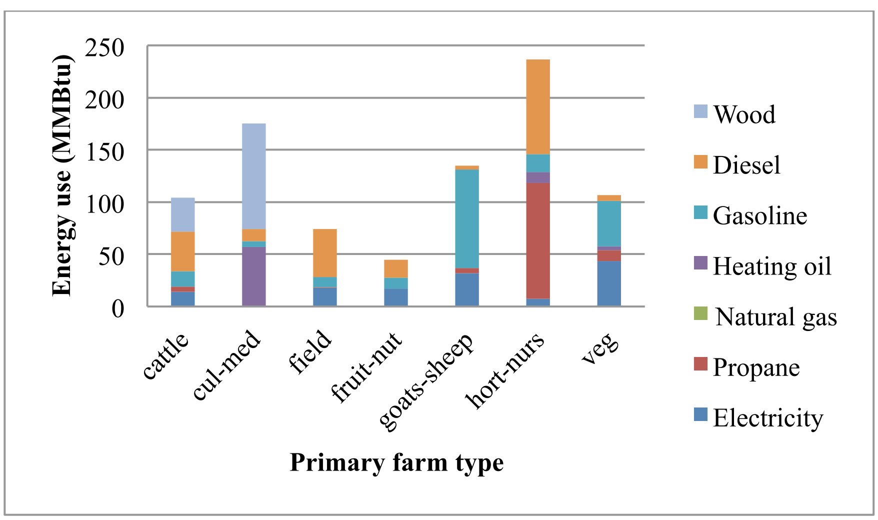

Figure 23. Totals of average MMBtus of all energy types used for each farm type.

A system-wide analysis of energy use can be helpful in identifying usage of energy types that are common to all farm types. Figure 24 shows that gasoline, diesel, and electricity are, respectively, the most highly used energy types system-wide (the same is also true from a cost basis). Energy use improvement opportunities, discussed later in this chapter, will consider the relationship between energy type and the categories of activities that uses each when discussing potential for system-wide improvement. This distribution of energy use for study farms is compared with that observed in the overall U.S. farm economy, in the "Comparisons with Centralized, Non-local Agriculture" section below.

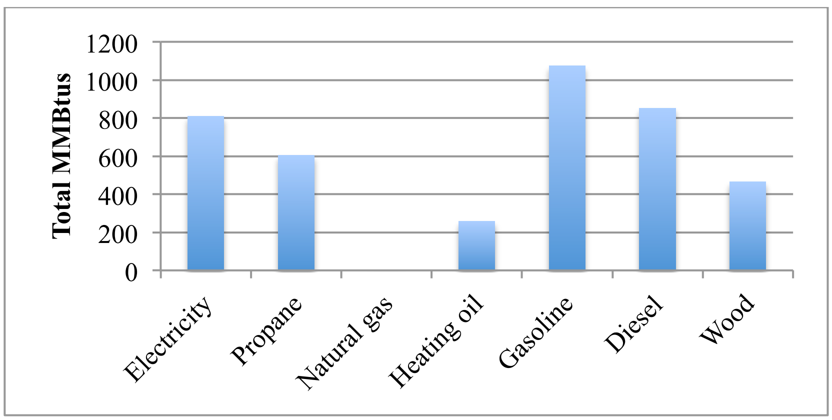

Figure 24. System-wide total energy usage by energy use dataset (n=33), by energy type.

Major Energy Use Activities by Farm Type

A summary of most commonly reported activities reported as using the top three energy types for each farm type is seen in Table 13. Numbering indicates first, second, and third highest cost-basis energy use. A more complete listing of activities and the frequency of farms reporting those activities can be found in Appendix B.

Table 13

Major Energy Use Activities, by Farm Type

Farm type	ELECTRICITY	PROPANE	HEATING OIL	GASOLINE	DIESEL
cattle	2. Lighting; Electric fencing; Product freezing			3. Running other farm equipment; Transporting people, supplies, and products; Running a generator	1. Running a tractor; Transportation of supplies and products
cul-med			1. Heating a greenhouse	3. Running a generator; Transportation of supplies	2. Running a tractor; Transportation of supplies, products, and people
field	2. Product cooling; Water pumping; Water heating; Lighting			3. Running other farm equipment; Running a tractor; Transportation of people and finished products	1. Running a tractor; Transportation of finished product
fruit-nut	1. Water pumping; Product cooling; Irrigation; Fencing; Lighting			3. Running other farm equipment; Transportation of supplies and finished products	2. Running a tractor; Transportation of finished product
goats-sheep	2. Lighting; Water heating; Water pumping; Product freezing.	3. Dairy parlor heating; Water heating		1. Transportation of supplies and finished products	
hort-nurs		1. Greenhouse heating; Heating other farm buildings			2. Running a tractor; Transportation of supplies and finished product
veg	1. Water pumping; Irrigation; Lighting	3. Greenhouse heating; Heating other farm buildings		2. Running a tractor; Transportation of supplies and finished product	

Note. Numbering indicates first, second, and third highest cost-basis energy use. Wood energy is not shown because it was never one of the top three energy types used.

While the survey was not able to assess the percentage breakdown of energy use allocated to the activities reported, general patterns can still be ascertained. Electricity is the most widely used energy type and the one for which the farms collectively incurred the greatest cost. It is mostly used for mechanical purposes like moving water (production), cooling and freezing products (storage), and for lighting in farm buildings. Gasoline and diesel, from a system-wide perspective, were associated with the mechanical uses of off-farm transportation of supplies, finished products, and people (transportation), and on-farm use in running tractors and other farm equipment (production). Gasoline tended toward transportation and farm equipment uses, while the activity of running a tractor was more often associated with diesel use. The remaining two energy types, heating oil and propane, were used exclusively for thermal purposes, mostly for heating greenhouses and other farm buildings.

Other Energy Use Characteristics

On-farm renewable electricity generation. Six farms reported the use of solar photovoltaic systems. When systems operated in a sell-all arrangement with the utility, this energy was accounted for in neither the cost-basis nor the BTU-basis usage of the electricity energy type. Systems connected to the grid and offsetting usage in a net-metering arrangement were accounted for in both the cost-basis and BTU-basis analysis. Off-grid systems did not factor into the cost-basis analysis, but their output was incorporated in the BTU-basis usage analysis for the electricity energy type.

Three farm types included farms using solar photovoltaic systems for revenue generation. One cattle farmer had a 25 KW system, one field crop farmer had a 10 KW system, and one fruit and nut grower had a 5 KW system.

One farm had a grid-connected solar photovoltaic system reducing the farm's annual electric bill. The energy generated by this system (as estimated from NREL data and the reported KW rating of the installed system) was included as a contributor to BTUs used in the analysis above, and the estimated savings of $0.10/kWh for that farm are reflected in the final costs of electricity in the analysis above.

Two off-grid solar photovoltaic systems were reported. One cattle farmer had a 0.4 KW system, which contributed 0.2 MMBtu to the average electricity usage for cattle farms seen in Table 12, and one fruit and nut grower had a 0.5 KW system, contributing 0.4 MMBtu to the average electricity usage reported for fruit and nut growers.

Energy records and electricity meter status. Of the respondents for this study, cattle and field crop farmers have the highest percentages of operators who keep good energy records. If the response "I sort of keep good energy records" is included, horticultural and nursery producers and vegetable growers are the next most fastidious record keepers. Goat and sheep farmers and culinary and medicinal herb farmers are mixed in their record-keeping tendencies, and fruit and nut growers—the lowest total energy users of all farm types—report the most lax record-keeping tendencies. There was no correlation between record-keeping tendencies and survey completion time.

A full breakdown of both of these farm characteristics can be seen in Table 14.

Table 14

Energy Use Recordkeeping and Farm-Residence Electric Use Relationship, by Farm Type

		Keeps good energy records?			**Farm and residence share an electric meter?**	
Farm type	Number reporting	Yes	Sort of	No	Yes	
cattle	5	3	2	0	2	(40%)
cul-med	3	1	1	1	2	(67%)
field	3	2	1	0	1	(33%)
fruit-nut	3	0	1	2	1	(33%)
goats-sheep	4	2	1	1	4	(100%)
hort-nurs	4	1	3	0	0	(0%)
veg	11	4	5	2	5	(45%)

Comparisons with Centralized, Non-local Agriculture

In an effort to identify key differences between local and non-local food systems, two major comparisons were conducted between the energy use dataset of small farms in the study and the U.S. farm economy overall. The first was a comparison of the distribution of energy sources used on farms and their associated activities, and the second was a comparison of the energy use efficiencies per unit of land area.

Energy Sources

While the larger farms in U.S. agriculture have larger shares of their energy use going toward diesel (largely for tractor use, and also for transportation) and electricity (largely for irrigation), the small farms of this study, taken together, had a more evenly distributed use of different fuel sources, as seen in Figure 25. The first major difference, that diesel comprises a smaller share of direct energy use for the small farms, is due to smaller farms tending more toward gasoline for production machinery and transportation vehicles, as described in Chapter 2. The other major difference between the two farm system scales appears to be the higher use of energy types that are used primarily for thermal purposes (propane, heating oil, and wood) amongst the small farms. This difference may be due to multiple factors, including lack of access to natural gas for most farmers in the study area, the relative cost benefits of natural gas where it is available elsewhere in the agricultural economy, the lack of any reported wood and heating oil use for the U.S. farm economy, and the effect of economies of scale in heating applications. However, it may also be that the 33 respondents in the energy use dataset have a higher proportion of farm operations that rely on thermal energy use as compared to the national agricultural system.

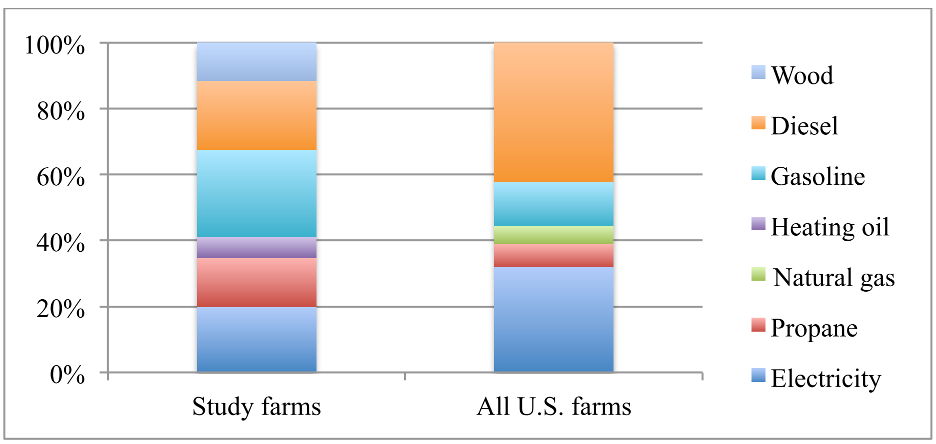

Figure 25. Comparison of distribution of direct energy use (in BTUs) on farms, by energy type. "All U.S. farms" data adapted from *Energy Use in Agriculture* by R. Schnepf, 2004, p. 5.

Energy Use Activities

Comparing the distribution of energy use toward the different activities of the four farm direct energy use categories identified in the literature (production, processing, packaging, transportation) is nearly impossible without a better percentage breakdown of energy use toward each individual farm activity, as fuel sources and energy use categories are not closely correlated. For example, while the activities using diesel fuel and gasoline are known for the energy use dataset respondents, it is impossible to allocate accurate amounts toward transportation and production stages. Similarly, activities using electricity could be put toward all stages but transportation, but ascertaining specific amounts for each activity is not possible.

Furthermore, the impacts of energy use in local food systems measured in this study do not consider the potential for resulting changes to stages outside the boundaries of direct farm energy use, such as retail, commercial, and residential energy use behaviors, or the changes in indirect energy inputs that come with these smaller farms.

Neither the activities using energy in the packaging of food, the largest share in U.S. farms overall (see Figure 26), nor the activities using energy for processing agricultural products are widely reported to be taking place on the study farms. Only one farm reported "grinding/milling/threshing" of their crops, and no farms report processing animals on-site. Drying herbs and vegetable products, and heating water for product cleaning are the only widely reported processing activities. Altogether, the extent of these activities is difficult to ascertain, but the generally low level of reporting of these activities suggests that their products either require less packaging or processing, or those stages are taking place off-farm. Therefore, the portion of farm direct energy used by the energy use dataset that goes toward processing and packaging stages is considerably lower than what is reported for the overall U.S. farm system (see Figure 26).

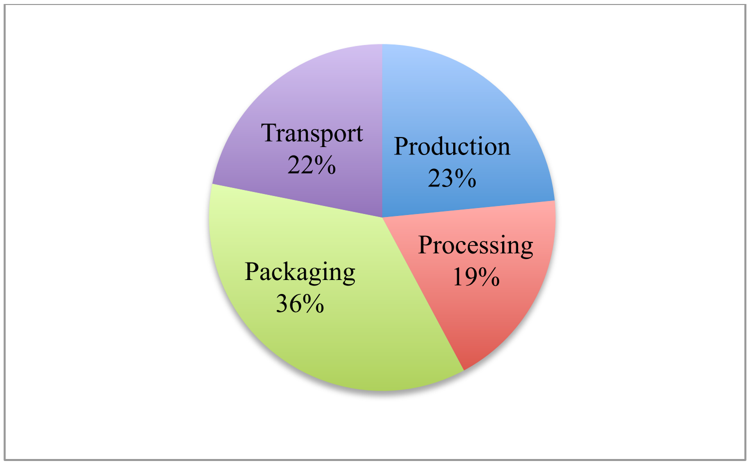

Figure 26. Distribution of U.S. direct energy uses in the food sector from production to transport. Adapted from *Energy Use in American Food Production* by M. Minn, 2009, p. 7.

Storage activities, which are mostly relegated to the off-farm stages of retail, commercial, and residential energy use (see Chapter 2) in the U.S. farm economy, are widely reported to take place on-site for the small farms in the study, which also contributes to some difficulty in establishing a comparison.

Overall, production and transport activities are most commonly reported by the study farms in proportions that, when observed qualitatively in combination with fuel sources used, appear to be a larger percentage of the total energy used than those observed by the centralized, non-local farms.

However, the distribution of fuel sources used and their associated activity stages do not draw a full comparison between the two farming scales. Efficiencies of energy use with reference to some measurement of farm production level should also be observed.

Energy Use Efficiencies Per Unit Land Area

An analysis was done to calculate the average values of direct energy use per unit land area for each farm type category represented in this study so that it could be compared to the averages observed for large, centralized farms of corresponding farm types. Results of this analysis are shown for all farm types in Table 15 in Gigajoules per hectare. While the average direct energy use efficiency for each farm type in the energy usage dataset was markedly higher than the average of farms nationwide, the small sample sizes and other limitations of the study make the process of this comparison more valuable than the results themselves. For instance, differences in indirect inputs from fertilizers and pesticides and differences in agricultural output between the study farms and the nationwide farm are not considered in this comparison. Such factors would need to be included in this comparison in order to draw conclusions about environmental advantages of one agricultural system over another.

Table 15

Provisional Comparisons of Direct Energy Use Efficiency (in GJ/ha)

	National farms GJ/ha		**Study farms** GJ/ha				
Farm type	MIN	MAX	AVG	MEDIAN	MIN	MAX	# of farms
cattle	2.1	2.5	5.0	4.1	2.5	8.5	5
field	15.7	65.5	145.4	149.9	14.5	271.9	3
fruit-nut	13.0	82.7	167.7	65.1	2.1	435.8	3
goats-sheep	0.3	0.3	32.9	21.7	5.5	82.6	4
veg	13.6	82.9	93.6	67.6	23.3	204.5	11

Culinary and medicinal herbs, and horticultural and nursery products, are not included in this comparative analysis, as literature values for energy use per unit land area for those farm types could not be found.

Initial observation of the comparison results suggests that none of the average values for energy use per land area within any of the farm type categories (Table 15) attains a level of energy use efficiency that is more favorable than their centralized agriculture counterpart average values. However, the median values for fruit-nut and vegetable farm types are within the U.S. farm range. The two animal operation farm types (cattle, goats and sheep) had no respondents that reached the apparent energy efficiency levels attained by their centralized agriculture counterparts. Vegetable growers and fruit and nut producers had median values that are within the centralized agriculture efficiency ranges, while averages were considerably higher, indicating that the least efficient energy users appear to be having an outsized effect on the ranges in these categories. The range for field crops indicates that some farms are capable of achieving centralized agriculture's level of efficiency, but the more central location of its average and median would suggest that its farms are distributed evenly across the wide range by their measure of efficiency.

Deeper investigation into the differences in energy use per unit of land area, between different farms within the same farm type, was carried out by creating and analyzing scatter plots with values for all reporting farms within each farm type. This process was intended to draw out patterns and relationships between energy use and land area to be discerned for each farm type and outliers to be identified and further investigated. Results, however, were inconclusive due to low response rates in most categories. Such graphical analysis, though, has the potential to identify patterns and indicate farm scales that operate at optimum efficiencies, especially if higher response numbers can be achieved. Examples of such analysis are seen in Figure 27.

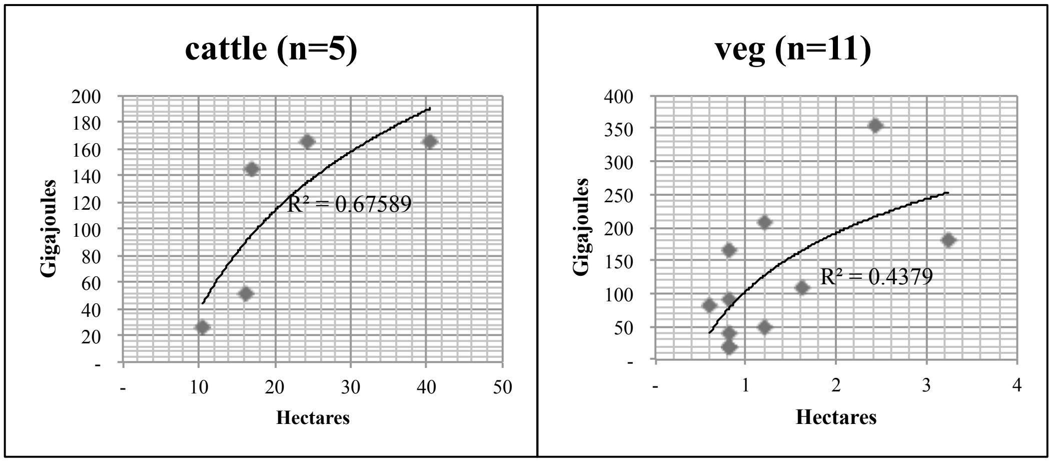

Figure 27. Example scatter plots showing energy used per unit land area for all farms within a given farm type category.

Energy Improvement Opportunities

The demographics dataset was analyzed to discern the attitudes and current relationship held by the farmers toward the use of renewable energy and energy efficiency improvements. This dataset, in conjunction with the smaller energy usage dataset, was used to identify potential funding needs and the challenges in attaining USDA grant assistance for the small farms serving local markets in western North Carolina.

Renewable Energy

Respondents who reported using renewable energy were asked for the system size and predicted annual savings provided by each type of renewable system they had. Only photovoltaic systems and solar hot water systems were represented in the responses for these questions. The answers for system sizes and annual savings provided by photovoltaic systems were at times incongruous with one other, or with the electricity use response, requiring follow-up calls and emails with some respondents. Recommendations for providing better clarity in the question and higher reliability in responses are made in Chapter 5.

Fifteen (26%) of the 58 respondents in the demographics dataset currently use some form of renewable energy on their farm: 12 photovoltaic systems, five solar hot water systems, one wind system, two ram pumps. No geothermal, micro-hydro, or anaerobic digestion systems were reported. When the remaining 74% of respondents were asked Survey Question #96, “What statement best describes your outlook on using renewable energy for your farm?”, options that the remaining 43 respondents chose from were “I would like to use renewable energy soon or in the future,” “I don't foresee using renewable energy on my farm,” and “I am uncertain about using renewable energy.” The percentages of respondents for each answer regarding renewable energy are displayed in Figure 28, including the 15 respondents already using some form of renewable energy. This graphic shows that 85% of respondents were receptive to the use of renewable energy on their farms.

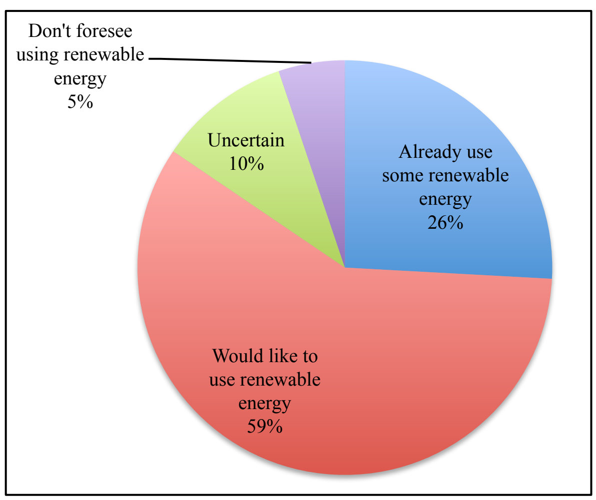

Figure 28. Reflection of farmer attitudes about renewable energy when asked “What statement best describes your outlook on using renewable energy for your farm?” (n=58)

Reasons for not having adopted renewable energy on the 43 farms without it varied, and all farms had multiple reasons. The three most common reasons given were “Too expensive" (26 responses), "Don't know how to make it happen" (17 responses), and "Not sure it's a good financial decision," (15 responses). A further breakdown of all reasons given in Figure 29 shows the number of respondents, per individual reason, who described their outlook on using renewable energy as would like to have, don't foresee, and uncertain.

Few respondents are ambivalent about whether or not they would like renewable energy on their farm. The methods and justifications for doing so are the missing element for those interested. It is also worth noting that all of the respondents who indicated they don't need it were also uncertain about renewables use, indicating potential need for further education.

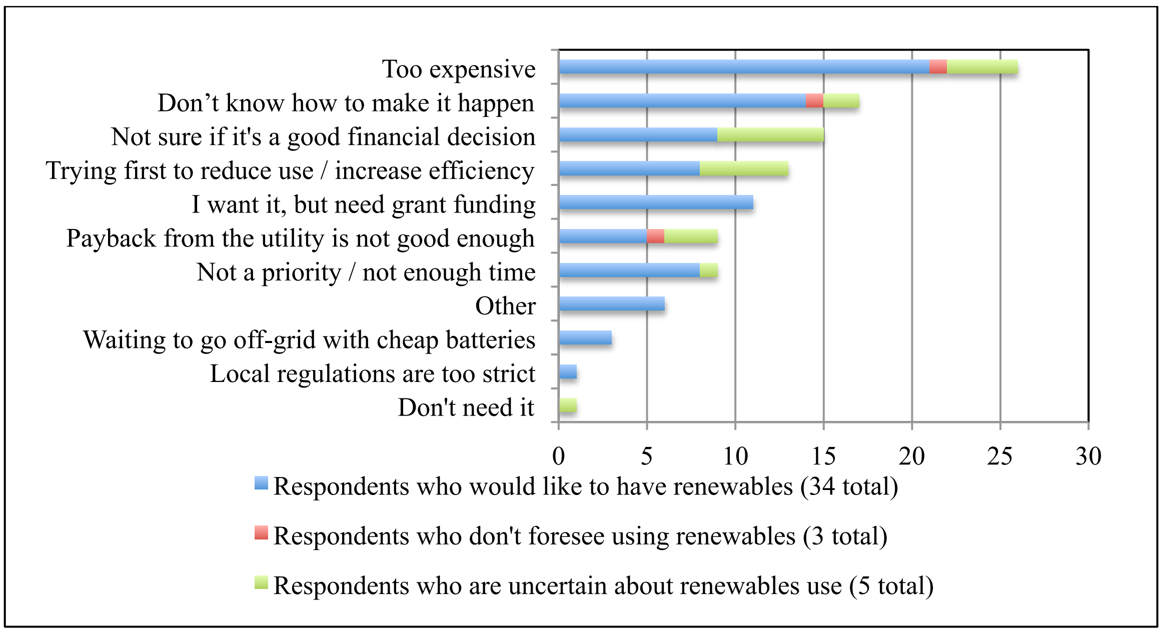

Figure 29. Reasons given for not adopting renewable energy on the farm.

Fifty-three of the respondents answered questions about renewable energy potential. When asked about potential renewable energy resources on their farms, 50 respondents (94%) claimed to have an area of their property with open solar access between the hours of 9 AM and 3 PM, and 46 respondents (87%) had a stream or surface water located on their property, with 21 (40%) self-reporting a stream flow and elevation drop which was promising for hydro-electric generation. Questions about wind generation were omitted from the survey due to the difficulty in apprising one's own wind generation potential, and questions regarding volume of crop and animal waste generated were too incompletely and rarely answered to have any reportable data. Another limiting factor for anaerobic digestion was respondents' claim to prioritize crop and animal wastes for the generation of compost on the farm for application on production beds.

Fifty-five respondents answered Survey Question #105, "Would you apply for grant funding for a renewable energy system if the grant funder required that you DO NOT use the generated energy in your home?" Of these respondents, 33 (60%) claimed that it would be acceptable to agree to not use the generated electricity in their home, while 21 (38%) claimed that they would need to be able to use the generated electricity in their home for the farm to benefit from a renewable energy system.

Farmers also indicated specific needs for renewable energy through fill-in-the-blank comments, which included solar electric energy for powering freezers (1 cattle farmer, 2 fruit and nut farmers, and 1 goat and sheep farmer), solar pumping for pasture irrigation (1 cattle farmer), solar electric boosted herb dehydrator (3 culinary and medicinal herb farmers), and solar electric generation for farm income (2 cattle farmers, 1 field crop farmer, and 1 fruit and nut farmer).

Summary of renewable energy opportunities. The opportunities for the use of renewable energy can be divided by three major energetic functions: mechanical, electrical and thermal energy. The above analysis indicated that the main interest was in electricity production with one farmer interested in mechanical and three farmers interested in thermal applications.

Mechanical energy. Major on-farm mechanical energy needs include running tractors and other equipment, and pumping water for irrigation and livestock. Equipment using diesel fuel could substitute biodiesel, with cattle farmers and field crop farmers showing the highest opportunity for improvement. For the irrigation needs, which are currently met largely by electricity, the 94% of farms with solar access could take advantage of solar photovoltaic systems, and 40% may be able to meet these needs with micro-hydro systems from their mountain streams. Further, storing pumped water could increase the viability of intermittent renewable resource use for the pumping, and the 40% of respondents with micro-hydro potential could just as well have the potential to pump using passive renewable technologies like the ram pump or High Lifter.

Major off-farm mechanical energy needs include transportation of people, supplies, and products. These activities lend themselves toward system-wide improvement considerations. The transportation needs could be met with either electric vehicles powered by renewable energy or with biodiesel, and per-farm transportation energy use could be reduced through an integrated food distribution system powered by renewable resources.

Electrical energy. Major on-farm electrical energy needs include refrigeration and freezing of finished products and manifold uses that appear to be relatively small (with the exception of greenhouse fans) and manifold, such as electrical fencing, computer use, and barn lighting (electrical use for irrigation is here considered a mechanical energy need).

As with the mechanical needs in transportation, the storage need could be met with an off-farm storage facility that could be housed at a food hub, a county extension office, or similar centrally located facility that could be powered by renewable electric energy and reduce per-farm energy use through efficiencies of scale of a single storage system (provided that any additional transportation of goods to the storage facility would not cancel out the benefits). A high correlation exists between lower distances to end-consumers and farm types selling highly perishable products currently reporting electricity use for storage (vegetables, fruits, and animal products).

***Thermal energy*.** On-farm thermal needs include the heating of greenhouses (most commonly used for culinary and medicinal herbs, horticultural and nursery products, and to a lesser extent, vegetables), heating other farm buildings, and heating water.

Culinary and medicinal herbs and horticultural and nursery plants did not report high levels of crop waste, and do not apparently have operations integrated with animals, so biological sources of heat through compost, anaerobic digestion, or gasification techniques could only be achieved through partnerships or transformed business models that integrate these operations. Efficient biomass heating systems may be a more promising pathway, especially in this particular local food system region where farm and landowners tend to have ready access to wood resources. Passive solar design and thermal mass heat storage could also be employed for space heating.

Water heating, commonly tied to dairy operations, could be improved upon through the use of solar hot water systems. Integrating dairy operations with high thermal load operations like culinary and medicinal herb farmers and horticultural and nursery crop farmers could create opportunities to use thermal energy more widely, efficiently, and flexibly.

Energy Efficiency

Fifty-six (97%) of the 58 respondents reported having undertaken some form of energy efficiency improvements on their farm. Common measures reported were LED lighting upgrades (40% of farms), insulation (31%), and efficient doors and windows (28%). A full summary of the number of farms reporting specific types of energy-efficiency measures that were choices on the survey is seen in Figure 30. Other efficiency upgrades that were not listed on the survey were reported by 17% of farms, and included "on demand hot water system," "small solar hot water," "saving up for more higher-efficiency models of HVAC," "added another solar panel," "greenhouse insulation project," "built house and winery to be energy efficient," "weather stripping and insulation to overhead doors," "installed a CoolBot in barn to cool produce," (a CoolBot is an electronic device that allows window AC units to reach lower temperatures and refrigerate insulated spaces) and "reducing walkin cooler operation hours, eliminating ice machine."

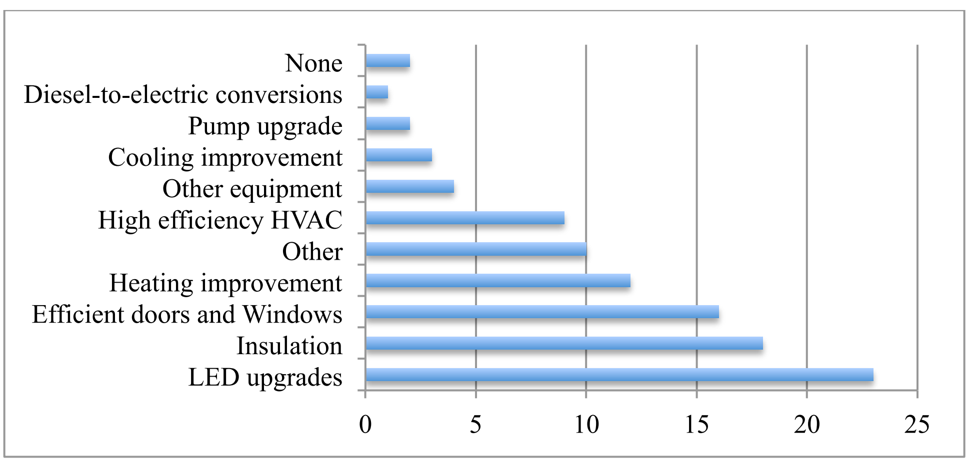

Figure 30. Number of farms reporting different energy efficiency improvements undertaken on the farm (58 total respondents).

Only 4 of 54 respondents (7%) reported having had an energy audit performed on their farm. None of the four implemented all recommendations resulting from the audit, two implemented “a few,” one implemented “some,” and one implemented “most.” Reasons for not implementing all recommendations included “too expensive” (two respondents) and “audit not accurate” (one respondent).

The other 50 respondents (93%) who answered the question reported that they had not had an audit performed on their farm. The top three reasons reported were “I already basically know where my energy goes” (37%), “I already try to conserve energy” (35%), and “Wasn’t aware of energy audits” (29%). The number of farms that indicated these and additional reasons are summarized in Figure 31. Respondents who replied “other” reported the following reasons for not having had an audit: “We are in a slow 'startup phase' both working full time jobs and farming on a very small scale,” “We're off grid and haven't been able to afford electric generation other than the generator,” “We would love an audit once we get more land cleared and closer to building new structure in 2017,” “privacy concerns,” “off farm job was an obstacle at one point - now full time farmer,” “VERY INTERESTED,” and “Have not had time to investigate advantages.”

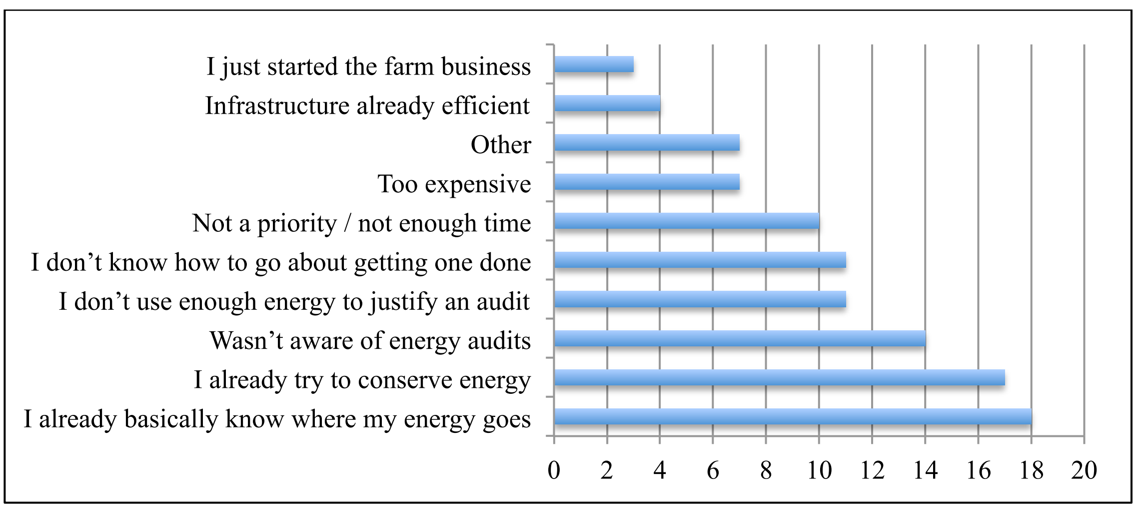

Figure 31. Reasons for not having had an on-farm energy audit (50 total respondents).

If respondents who affirmed some combination of “I already basically know where my energy goes,” “not a priority,” “I don’t use enough energy to justify an audit,” “I already try to conserve energy,” and “I already have efficient infrastructure” are excluded, only six farms (12%) remain, all of whom say they weren’t aware of audits, or that they don’t know how to go about having one performed on their farm. Therefore, it can be said that interest in having audits performed on the farm was low.

Farmers also indicated specific needs for energy through fill-in-the-blank comments, which included efficiency upgrades to walk-in coolers (1 cattle farmer, 4 vegetable farmers), greenhouse upgrades for light transmission and other thermal greenhouse improvements (1 culinary and medicinal herb farmer, 4 vegetable farmers).

Summary of energy efficiency opportunities. The opportunities for the implementation of energy efficiency measures was more difficult to assess than the renewable energy opportunities, largely because per-farm, on-site assessments of energy use were not performed. Looking at the fill-in-the-blank comments about the respondents’ energy needs, 23 out of 37 commenters within the demographics dataset mentioned the need for new infrastructure on the farm (e.g. tractors, hoophouses, fencing, walk-in coolers, dehydrators, buildings, and well pumps), most of which would require additional energy use. Most farmers, and especially those reporting new infrastructure needs, are using low levels of energy to begin with, as should be expected with the lower outputs inherent to farming at a smaller scale. As these farms increase output and continue to grow, there are ample opportunities to build and buy the most efficient buildings and equipment.

Some of the higher energy users did indicate needs for greater efficiencies, usually for thermal and equipment uses. On-farm production efficiencies could be improved through greenhouse insulation and heating equipment improvements, in particular for culinary and medicinal herbs, horticultural and nursery products, and vegetables. System-wide efficiencies appear to be available through integration with other farms for non-production elements of the farm's operation, including storage and transportation.

Funding Needs and Obstacles

Over half (60%) of those farmers without renewable energy (n=43) included "too expensive" as a reason for not having it. Based on the criteria reported that was relevant to grant funding eligibility, two thirds of these small farms (n=48) do not have enough of their household income coming from the farm (50% or more) to qualify for grant funding for renewable energy systems through USDA's Rural Energy for America Program. Of the remaining 16 farmers, only 7 of them use enough electricity to build a solar system that would meet the project cost minimum for the grant ($10,000), based on an installed system cost of $3.00/W, NREL's solar generation figure for the Asheville area (1,430 kWh per W installed) and a Duke Energy's residential price per kWh of $0.0924. This brings the percentage of small farmers eligible for grant funding through USDA to 15%. Two of these 7 farms said that they would not go through with the construction of a system if it could not be jointly used by their residence, This would bring the number of eligible farmers to five, which is just 10% of the study population.

Grant funding for energy efficiency projects through NRCS-EQIP and USDA-REAP presents an even lower percentage of eligible farmers, mostly due to the requirement of an energy audit to be performed as a first step toward funding. Energy audits are prohibitively expensive for small farms (as described in Chapter 2 and confirmed by the survey responses), and free energy audits are only available to farmers who use greater than $10,000 in on-farm, non-transportation energy. Only 1 of 54 farms would meet this requirement, and only 4 of 54 would meet it if the threshold were lowered to $5,000. Generously, only 7% of farmers would be eligible. The rest do not use enough total energy to justify the audit step.

Interview Results

Five follow-up interviews were conducted with one farm in each farm type category with three or more respondents that was close to the average energy usage profile for that category. These interviews consisted of approximately 45 minutes of semi-structured interview questions (seen in Appendix A), followed by a farm tour that identified high energy-use areas of the farm. The farmers profiled were a diverse group across a wide range of ages, occupational status, years farming, and reasons for farming. These case study profiles can be seen in Appendix C.

The main benefit of the interviews was a qualitative apportioning of total energy usage toward the different activities reported by the farm, which helped to identify owner interest and prioritize energy use improvement opportunities for that farm type. It also provided insight regarding the difficulty of separating energy use on the farm from personal use and allocating portions of energy type to particular activities. Future studies may wish to collect actual energy bills when available, or include specific appliance and equipment specifications in the data analysis in order to improve upon these limitations. They could also choose to do more intensive live tracking of energy use on individual farms using energy measurement devices or manual logging by participant farmers.

While being on-site with the farmers for this interview would be helpful if a full quantitative energy assessment were to be performed on the farm, this study could have achieved its goals in qualitative data collection with over-the-phone interviews. In this way, more qualitative data could have been collected from more farmers.

CHAPTER 5: CONCLUSIONS AND DISCUSSION

This study focused on (1) a survey approach for characterizing farm types and collecting energy use information from small-scale farms serving local markets in the 23-county area that makes up the mountain region of western North Carolina, (2) a comparison of small farm energy use profiles with large-scale**,** centralized agriculture, and (3) identifying opportunities for on-farm energy use improvement through renewable energy systems and energy efficiency improvements.

Overview

This pilot study contributed new knowledge about small farm energy usage to the field of agricultural energy research. While the resulting energy usage profiles required significant qualifications to be made before being compared to national farm energy statistics, general patterns were evident where response rates were higher, and much was learned about how future studies could capture more and higher-value data. The general takeaway messages of the study, to be discussed further below, can be divided into three categories: the survey instrument, energy profiles, and energy use improvements.

Regarding the survey approach, acquiring a representative survey sample with complete data has many challenges, and this study provided valuable lessons learned for using this approach in future studies. Regarding survey content, documenting energy use for small-scale farms is complex and somewhat nuanced, and a number of shortcomings in the survey instrument used for this study became evident as the data sets were prepared and analysis was conducted.

Higher proportions of the system-level direct energy use across all farm types came from gasoline and electricity as compared to the centralized agricultural system. Preliminary comparisons of energy usage efficiency (in GJ/ha) were made between the study farms and large, centralized farms from literature data, but the small number of data points for each farm type and lack of data about indirect energy usage and agricultural output per hectare suggested further study is needed.

Opportunities for on-farm energy improvement, as well as system-wide energy improvement, are available and farmer interest levels are high. Solar energy resources are available on 94% of study farms and, due to the mountain terrain, micro-hydro resources are also available, but to a lesser extent. However, USDA grant funding programs are not designed to benefit the small farms participating in the expanding local food sector.

Overall, if emerging local food systems are to play a role in a future economy that is both data-driven as well as diligent in its response to climate change, they especially will need more refined tools for assessing and reporting their energy use. This study, along with the literature it references, leaves many questions unanswered regarding a full understanding of energy use in the young and growing local food sector. The discussion that follows is aimed at guiding further research to more thoroughly and accurately capture the energy use realities of local food systems. The impacts of study findings, lessons learned, and recommendations for improvement will be discussed for each of these study components—energy use profiles, comparisons with centralized agriculture, and energy improvement opportunities.

Survey Instrument Improvements

Although the goal for responses to the study survey of 80 farms (10% of the estimated 800 farms serving local markets in the study region, as determined in Chapter 3) was achieved, not all of the collected data were suitable for analysis. Of the 81 responses received, the viable subsets were reduced to 58 farms for analysis about farm characteristics and renewable energy potential and attitudes (demographics dataset), and to 33 farms for analysis of questions pertaining to energy use by farm type (energy usage dataset). Having at least five results in each farm type category would have allowed for more clarity about the energy use patterns for those categories. Suggested improvements to the survey itself and the analysis of its results, discussed below, would likely increase the number of respondents providing data and increase the usability of that data.

Improving Response Rates

Increasing the number of usable responses would improve representation and generalizability of the results. This could be done through making more questions mandatory, making the survey shorter, and addressing bias that may have limited the number of interested respondents.

Mandatory questions. Due to a concern of having too many respondents leave the survey midway through, it was not mandatory to answer any survey question before a respondent could continue the survey. It is difficult to know what effect this decision had on survey completion, but it clearly caused some degree of difficulty in cleaning the data and determining whether answers at times were intentionally skipped. Further, if an analysis step required a calculation with two or three different survey answers among completed surveys, the lessened likelihood of all three being answered completely—albeit within completed surveys—necessarily lowered the number of complete surveys available for that calculation.

Some questions in this survey that would have been particularly beneficial to make mandatory were questions about the county of operation (seven otherwise viable survey responses were thrown out because they could not be confirmed to have been in the sample area) and the farm's electric utility provider (this would provide certainty about electric rates and renewable power purchase rates and policies).

Survey length. Average time to complete the survey was 25.2 minutes. Various survey strategy guides suggest that lower survey completion times would increase response rates. Some questions in this survey proved to not have been particularly useful. The questions about what farm activities were done with each energy type were useful up to a point, but those answers could have been more readily determined and fully understood through the interview portion of the study. A narrower focus on energy types used, usage amounts, and a solid understanding of the scale of the operation would likely increase response rates and usability of the data for energy profiling.

Potential bias. Sources of potential bias and deviation from a true representative sample were evident in the recruitment and data collection process itself. While hard copies were distributed to NC cooperative extension offices in the 23-county area, no completed hard copies were returned, and all 81 survey responses were completed online. Realistically, some percentage of the farming community will not be comfortable enough working with computers to do the survey online, or possibly even be exposed to the recruitment methods undertaken online through newsletters, press releases, and website and social media posts. Thus, some section of the target group can be assumed to be missing in the results.

Another standout indicator of potential bias was that 26 of the 58 viable respondents (45%) were already using some form of renewable energy on their farm, a dramatically higher percentage than that observed on all farms nationwide, which is 2.7% of farms. This suggests that the sample skews toward those with perspectives and attitudes already conscious of on-farm energy issues, and favorable toward renewable energy use.

Further studies should place emphasis on capturing a more representative sample. This could be done through more in-person recruitment at events like cattlemen's association meetings, NC Soil and Water Conservation District area meetings, and other regional meetings organized by and for specific farm types. Recruitment at such meetings would likely capture the part of the population less inclined toward internet-based communication, and possibly avoid the self-selecting of those already interested in energy issues and comfortable with technology that internet-based recruitment seems to favor.

Improving Energy Use Analysis

The second way of improving the survey has to do with the methodology for selecting and analyzing questions asked. Recommended improvements to questions in the survey include organizing energy use by amount toward different activities, capturing the data of diversified farms better, subtracting residential energy use with finer detail, assessing the data impacts of renewable energy systems better, and recording forested farmland acreage.

Energy use by difference activities. The percentage breakdown of energy used by different activities was not ascertained quantitatively in this study. Collecting this level of information would allow energy use profiles to be better broken down into the four farm direct energy use categories (production, processing, packaging, transportation). It could also provide a more detailed matching analysis of appropriate renewable energy substitutes for those farm energy uses. Such data would be best acquired in over-the-phone follow-up interviews (for respondents so willing) in order to keep the survey instrument brief and uncomplicated.

Capturing diversified farms. Diversified farms with more than one type of operation accounting for 20% or more of a farm's income remain an important and substantial subsection of small farms serving local markets, and accounted for 25% of the 81 surveys submitted. Although 15 of these surveys had complete enough data to have been included in the analysis datasets, they were excluded due to difficulties in accurately allocating energy used across the various operations on such farms. Due to the compounded variation of operational mixes that emerges when two and even three operations are reported for a single farm, further studies interested specifically in these diversified farms may do well to limit their focus to minimally overlapping and easily identified operations for each, e.g. vegetables farms that integrate pastured poultry. Based on how farmers responded to the survey instrument in this study, it is recommended that an apportioning of energy usage to the different farm operations be done in follow-up phone interviews.

Subtracting residential energy use. The proxy values used to subtract out residential electricity and propane use from the 13 responses reporting combined residential and farm energy use likely introduced a large margin of error. Due to the apparent higher interest in energy use issues shown by the reporting sample group, residential usage for these respondents was probably lower than the regional averages reported by EIA that were used in the proxy values. Some responses dipped into negative usage after subtracting this value, proving the point in at least some instances. Further studies should more accurately assess or estimate residential energy uses, either through more sophisticated analysis-side modeling using OpenEI residential energy use models, or through case-by-case follow-up phone interviews.

Impact of renewable energy used. Although energy impacts from an energy-use basis and a cost-savings basis were reflected in this study, self-reporting renewable energy savings proved to be a difficult task for this sample of respondents. Since only seven utilities service the sample territory, it would have been straightforward to research the available renewable energy rate structures (e.g. sell all, net metering, parallel generation) for each utility and include questions to ask the respondents with renewable energy generation which rate structure their system uses. With this, and a basic understanding of system performance parameters (shading, age of system, etc.), the respondent could answer a single question about their energy bill which would allow savings provided by their renewable energy system to be back-calculated with the other data available.

Savings from solar hot water systems were even more difficult to self-report because there is no metering of heat produced or hot water used. Because so few solar hot water systems were reported by the respondents, a case-by-case follow-up interview would be the best way to discern each system's impact on the farm's energy use for hot water.

Forested farmland acreage. Access to wood resources would be an important farm resource to ascertain in future studies. This would facilitate assessment of the potential for this form of renewable energy that could be used for thermal operations and electrical applications through gasification and pyrolysis technologies. In addition, biomass energy with carbon capture and storage is cited as a necessary resource in the pursuit of avoiding the worst effects of climate change according to the IPCC (Edenhofer et al., 2014).

Energy Use Profiles (Research Question #1)

Electric, gasoline, and diesel were the most widely used energy types on the small farms in this study. The contribution of electricity and diesel energy were in roughly equal proportion to what is observed in the overall U.S. farm economy, with a higher proportion of gasoline use. This finding was consistent with the tendency of smaller operations to more commonly adopt gasoline-powered equipment and transport vehicles (USDA, 2008). Much like the overall profile of national farms, the most common use for diesel fuel was on-farm tractors and other equipment. For gasoline, it was transport of materials and finished products, while electricity had a wide range of uses, predominately irrigation and then product cooling and freezing.

Small Farm Profiles

Of the five farm types with comparable national average data, the cattle farmers, field crop farmers, and fruit and nut growers were the three farm types most closely aligned with the energy source distribution profile observed nationally, with diesel and electricity being, respectively, the first- and second-highest energy-use fuels. The vegetable farmers and goat and sheep farmers were more heavily weighted toward gasoline and electricity, commonly for product storage, irrigation, and transport.

The other two farm types without comparison values (culinary and medicinal herb growers and horticultural plant producers) had energy use profiles that were highest in propane, heating oil, and wood use, predominately for heating greenhouses. All three of these fuels were used in higher proportion by the small farms in the local food system than what was observed in the overall national data. The lack of natural gas in the region may have been a factor in the overrepresentation of these fuel types for thermal applications.

The preliminary findings suggested a relationship between reported use of on-farm storage (cooling or freezing) of finished products and tendency toward higher percentages of farm products reaching end-consumers 100 miles from the farm or less. This included vegetable farmers, cattle farmers, goat and sheep farmers and, to a slightly lesser extent, fruit and nut growers.

Comparisons with Centralized Agriculture (Research Question #2)

For all five of the farm types observed with comparable data available in the literature, average direct energy use per unit land area (represented in GJ/ha) was higher on the study farms as compared to large, centralized farms of the same type. However, there are several methodological limitations to the study in need of consideration when interpreting these results. Recognizing the differences in production methods, the uses of indirect energy in fertilizers and pesticides, the ultimate yield per acre in agricultural output that results from these differing farming practices, and how farmers self-report their energy use are all essential aspects to any complete comparison. The inclusion of these factors could allow a more complete evaluation of the full environmental advantages and disadvantages of local food systems.

Production methods and intensity. Data from the literature is several decades old in some instances, suggesting that improvements in efficiencies in the centralized agriculture industry would show increased favorability for centralized farms from a strictly fossil fuel-usage per hectare perspective. Further, production levels per hectare were not considered in this study, and the lower yield per hectare often shown in non-industrial farming contexts would further penalize the small-scale farms in this comparison to the extent that they adopt organic and less spatially intensive, lower-yielding agricultural practices.

Recording production volumes. The exclusion of agricultural production estimates in the scope of this survey prevented comparisons of energy use per unit of output with large, centralized forms of agriculture. Beta-test farmers who proofed the first draft of the survey indicated that production volumes would be difficult to self-report, especially if length of time to complete the survey was already a point of concern. An assumption of this study was that levels of production per hectare would be similar for the same farm type regardless of size or location. However, if production figures could be collected, comparative analysis could explore effects of diversified and integrated farm approaches, differences in yield from organic production, and operational differences in the approach to land utilization by the two farming categories compared in this study.

Indirect uses of energy. Another difference between large- and small-scale farms is the extent to which indirect energy inputs through fertilizers and pesticides are used and/or accounted for. This study assumed similar levels of usage across the two major farming categories. However, to the extent that larger, centralized forms of agriculture are correlated with fossil fuel-intensive indirect energy inputs, smaller scale farms serving local markets may show a comparative advantage if fertilization and pest control methods and their associated fossil fuel energy use were better understood.

Self-reported energy use. One of the major limitations to the potential accuracy of this study was that energy use numbers were self-reported. The benefit of this approach was that higher volumes of responses were attained. The interview component of this study showed minor discrepancies between reported energy use numbers and the reality of energy use as understood through in-person discussions. In order to provide further certainty regarding responses, a select number of energy assessments could be performed during the interview process to better understand the relationship between what is self-reported and what is measured in an on-site assessment.

Ultimately, the data from studies such as this one can be used as a starting place for decision makers seeking to understand energy use in local food systems, as well as the need to explore strategies to lower the fossil fuel use.

Opportunities and Barriers for Energy Improvements (Research Question #3)

Among the demographics dataset's small farm respondents, interest in farm energy use improvements was high, especially toward renewable energy measures. Interestingly, energy efficiency measures sparked less interest. As a group, the respondents were relatively small net users of energy, often with new and efficient infrastructure or infrastructure that had yet to be built. Corresponding interest in energy audits as a tool for identifying energy saving opportunities was also low. By integrating these predispositions toward energy improvement technologies with the farms' reported on-farm energy uses, energy-use activities, and renewable energy resource access, priorities for individual farm and system-wide energy improvements can be identified.

Individual Farm Energy Use Improvements

Access to full-day sunlight (94% of farms) and to creeks and streams (87%) was widespread, and the study region's mountain coves led to a substantial portion of respondents (40%) reporting a sufficient vertical drop and flow to investigate power production. These conditions present the best opportunities for solar photovoltaic electricity generation, micro-hydro electricity generation, and passive pumping of water to be stored (or solar photovoltaic pumping for those water sources without sufficient vertical drop). This renewable energy produced could be used for the major on-farm electricity demands including irrigation water collection, storage, and delivery; and on-farm storage (cooling and freezing) of products.

Solar energy resources can also be used to satisfy thermal energy needs such as space and water heating, and production applications such as root zone heating or food dehydration. Water heating needs were not regularly reported, hot water usage volumes were impossible to verify. However, solar hot water would be a potential benefit in high use instances, such as dairy and other farms engaged in food processing activities with consistent volumes, or as a solution to be combined with hot water used in farm residences. Diversified farms may also present situations that would justify the incorporation solar hot water systems. Passive solar food dehydration is another thermal energy use improvement method that could decrease the energy consumption of culinary and medicinal herb farmers and vegetable farmers.

Generally low volumes of available crop and animal wastes (not already being used for compost) were reported, thus limiting their availability for use in biologically-driven renewable heat generation. However, in cases where there is an adequate supply of feedstock, this renewable energy approach would be especially useful for the two farm types reporting high thermal energy demands for greenhouse heating (culinary and medicinal herb farmers and horticultural and nursery plant producers). An analysis of the diversified-income farms that were excluded from the energy use analysis portion of this study may present opportunities for operationally pairing farm wastes with heating needs.

Though wooded acreage was not solicited by the survey, voluntary responses about energy use practices and wood sourcing suggest that wood is a commonly available resource to most farmers in the study region. Therefore, renewable biomass heating from an efficient system could be pursued if access to wood resources was favorable. An efficient biochar kiln fueled by local wood resources could provide renewable heat and soil amendments as a byproduct, and provide unique carbon sequestration benefits (Gaunt & Lehmann, 2008). Such a system would be most readily paired with the small plant-producing farm types (culinary and medicinal herbs, horticultural and nursery products, and vegetables) for use in greenhouses.

System-wide Energy Use Improvements

Individual farm energy use improvements are constrained by each farm's available financial and labor resources and may therefore offer limited cumulative benefits to the local food system as a whole. Improvement strategies that address system-wide shortcomings are contingent instead upon the organization of a collective community's financial and labor resources. A system-wide approach to energy-use improvement offers combinatory benefits toward energy use reduction through consolidation of redundant farm energy use activities. By focusing on those reported farm energy use activities that do not necessarily need to be tied directly to the farm site, a new set of common patterns by all farm types emerges, and opportunities for system-wide improvement are revealed with regard to transportation, storage, labor, and miscellaneous other factors.

Transportation. The high gasoline usage reported system-wide could be improved through an integrated, possibly web- and data-driven distribution system that could take advantage of full load sizes and more efficient routing. Such a higher load capacity would allow for the conversion to a more powerful and energy-efficient diesel engine fleet, which could be run on biodiesel. Other potential increases in agricultural production could result from a network of participating small farms taking joint responsibility for shared activities, thus providing more time available for on-farm tasks. While such improvements would likely benefit individual farms or small groups, their scale of impact would be manifold if implemented for an entire distribution network of regional small farms.

Storage. While the exact amount of the study farms' electricity usage dedicated to cooling and freezing products is unknown, the activity is widely reported and is likely the next highest electricity use activity after water pumping. Combining these similar energy-use storage activities into consolidated food storage hubs could present unique energy-use advantages to local food systems in comparison with the centralized food economy. Hubs could be created at a conveniently located farm, extension office, or through a direct partnership with an area grocery store already cooling and freezing food. Extra benefits could be realized if combined with transportation to the central hub through an efficient and integrated distribution system.

Labor force integration. All of the small farms in the study were family owned and operated. The smaller acreages and lower practical access to the high-capital, high-capacity equipment of larger farm systems tacitly restrict farm output to limitations in human labor capacity. Reversing the industrial era's trend toward lower human labor per unit of food produced may be an essential complementary element of making small-scale local food farms viable from an energy use perspective. Such a reversal would require transformations to the political and economic structures of communities well outside the scope of this study, but is worthy of consideration from a whole systems view.

Given the labor output limitations of individual families, co-locating families and their different farm operations could provide opportunities for energy use improvements. These could be in the form of the reigning in of large nutrient and resource cycles, sharing and responsibly redirecting agricultural and animal wastes for increased soil health (which leads to lower indirect energy use from external inputs) and bioenergy, and increasing localized labor availability.

Other factors. If optimization of the energy use of the entire system is the goal, other opportunities for energy use improvement that emerge through reflection on the results of this study and are worthy of system-level consideration include:

- changing local consumer behavior through education about diet and dining choices that favor seasonal and fresh foods, impacting energy use in the retail, commercial, and residential stages of the value chain;
- integrating waste heat generated from thermal processes in production stage with heat needs in the processing stage;
- selecting agricultural products and varieties and processing techniques suited for energy-free storage;
- reducing the need for indirect energy use farm inputs through adoption of integrated pest management, no-till cropping, and responsible recycling of animal and crop wastes; and
- utilizing marginal lands on forest edges with agro-forestry techniques, treating forests responsibly as valuable resource for energy, animal fodder, and carbon sequestration.

Barriers to Accessing USDA On-Farm Energy Project Funding

Very few study farmers reported answers that indicated eiligibility for USDA grant funding for renewable energy projects (10% of farmers) and energy efficiency projects (7% of farmers). Analysis of potential barriers faced by small farms shows that USDA could increase participation in their energy programs of small farms serving local markets by (1) lowering the required minimums for project costs, (2) developing a reasonable method of accounting for shared residential energy use instead of an outright disqualification of dual-use projects, (3) relaxing the requirement that a full 50% of household income must come from farming, and (4) developing guidelines for accepting the findings of lower-cost energy assessments as a substitute for expensive audits in the pathway toward funding.

Making Local Food Systems More Resilient

Because the local food movement in the U.S. is in a relatively nascent phase of development, great variation exists in the energy use profiles, farm scales, and production practices of its participating small farms. These intra-system variations, along with its decentralized structure as a network of numerous discrete local food systems, make for greater difficulty in assessing the energy use realities and identifying opportunities for energy use improvement as compared to doing so within the more familiar, centralized agriculture model. The root cause of this difficulty should not necessarily be considered a problem. Instead, local food systems should be seen as complex and variegated, demanding more careful study to be better understood. The results of such studies can help craft more resilient national food policies and guide regional decision-makers toward stronger economies and communities.

Suggestions for Further Research

The findings of this study suggest a number of improvements to be undertaken for additional research, most of which are geared toward collecting more high-quality data that could be more usefully compared to large-scale, centralized agriculture.

Agricultural output proved to be a much more desirable denominator unit for analysis and comparison of farm energy use efficiency, as compared to acreage. Using this unit, which is more widely used in the literature, would illuminate the effects on agricultural yield of different production methods, pest management techniques, and mixed and diversified use of land. While excluded from this study's survey instrument on the advice of beta-test farmers, a shorter and more focused survey could incorporate the question of agricultural output. Otherwise, it could be part of targeted follow-up phone interviews. Because the units of output for a given farm type differ (e.g. pounds of meat, gallons of milk, bushels of apples), data collection instruments should be targeted for specific farm types to answer with ease. The literature and beta-test farmers should be solicited for the best units to use.

Indirect energy use from fertilizers and pesticides should also be studied, as this effect would have a bearing on total fossil fuel energy used as well as agricultural output. Acquisition of this data could be done with follow-up phone interview questions for those indicating a willingness to participate in a short phone interview as a follow-up to their brief energy-use survey. Information about the fertilization and pest management programs farmers use, in terms of types and amounts of specific products used, in combination with agricultural output, would significantly improve the data's value and comparability.

Creating a methodology for accurately apportioning the energy use on diversified farms with multiple farm outputs observed over shared acreage could constitute a whole study itself. Such knowledge would be a key step toward understanding the energy use of a local food system, which in this study was comprised of 25% diversified farms.

Differences in labor characteristics on small farms as compared to large farms were evident but not fully analyzed in this study. Future studies could assess the impact that labor inputs have on agricultural yield, operating cost, and energy balance on small farms as compared to large. Another ancillary benefit worth investigating is the impact on local employment and workforce demographics such as under-employed young people during summer months.

Finally, the use of GIS tools and NREL data to identify opportunities for matching wind, water, biomass, and solar energy supply resources with the self-reported energy demands of proximate farming operations. Creating a clearing house of such information could disburden the respondents from self-assessing these resources and finding neighboring farms with complementary operations. The creation of an integrated local food system would provide an interesting, and perhaps more advantageous, entity to be compared with large, centralized farms.

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APPENDIX A

Recruitment Letter, Survey Questions, and Interview Questions

Recruitment letter

Dear small farms of WNC,

As a nonprofit working to bring clear, headache-free grant funding to WNC small farms, we understand that you work hard every day to make your farm more profitable, and self-sufficient. Time and again, we find that small farms like yours are overlooked by federal funding programs, which are often geared toward larger operations. The activity of small farms in WNC is only growing, and reflecting the needs of this community is, more than ever, an important step in making this community stronger.

By participating in this survey, you can help the WNC small farm community to become more self-sufficient in one key area: ENERGY. Our goal is to learn the major energy needs on WNC small farms, and then expand our grant funding programs to help meet those needs. Hearing your voices can raise awareness about the realities of operating our mountain farms and bring more opportunities to the small farms in our region.

We understand that you are busy, so we have tried to make the survey easy and helpful to you personally. We hope it will serve as a chance to think about your energy costs and where improvements can be made. As a thank you, when the study is complete, you can choose to receive a resource guide that includes WNC's small farm energy use profile, recommendations for energy savings, profiles of similar farmers who have undertaken successful energy projects, and resources in our area to get started.

The survey takes around 20 minutes to complete, is made mostly of checkboxes, and has plenty of content you can skip! (It's even easier to take online at www.energycap.org/survey.) It asks basic questions about the types and estimated amounts of energy your farm uses. For those interested, follow-up interviews and free whole-farm energy assessments may be conducted as time and resources allow. However, if you are only able to complete this survey your effort will be truly appreciated! The survey period will close January 15, 2017.

Before you begin, you should collect any 2015 energy bills (electricity, propane, etc.) and basic revenue and operating cost totals you may have available. If not, your best estimates will be OK! A calculator may come in handy for short calculations. If you have any questions, please feel free to contact us.

Thank you for your help, and for the work that you do!

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Survey Questions

Here we go! Please do your best to give accurate answers, but remember that your best estimates are always acceptable, too. If you feel like a question is too hard to estimate, or you'd rather not give an answer, skip the question.

We'll start with the first of three sections:

1. Getting to know your farm
2. Looking at your energy use
3. Discovering energy improvements

If you'd prefer to skip the post office box trip, you can complete this survey online instead at:

www.energycap.org/survey

BASIC FARM INFO

County: ______________________

Year farm started: _____________

How would you describe your farm work?
(select ALL that apply)

- ❑ Farming is 50% or more of my total income
- ❑ Farming is my primary occupation
- ❑ My primary occupation is something else
- ❑ Some of my household works full-time farming, and others have a different occupation
- ❑ I am retired, and still do some farming

Do you have a Farm Number with the Farm Service Agency (FSA)?
(You might have gotten one from your county's office for a loan, crop insurance, or to apply for other federal programs)

- ❍ Yes
- ❍ No
- ❍ I'm not sure

In 2015, what was the FIRST month of your farm's active production season?

January	July
February	August
March	September
April	October
May	November
June	December

In 2015, what was the LAST month of your farm's active production season?

January	July
February	August
March	September
April	October
May	November
June	December

Your products are sold directly to:
(select all that apply)
- ❑ Restaurants
- ❑ Grocery stores
- ❑ Farmers markets
- ❑ Farm stands
- ❑ CSAs
- ❑ Regional distributors / food hubs
- ❑ None of the above

Roughly, what percentage of your product reaches end-consumers (people who eat it) within 100 miles of the farm?

______%

Roughly, what percentage of your product reaches end-consumers (people who eat it) within 275 miles of the farm?

______%

Are your products "certified locally grown" through the Appalachian Sustainable Agriculture Project (ASAP)?
- ❍ Yes
- ❍ No
- ❍ I don't know

What are your primary sources of farm income?
Please rank only your top three sources, with "1" being the highest income. (Only include an income source if it makes up >20% of your total farm income.)

____ Field crops
____ Vegetables
____ Fruits and nuts
____ Horticultural/nursery
____ Cattle
____ Goats/sheep
____ Poultry
____ Culinary/medicinal herbs
____ Forest products
____ Honey
____ Other: ____________________

In 2015, roughly how many acres were used for each of the income streams noted in the last question?
(growing acres or, for animals, grazing acres)

Source #1: ________ acres
Source #2: ________ acres
Source #3: ________ acres

SECTION 1 COMPLETE

Moving on to the next section...

1. Getting to know your farm
2. **Looking at your energy use**
3. Discovering energy improvements

The following questions are about the energy you use on your farm. If you have any energy bills from 2015 (e.g. electricity, propane, or gas bills), it would be helpful to have them here. Otherwise, your best estimate will do!

ELECTRICITY

In 2015, did your farm use ELECTRICITY?
- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used electricity?
(select all that apply)
- ❑ Lighting
- ❑ Ventilation
- ❑ Communications/computers
- ❑ Electric fencing
- ❑ Greenhouse heating
- ❑ Dairy parlor heating
- ❑ Heating other farm buildings
- ❑ Incubators/Poultry brooders
- ❑ Water heating
- ❑ Water pumping
- ❑ Irrigation
- ❑ Drying
- ❑ Pasteurizing
- ❑ On-farm slaughter
- ❑ Grinding/milling/threshing
- ❑ Product cooling
- ❑ Product freezing
- ❑ Transportation
- ❑ Other (please describe):

  ____

In 2015, what was the farm's total estimated cost of electricity?

$______________

Does this estimate include residential or non-farm use of electricity?
- ❍ Yes
- ❍ No

Do your farm operations and your residence share a single electric meter?
- ❍ Yes
- ❍ No
- ❍ I'm not sure

PROPANE

In 2015, did your farm use PROPANE?
- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used propane?
(select all that apply)
- ❑ Greenhouse heating
- ❑ Dairy parlor heating
- ❑ Heating other farm buildings
- ❑ Incubators, poultry brooders
- ❑ Water heating
- ❑ Drying
- ❑ Pasteurizing/boiling
- ❑ On-farm slaughter
- ❑ Running a generator
- ❑ Processing
- ❑ Weed control
- ❑ Other (please describe):

  ____

In 2015, what was the farm's total estimated cost of propane?

If you only know your propane number in gallons, you can use $2.50/gallon to convert to dollars.

$____________

Does this estimate include regular residential use of propane?
(It would be great if residential use is not included in the estimate, but if it's unavoidable, no problem.)
- ❍ Yes
- ❍ No

NATURAL GAS

In 2015, did your farm use NATURAL GAS?
- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used natural gas?
(select all that apply)
- ❑ Greenhouse heating
- ❑ Dairy parlor heating
- ❑ Heating other farm buildings
- ❑ Incubators/Poultry brooders
- ❑ Water heating
- ❑ Drying
- ❑ Pasteurizing/boiling
- ❑ On-farm slaughter
- ❑ Running a generator
- ❑ Processing
- ❑ Other (please describe):
  ____

In 2015, what was the farm's total estimated cost of natural gas?

$______________

Does this estimate include residential or non-farm use of natural gas?
- ❍ Yes
- ❍ No

HEATING OIL

In 2015, did your farm use HEATING OIL?
- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used heating oil?
(select all that apply)
- ❑ Greenhouse heating
- ❑ Dairy parlor heating
- ❑ Heating other farm buildings
- ❑ Incubators / Poultry brooders
- ❑ Water heating
- ❑ Drying
- ❑ Pasteurizing/boiling
- ❑ On-farm slaughter
- ❑ Running a generator
- ❑ Processing
- ❑ Other (please describe):
  ____

In 2015, what was the farm's total estimated cost of heating oil?

$______________

Does this estimate include residential or non-farm use of heating oil?
(It would be great if residential use is not included in the estimate, but if it's unavoidable, no problem.)
- ❍ Yes
- ❍ No

Roughly what percentage of your heating oil estimate is from a biodiesel blended product like BioHeat (from a producer like Blue Ridge Biofuels)?
_________%

GASOLINE

In 2015, did your farm use GASOLINE?
❍ Yes
❍ No

--If your answer is “No,” skip this COLUMN.--

In 2015, which farm activities used gasoline?
(select all that apply)
❑ Running a generator
❑ Transportation of people
❑ Transportation of supplies and raw materials
❑ Transportation of finished products
❑ Running a tractor
❑ Running other farm equipment
❑ Other (please describe):
____

In 2015, what was the farm's total estimated cost of gasoline?

If you only know your total in gallons, you can use $2/gallon to convert to dollars.

If you only know your total miles driven, just divide those miles by the vehicle's "miles per gallon," and then multiply that result by $2/gallon.

Please do NOT include any personal or non-farm related use of gasoline in this estimate.

$____________

DIESEL FUEL

In 2015, did your farm use DIESEL FUEL?
❍ Yes
❍ No

--If your answer is “No,” skip this COLUMN.--

In 2015, which farm activities used diesel fuel?
(select all that apply)
❑ Running a generator
❑ Transportation of people
❑ Transportation of raw materials and supplies
❑ Transportation of finished products
❑ Running a tractor
❑ Running other farm equipment
❑ Other (please describe):
____

In 2015, what was the farm's total estimated cost of diesel fuel?
Please do NOT include any personal or non-farm related use of gasoline in this estimate.

$______________

Roughly what percentage of your diesel fuel estimate is bio-diesel (from a manufacturer like Blue Ridge Biofuels, or some other source of waste-derived bio-diesel)?
_______%

FIREWOOD

In 2015, did your farm use FIREWOOD?

- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used firewood as a combustion energy source?

(select all that apply)

Do not include residential uses.

- ❑ Greenhouse heating
- ❑ Dairy parlor heating
- ❑ Heating other farm buildings
- ❑ Incubators/poultry brooders
- ❑ Water heating
- ❑ Drying
- ❑ Pasteurizing/boiling
- ❑ On-farm slaughter
- ❑ Running a generator
- ❑ Processing
- ❑ Other (please describe):

____

How do you provide firewood to your farm?

- ❍ I buy it from off-site.
- ❍ It is grown and prepared from trees or woody material on my farm.
- ❍ Some combination of the two responses above.

In 2015, roughly how many CORDS of firewood were used for your farm operations?

(1 cord = 4 ft x 4 ft x 8 ft stack of firewood)

Please do not include residential use of firewood in this estimate.

__________ cords

WOOD PELLETS

In 2015, did your farm use WOOD PELLETS?

- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used wood pellets as a combustion energy source?

(select all that apply)

Do not include residential uses.

- ❑ Greenhouse heating
- ❑ Dairy parlor heating
- ❑ Heating other farm buildings
- ❑ Incubators/poultry brooders
- ❑ Water heating
- ❑ Drying
- ❑ Pasteurizing/boiling
- ❑ On-farm slaughter
- ❑ Running a generator
- ❑ Processing
- ❑ Other (please describe):

____

In 2015, roughly how many 40 lb. bags of wood pellets were purchased for your farm operations?

Please do not include residential use of wood pellets in this estimate.

________ bags

MANUAL LABOR

In 2015, which farm activities used manual labor only?

(select all that apply)

i.e. you DID NOT use a powered machine/device to assist you.

- ❑ Cutting/hauling/stacking wood
- ❑ Watering/pumping/irrigation
- ❑ Land prep and sowing/planting
- ❑ Weed/pest/disease control
- ❑ Harvesting/milking
- ❑ Processing
- ❑ Manure management
- ❑ Maintenance and upkeep of farm
- ❑ Other (please describe):

____

In 2015, which farm activities used powered machine/device assistance?

(select all that apply)

- ❑ cutting/hauling/stacking wood
- ❑ Watering/pumping/irrigation
- ❑ Land prep and sowing/planting
- ❑ Weed/pest/disease control
- ❑ Harvesting/milking
- ❑ Processing
- ❑ Manure management
- ❑ Maintenance and upkeep of farm
- ❑ Other (please describe):

____

In 2015, what was the farm's estimated total number of human hours spent doing manual labor? Please include all labor, regardless of whether it was paid or unpaid, including your own. (You might find a calculator useful!)

__________ hours

ANIMAL TRACTION / ANIMAL POWER

In 2015, did your farm use ANIMAL TRACTION / ANIMAL POWER?

- ❍ Yes
- ❍ No

--If your answer is "No," skip this COLUMN.--

In 2015, which farm activities used animal traction / animal power? (select all that apply)

- ❑ Irrigation/pumping
- ❑ Land preparation
- ❑ Sowing/planting
- ❑ Weed/pest/disease control
- ❑ Harvesting
- ❑ Grinding/milling/threshing
- ❑ Transportation
- ❑ Animal management/herding
- ❑ Other (please describe):

____

In 2015, what was the farm's estimated total number of animal hours spent doing work in the above farm activities?

_____________ hours

RENEWABLE ENERGY

In 2015, did your farm use RENEWABLE ENERGY?

❍ Yes
❍ No

--If your answer is "No," skip this PAGE.--

What type(s) of renewable energy do you use on your farm?

❑ Solar PV - Electricity
❑ Solar hot water
❑ Wind - Electricity
❑ Wind - Water pumping
❑ Micro-hydro - Electricity
❑ Ram pump
❑ Geothermal
❑ Anaerobic digestion
❑ Other (please describe): ____________________

If applicable…

How large is your SOLAR PV system?

________ KW

In 2015, roughly how much money did your SOLAR PV system save you on your electricity bill? (skip if unsure)

$__________

How many collector panels does your SOLAR HOT WATER system have?

_________ panels

In 2015, roughly how much money did your SOLAR HOT WATER system save you on your energy costs? (skip if unsure)

$__________

How large is your WIND system?

________ KW

In 2015, roughly how much money did your WIND system save you on your electricity bill? (skip if unsure)

$_____________

How large is your MICRO-HYDRO system?

______________ KW

In 2015, roughly how much money did your MICRO-HYDRO system save you on your electricity bill? (skip if unsure)

What is the electric utility that your renewable energy system (or systems) is connected to?

❍ Duke Energy
❍ French Broad EMC
❍ Blue Ridge EMC
❍ Rutherford EMC
❍ Haywood EMC
❍ Other: ____________________
❍ My system is not connected to the grid

SECTION 2 COMPLETE

Only one more to go! And it's the easiest...

1. Getting to know your farm
2. Looking at your energy use
3. **Discovering energy improvements**

Would you be willing/interested in participating in a follow-up interview or a whole-farm energy assessment after this survey is completed?

- ❍ No
- ❍ Yes – Interview only
- ❍ Yes – Energy assessment only
- ❍ Yes – Both the interview and the energy assessment

Do you keep complete records of on-farm electrical, heating, and other energy costs?

- ❍ Yes
- ❍ Sort of
- ❍ No

Did any of your energy use estimates in the last section's questions include your residential use of that energy?

- ❍ Yes
- ❍ No

--If your answer is "No," skip the rest of this page.--

Please complete the following to help us understand the residential portion of your energy use.

	How many adults live in the residences that are included in some of your energy estimates?	How many kids live in the residence(s) that are included in some of your energy estimates?	Roughly how many stories tall are each of the residences included in your energy bill estimates?	Roughly how many total square feet are each of the residences included in your energy bill estimates?	Roughly how many years old are each of the residences included in your energy bill estimates?	Are the residences insulated? (YES or NO)
Residence #1						
Residence #2						
Residence #3						

RENEWABLE ENERGY OUTLOOK

What statement best describes your outlook on using renewable energy for your farm?

- ❍ I would like to use renewable energy soon or in the future.
- ❍ I don't foresee using renewable energy on my farm.
- ❍ I am uncertain about using renewable energy.

Why doesn't your farm currently use renewable energy? *(check all that apply)*

- ❑ Don’t need it
- ❑ Not a priority / not enough time
- ❑ Not sure if it is a good financial decision
- ❑ Too expensive
- ❑ I want renewable energy, but only if it can be partially grant-funded
- ❑ Don’t know how to make it happen
- ❑ Local regulations are too strict
- ❑ Payback from the utility is not good enough
- ❑ I'm waiting to go off-grid when batteries are cheaper
- ❑ Trying first to reduce energy use and increase efficiency
- ❑ Other (please explain): ____________________

Do you have an area in an unused field or on a roof that gets full sunlight from 9AM-3PM?

- ❍ Yes
- ❍ No
- ❍ I don't know

In 2015 (or in a given year), how many CUBIC YARDS PER YEAR of crop waste were generated?

- ❍ Roughly _______ cu. yards per year
- ❍ I don't know

In 2015 (or in a given year), how many CUBIC YARDS PER YEAR of animal manure were generated in your animal housing/shelter area? (i.e. do not include any manure left in pasture)

- ❍ Roughly _______ cu. yards per year
- ❍ I don't know

Do you have a running stream or river on your property?

- ❍ Yes
- ❍ No

Would you apply for grant funding for a renewable energy system if the grant funder required that you DO NOT use the generated energy in your home?

- ❍ Yes. That's no problem. I would apply and only connect the system to my farm operations.
- ❍ No. I would only be interested in the grant-funded project if I could power my home as well.
- ❍ No. I would not want to do such a project anyway.

ENERGY EFFICIENCY OUTLOOK

What energy-saving devices and procedures have you done on your farm in the past 5-10 years? Please exclude anything done to your residence.
(select all that apply)

- ❑ Adding High efficiency Heating, Ventilation, or Air Conditioning (HVAC) systems
- ❑ Adding insulation to uninsulated buildings
- ❑ Upgrading lights to LED lighting
- ❑ Improving heating system efficiency
- ❑ Improving cooling system efficiency
- ❑ Replacing doors and windows
- ❑ Upgrading pumps higher-efficiency models
- ❑ Replacing diesel equipment with electric-drive
- ❑ Replacing other equipment with more efficient models
- ❑ Other (please describe): ____________________
- ❑ None of the above

Has your farm ever had an energy audit performed?
(An energy audit is an inspection, survey and analysis of energy flows, usually performed by a licensed energy assessor or engineer. The purpose is to identify high-priority areas for improvement that will reduce the amount of energy used and lower energy costs.)

- ❍ Yes
- ❍ No

What recommendations from the audit did you choose to implement?

- ❍ All
- ❍ Most
- ❍ Some
- ❍ A few
- ❍ None

Why did you not implement all recommendations?
(select all that apply)

- ❑ I intend to. I just haven't yet.
- ❑ Not enough time.
- ❑ Too expensive.
- ❑ Audit isn't accurate.
- ❑ Other: (please describe) ____________________

Why have you not had an audit done? (check all that apply)

- ❑ I already basically know where my energy goes
- ❑ Not a priority / not enough time
- ❑ Wasn't aware of energy audits
- ❑ Too expensive
- ❑ I don't use enough energy to justify an audit
- ❑ I don't know how to go about getting one done
- ❑ I just started the farm business and don't have energy use history
- ❑ I already try to conserve energy
- ❑ All of my infrastructure is already highly energy efficient
- ❑ Other (please explain): ____________________

GROSS SALES

We ask this question to show grant funding agencies the average sales of different types of small farms in our region, in comparison to large conventional farms.

In the year 2015, the farm's total gross sales (i.e. total receipts) from all farm products were roughly:

- ❍ I prefer not to share.
- ❍ $0 to $10,000
- ❍ $10,001 to $50,000
- ❍ $50,001 to $100,000
- ❍ $100,001, to $150,000
- ❍ $150,001 to $250,000
- ❍ Greater than $250,000

<u>SOME</u> OPERATING EXPENSES

This question helps us to justify the need for WNC small farmer grant funding. We will also use it to compare average operating costs for small farms with large conventional farms.

For the year 2015, what would you estimate the <u>sum</u> of the following operating costs to be?

- supplies and equipment
- feed
- raw material inputs
- rental of farm land and equipment
- repairs
- maintenance
- marketing costs

Basically, all operating costs <u>excluding</u> costs of human labor, energy, and transportation fuel.

Remember: this can be an estimate! You may also **skip** this question if you prefer not to share.

$______________

(OPTIONAL, BUT HELPFUL)

The Energy Cost-share Assistance Program wants to attract grant funding for small farm projects in our area. **What key areas of your infrastructure have you been wanting to improve**, where grant-funding would be of particular benefit (walk-in coolers? greenhouse heating? something innovative and exciting? something boring and practical?)? Please feel free to share your thoughts (what you could use and why) and we will do our best to deliver programs that may be helpful!

____
____
____
____
____
____
____
____
____

CONTACT INFO: (OPTIONAL)

Your contact information will not be shared. We will only use your contact information if you have expressed interest in the follow-up interview or energy assessment, or if you have checked one of the boxes below.

First and Last Name: ________________________________

Farm Name: ________________________________

Email: ________________________________

Phone Number: ________________________________

- ❑ I want to receive a free resource guide when the study is complete.
- ❑ I want to be notified of future cost-share grants available through the Energy Cost-share Assistance Program. (ECAP)

That's it! Thank you so much for completing the survey! We hope it's been a useful exploration into your farm's energy use. You may return the survey to:

Alex Arnold
Energy Cost-share Assistance Program
4388 US Hwy 25/70, Suite #3
Marshall, NC 28753

www.energycap.org

(OPTIONAL, BUT HELPFUL)

The Energy Cost-share Assistance Program wants to attract grant funding for small farm projects in our area. **What key areas of your infrastructure have you been wanting to improve**, where grant-funding would be of particular benefit (walk-in coolers? greenhouse heating? something innovative and exciting? something boring and practical?)? Please feel free to share your thoughts (what you could use and why) and we will do our best to deliver programs that may be helpful!

____
____
____
____
____
____
____
____
____

CONTACT INFO: (OPTIONAL)

Your contact information will not be shared. We will only use your contact information if you have expressed interest in the follow-up interview or energy assessment, or if you have checked one of the boxes below.

First and Last Name: ____

Farm Name: ____

Email: ____

Phone Number: ____

- ❑ I want to receive a free resource guide when the study is complete.
- ❑ I want to be notified of future cost-share grants available through the Energy Cost-share Assistance Program. (ECAP)

That's it! Thank you so much for completing the survey! We hope it's been a useful exploration into your farm's energy use. You may return the survey to:

Alex Arnold
Energy Cost-share Assistance Program
4388 US Hwy 25/70, Suite #3
Marshall, NC 28753

www.energycap.org

Interview Questions

Warm-up questions

- How long have you been farming?
- How did you come to be a farmer?

FARM PROFILE

- Work
    - If primary work is other, how do you think about the farm as an income stream? Is the goal to be >50% farm income? What are the barriers to that goal?
- Season
    - When you think about your season's start and end, what kind of activities does the "start" period represent, and the "end" period? What are you doing at those times?
    - What do you do in the off-season? What farm activities are still "on" in the off-season?
    - What kind of cycles of work for production, and for sales?
- Local
    - Where do you sell your product?
    - Look at the % within 100 mile radius and ask for comment/elaboration.
    - Do products go to wholesalers or food hubs? At what point are you disconnected from the sale and from the knowledge of end location? Are others doing the transportation and other energy use steps after the farm stage?
- Production
    - Confirm acreages
    - How intensively are those acres "produced" upon?
    - Any greenhouse being used? What kind of energy? Temps? Months of year?
    - How many animal head? How many [production units] of crops?
    - Are the animals confined?
    - What do you do with crop wastes and animal wastes?
- Production/Processing/Packaging/Storage/Distribution
    - Which of these activities are you involved in?
- Uniqueness of small farms
    - In what ways might your farm contrast with a conventional, large farm producing the same products?
        - Integration with diversified operations?
        - Integration with residence- what role does your home's energy play in your production/processing/packaging/storing?

ENERGY USE

- Look at energy responses and confirm
    - Amounts
    - Activities
        - estimate percentage of fuel type toward each activity
        - Break activities down by production/processing/packaging/storage/distribution
        - What are the activities like ‘water heating’ used for?
    - Residential tie-in, activities in home
    - Note absences of fuel types, possibly absent activities (e.g. transportation?), absent thermal needs etc, and ask for comment.

RE/EE

- Renewable energy
    - Review survey response
- Energy efficiency
    - Review survey response
- Grants
    - What grant programs for farm energy projects are you aware of?
    - Have you or anyone you know participated in federal programs for energy grants? Why/why not?
    - What would a better program look like in your opinion?
- Energy use sentiments
    - How has the price of energy affected your farm’s operation?
    - (Describe EQIP and REAP. Mission statements first, then eligibility requirements.)
    - Do you think it is important for USDA et al to support local food? Why/why not?
    - Do you think it is important for USDA et al to support local small farm energy use through grants for energy? Or are other avenues of support more important? For production enhancements? Local distribution systems? What barriers do you think exist in the way of local food being able to fully thrive/take off?

Wrap-up

Where do you see the farm 10 years in the future? 50 years?
Any other comments?

Farm Tour

- Could you walk me through the procedure of activities from production to sale (or starting in the spring) for your farm operation? (take pictures of all areas and devices) Extend the conversation beyond the walkthrough to steps that take place after those performed on the farm. Ask percentage of energy use going toward the activities described.

Take Pictures

Appendix B

Descriptive Statistics of Energy Use and Major Activities, by Farm Type

Cattle

COST BASIS ($)

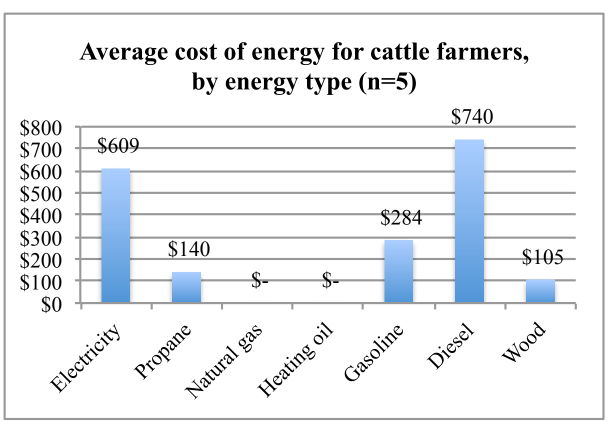
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	5	5	5	5	5	5	5
AVERAGE	$609	$140	$-	$284	$740	$105	$1,878
STDEV	$705	$313	$-	$165	$953	$196	$1,621
MAX	$1,800	$700	$-	$400	$2,200	$450	$4,100
MIN	$-	$-	$-	$-	$-	$-	$75
MEDIAN	$450	$-	$-	$320	$300	$-	$1,300

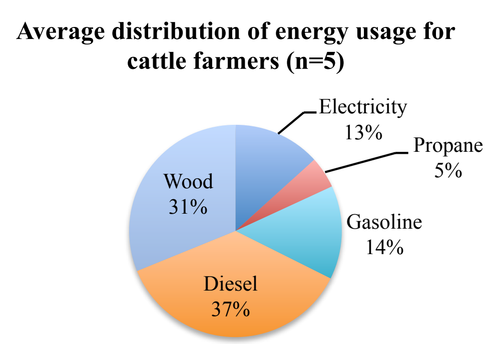
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	5	5	5	5	5	5	5
AVERAGE	13.9	5.0	0.0	14.9	38.1	32.6	104.5
STDEV	19.7	11.3	0.0	8.7	49.1	60.7	62.9
MAX	48.2	25.2	0.0	21.0	113.3	139.6	156.4
MIN	0.0	0.0	0.0	0.0	0.0	0.0	25.2
MEDIAN	7.4	0.0	0.0	16.8	15.4	0.0	136.4

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	5	5	5	5
AVERAGE	53.6	21.7	110.8	5.0
STDEV	28.6	11.6	66.7	2.5
MAX	100.0	40.5	165.8	8.5
MIN	26.0	10.5	26.7	2.5
MEDIAN	42.0	17.0	144.6	4.1





Cattle
Most common activities, by number of affirmative responses
Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC	
Lighting	4
Ventilation	1
Communications/Computers	3
Electric fencing	4
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators/Poultry brooders	0
Water heating	2
Water pumping	1
Irrigation	1
Drying	0
Pasteurizing	0
On-farm slaughter	0
Grinding/milling/threshing	0
Product cooling	1
Product freezing	3
Transportation	0
Other	0

PROPANE	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	2
Incubators, poultry brooders	0
Water heating	1
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	1
Processing	0
Weed control	0
Other	0

HEATING OIL	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

GASOLINE	
Running a generator	2
Transportation of people	2
Transportation of supplies	2
Transportation of finished product	2
Running a tractor	1
Running other farm equipment	3
Other	0

DIESEL	
Running a generator	0
Transportation of people	0
Transportation of supplies	1
Transportation of finished product	1
Running a tractor	3
Running other farm equipment	1
Other	0

WOOD	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	2
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

Culinary and Medicinal Herbs

COST BASIS ($)

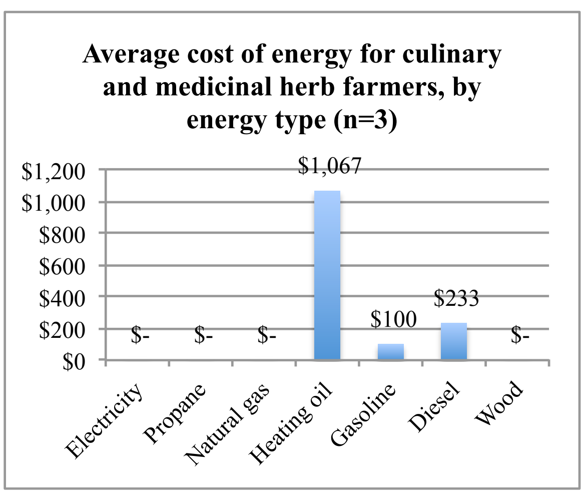
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	3	2	3	3	3	3	3
AVERAGE	$-	$-	$1,067	$100	$233	$-	$1,400
STDEV	$-	$-	$1,848	$100	$404	$-	$2,339
MAX	$-	$-	$3,200	$200	$700	$-	$4,100
MIN	$-	$-	$-	$-	$-	$-	$-
MEDIAN	$-	$-	$-	$100	$-	$-	$100

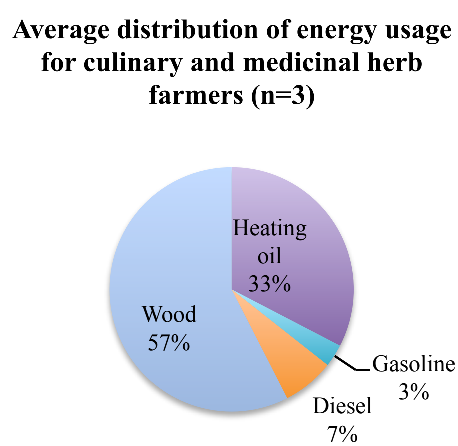
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	3	2	3	3	3	3	3
AVERAGE	0.0	0.0	57.2	5.3	12.0	100.8	175.2
STDEV	0.0	0.0	99.0	5.3	20.8	136.3	260.0
MAX	0.0	0.0	171.5	10.5	36.0	255.9	473.9
MIN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MEDIAN	0.0	0.0	0.0	5.3	0.0	46.5	51.8

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	3	3	3	3
AVERAGE	1.3	0.5	185.8	459.0
STDEV	0.6	0.2	275.6	681.0
MAX	2.0	0.8	502.4	1241.4
MIN	1.0	0.4	0.0	0.0
MEDIAN	1.0	0.4	54.9	135.6





Culinary and medicinal herbs

Most common activities, by number of affirmative responses

Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC

Lighting	1
Ventilation	1
Communications/Computers	1
Electric fencing	0
Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	0
Incubators/Poultry brooders	0
Water heating	1
Water pumping	1
Irrigation	0
Drying	0
Pasteurizing	0
On-farm slaughter	0
Grinding/milling/threshing	1
Product cooling	0
Product freezing	0
Transportation	0
Other	0

PROPANE

Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	0
Processing	0
Weed control	0
Other	0

HEATING OIL

Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

GASOLINE

Running a generator	2
Transportation of people	1
Transportation of supplies	2
Transportation of finished product	1
Running a tractor	0
Running other farm equipment	1
Other	0

DIESEL

Running a generator	0
Transportation of people	1
Transportation of supplies	1
Transportation of finished product	1
Running a tractor	1
Running other farm equipment	0
Other	0

WOOD

Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	1
Incubators, poultry brooders	0
Water heating	1
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

Field Crops

COST BASIS ($)

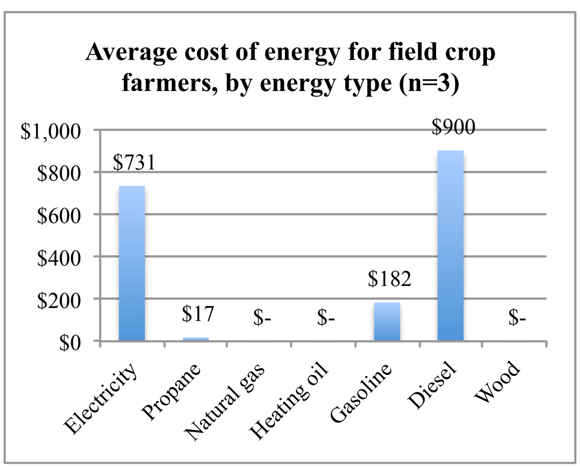
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	3	3	3	3	3	0	3
AVERAGE	$731	$17	$-	$182	$900	-	$2,313
STDEV	$747	$29	$-	$103	$529	-	$1,153
MAX	$1,493	$50	$-	$300	$1,500	-	$3,643
MIN	$-	$-	$-	$120	$500	-	$1,625
MEDIAN	$700	$-	$-	$125	$700	-	$1,670

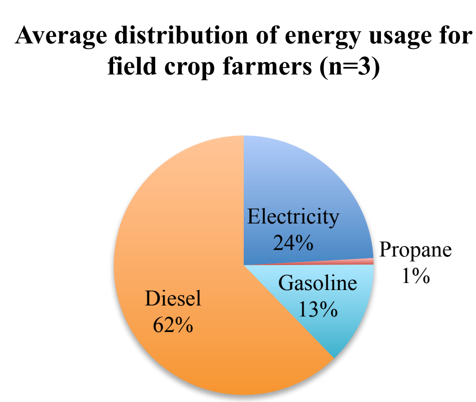
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	3	3	3	3	3	0	3
AVERAGE	18.0	0.6	0.0	9.5	46.3	-	208.6
STDEV	19.6	1.0	0.0	5.4	27.2	-	96.3
MAX	38.9	1.8	0.0	15.8	77.2	-	293.1
MIN	0.0	0.0	0.0	6.3	25.7	-	103.8
MEDIAN	14.9	0.0	0.0	6.6	36.0	-	228.9

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	3	3	3	3
AVERAGE	19.3	7.8	221.1	145.4
STDEV	29.2	11.8	102.1	128.8
MAX	53.0	21.4	310.7	271.9
MIN	1.0	0.4	110.0	14.5
MEDIAN	4.0	1.6	242.6	149.9





Field crops

Most common activities, by number of affirmative responses

Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC	
Lighting	2
Ventilation	0
Communications/Computers	1
Electric fencing	0
Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	1
Incubators/Poultry brooders	1
Water heating	2
Water pumping	2
Irrigation	1
Drying	1
Pasteurizing	0
On-farm slaughter	0
Grinding/milling/threshing	1
Product cooling	2
Product freezing	0
Transportation	0
Other	0

PROPANE	
Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	0
Processing	0
Weed control	0
Other	0

HEATING OIL	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	1
On-farm slaughter	0
Processing	0

GASOLINE	
Running a generator	0
Transportation of people	2
Transportation of supplies	1
Transportation of finished product	2
Running a tractor	2
Running other farm equipment	2
Other	1

DIESEL	
Running a generator	0
Transportation of people	2
Transportation of supplies	2
Transportation of finished product	3
Running a tractor	3
Running other farm equipment	2
Other	0

WOOD	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

Fruit and Nut

COST BASIS ($)

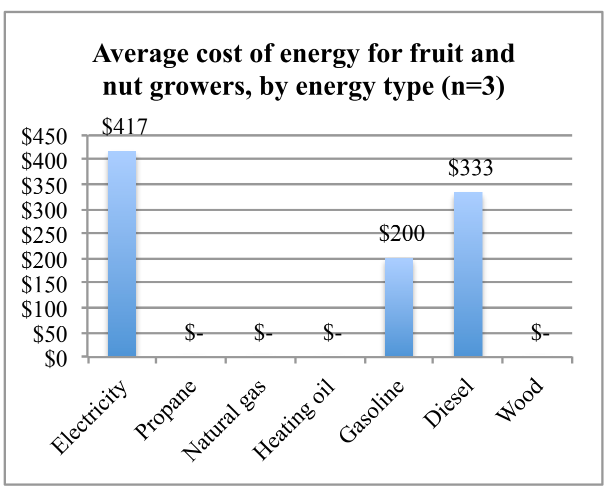
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	3	3	3	3	3	2	3
AVERAGE	$417	$-	$-	$200	$333	$-	$950
STDEV	$382	$-	$-	$346	$577	$-	$1,238
MAX	$750	$-	$-	$600	$1,000	$-	$2,350
MIN	$-	$-	$-	$-	$-	$-	$-
MEDIAN	$500	$-	$-	$-	$-	$-	$500

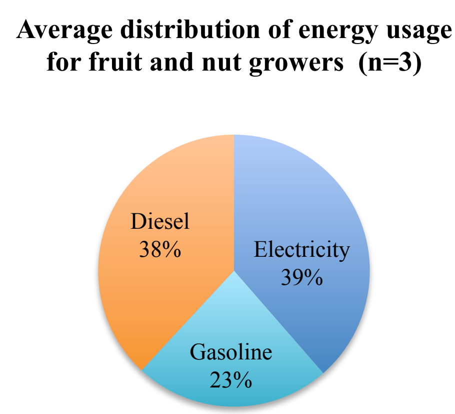
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	3	3	3	3	3	3	3
AVERAGE	17.4	0.0	0.0	10.5	17.2	0.0	45.1
STDEV	15.4	0.0	0.0	18.2	29.7	0.0	49.6
MAX	33.3	0.0	0.0	31.5	51.5	0.0	99.5
MIN	2.4	0.0	0.0	0.0	0.0	0.0	2.4
MEDIAN	16.4	0.0	0.0	0.0	0.0	0.0	33.3

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	3	3	3	3
AVERAGE	2.4	1.0	47.8	167.7
STDEV	2.0	0.8	52.6	234.3
MAX	4.0	1.6	105.4	435.8
MIN	0.2	0.1	2.6	2.1
MEDIAN	3.0	1.2	35.3	65.1





Fruit and nut
Most common activities, by number of affirmative responses
Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC	
Lighting	1
Ventilation	0
Communications/Computers	1
Electric fencing	1
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators/Poultry brooders	0
Water heating	0
Water pumping	2
Irrigation	1
Drying	0
Pasteurizing	0
On-farm slaughter	0
Grinding/milling/threshing	0
Product cooling	1
Product freezing	0
Transportation	1
Other	1

PROPANE	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	0
Processing	0
Weed control	0
Other	0

HEATING OIL	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

GASOLINE	
Running a generator	0
Transportation of people	0
Transportation of supplies	1
Transportation of finished product	1
Running a tractor	0
Running other farm equipment	1
Other	0

DIESEL	
Running a generator	0
Transportation of people	0
Transportation of supplies	0
Transportation of finished product	1
Running a tractor	1
Running other farm equipment	0
Other	0

WOOD	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	1
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

Goats and Sheep

COST BASIS ($)

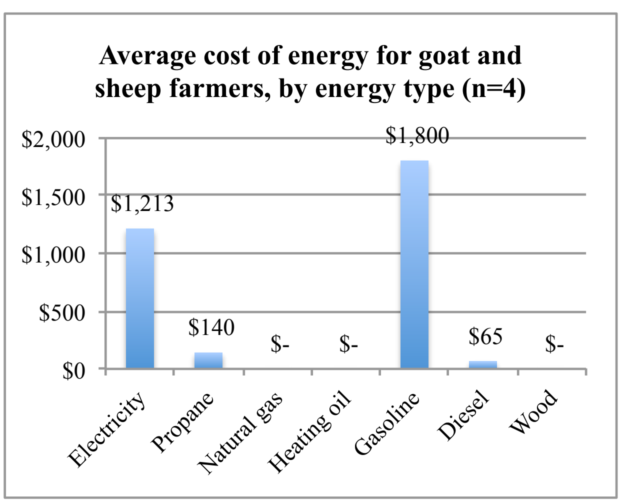
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	4	4	4	4	4	3	4
AVERAGE	$1,213	$140	$-	$1,800	$65	$-	$3,218
STDEV	$924	$280	$-	$2,298	$130	$-	$2,950
MAX	$2,293	$560	$-	$4,800	$260	$-	$7,093
MIN	$53	$-	$-	$-	$-	$-	$53
MEDIAN	$1,252	$-	$-	$1,200	$-	$-	$2,862

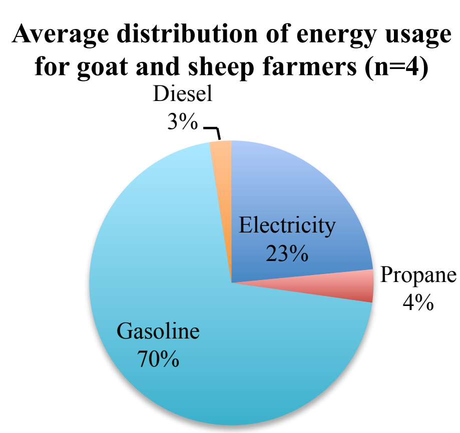
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	4	4	4	4	4	3	4
AVERAGE	31.6	5.0	0.0	94.6	3.3	0.0	175.3
STDEV	26.0	10.1	0.0	120.8	6.7	0.0	102.4
MAX	63.1	20.2	0.0	252.3	13.4	0.0	315.4
MIN	0.0	0.0	0.0	0.0	0.0	0.0	69.7
MEDIAN	31.6	0.0	0.0	63.1	0.0	0.0	158.0

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	4	4	4	4
AVERAGE	28.3	11.4	185.8	32.9
STDEV	32.6	13.2	108.5	34.1
MAX	77.0	31.2	334.3	82.6
MIN	10.0	4.0	73.8	5.5
MEDIAN	13.0	5.3	167.5	21.7





Goats and sheep

Most common activities, by number of affirmative responses

Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC

Lighting	4
Ventilation	1
Communications/Computers	3
Electric fencing	2
Greenhouse heating	0
Dairy parlor heating	1
Heating other farm buildings	1
Incubators/Poultry brooders	0
Water heating	3
Water pumping	3
Irrigation	0
Drying	0
Pasteurizing	1
On-farm slaughter	0
Grinding/milling/threshing	0
Product cooling	2
Product freezing	3
Transportation	2
Other	2

PROPANE

Greenhouse heating	0
Dairy parlor heating	1
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	1
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	0
Processing	0
Weed control	0
Other	0

HEATING OIL

Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

GASOLINE

Running a generator	0
Transportation of people	1
Transportation of supplies	2
Transportation of finished product	2
Running a tractor	1
Running other farm equipment	1
Other	0

DIESEL

Running a generator	0
Transportation of people	0
Transportation of supplies	1
Transportation of finished product	0
Running a tractor	1
Running other farm equipment	0
Other	0

WOOD

Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

Horticultural and Nursery Products

COST BASIS ($)

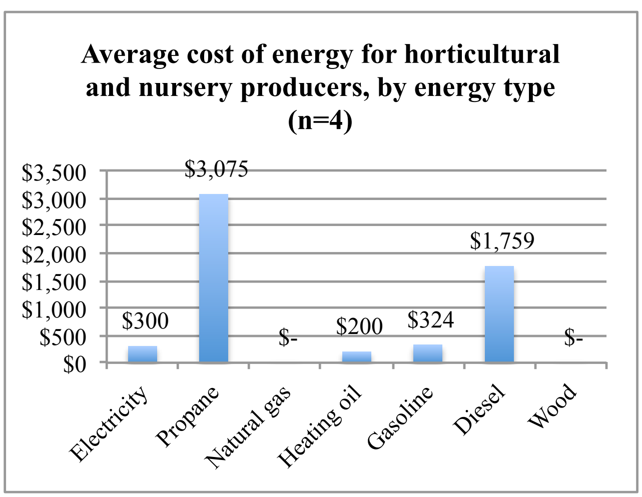
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	4	4	4	4	4	3	4
AVERAGE	$300	$3,075	$200	$324	$1,759	$-	$5,658
STDEV	$600	$5,952	$400	$460	$1,592	$-	$4,599
MAX	$1,200	$12,000	$800	$1,000	$3,637	$-	$12,000
MIN	$-	$-	$-	$-	$-	$-	$1,075
MEDIAN	$-	$150	$-	$148	$1,700	$-	$4,779

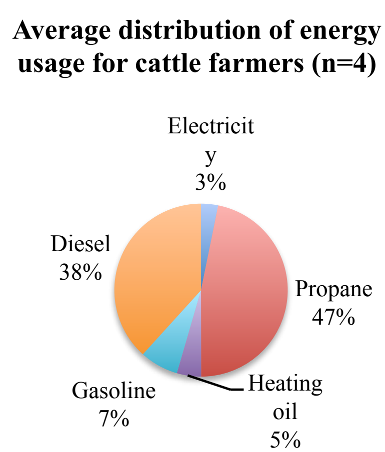
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	4	4	4	4	4	4	4
AVERAGE	7.5	110.7	10.7	17.0	90.6	0.0	236.6
STDEV	15.0	214.3	21.4	24.2	82.0	0.0	154.3
MAX	30.1	432.2	42.9	52.6	187.3	0.0	432.2
MIN	0.0	0.0	0.0	0.0	0.0	0.0	55.4
MEDIAN	0.0	5.4	0.0	7.8	87.5	0.0	229.4

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	4	4	4	4
AVERAGE	11.3	4.6	250.8	284.0
STDEV	19.1	7.7	163.5	275.6
MAX	40.0	16.2	458.1	628.0
MIN	1.0	0.4	58.8	14.3
MEDIAN	2.1	0.9	243.1	246.7





Horticultural and nursery products
Most common activities, by number of affirmative responses
Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC	
Lighting	2
Ventilation	0
Communications/Computers	1
Electric fencing	1
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	1
Incubators/Poultry brooders	0
Water heating	1
Water pumping	1
Irrigation	1
Drying	0
Pasteurizing	0
On-farm slaughter	0
Grinding/milling/threshing	0
Product cooling	1
Product freezing	1
Transportation	0
Other	0

PROPANE	
Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	1
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	0
Processing	0
Weed control	0
Other	0

HEATING OIL	
Greenhouse heating	0
Dairy parlor heating	0
Heating other farm buildings	0
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	1
On-farm slaughter	0
Processing	0

GASOLINE	
Running a generator	2
Transportation of people	2
Transportation of supplies	3
Transportation of finished product	3
Running a tractor	1
Running other farm equipment	2
Other	1

DIESEL	
Running a generator	0
Transportation of people	0
Transportation of supplies	2
Transportation of finished product	2
Running a tractor	2
Running other farm equipment	0
Other	0

WOOD	
Greenhouse heating	
Dairy parlor heating	
Heating other farm buildings	
Incubators, poultry brooders	
Water heating	
drying	
Pasteurizing/boiling	
Running a generator	
Other	
On-farm slaughter	
Processing	

Vegetables

COST BASIS ($)

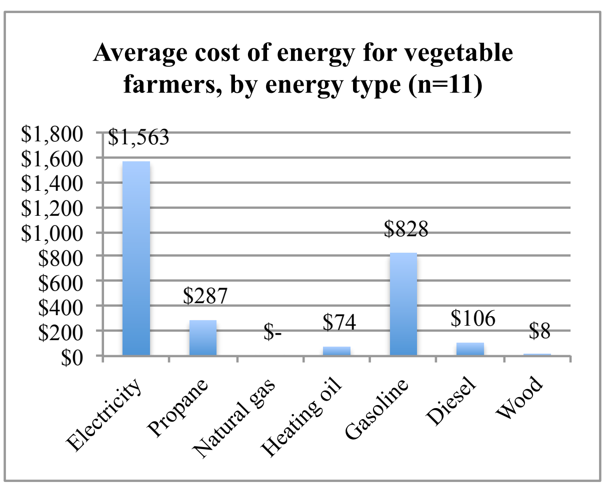
	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	11	11	11	11	11	10	11
AVERAGE	$1,563	$287	$74	$828	$106	$8	$2,865
STDEV	$1,397	$749	$131	$889	$158	$24	$2,372
MAX	$4,187	$2,500	$319	$3,000	$500	$75	$8,137
MIN	$-	$-	$-	$-	$-	$-	$700
MEDIAN	$800	$-	$-	$784	$24	$-	$2,425

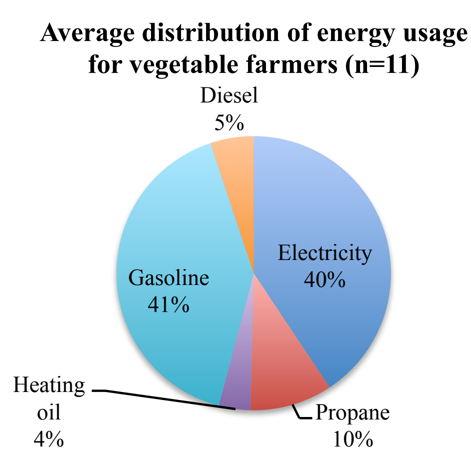
BTU BASIS (MMBtu)

	ELECTRIC	PROPANE	HEATING OIL	GAS	DIESEL	WOOD	TOTAL
COUNT	11	11	11	11	11	11	11
AVERAGE	43.4	10.3	4.0	43.5	5.4	6.3	113.0
STDEV	40.6	27.0	7.0	46.7	8.1	15.0	95.2
MAX	120.4	90.0	17.1	157.7	25.7	46.5	332.9
MIN	0.0	0.0	0.0	0.0	0.0	0.0	17.8
MEDIAN	31.4	0.0	0.0	41.2	1.2	0.0	86.0

ENERGY PER UNIT LAND AREA (GJ/ha)

	ACRES	Ha	GJ	GJ/Ha
COUNT	11	11	11	11
AVERAGE	3.2	1.3	119.8	93.6
STDEV	2.0	0.8	100.9	62.9
MAX	8.0	3.2	352.9	204.5
MIN	1.5	0.6	18.8	23.3
MEDIAN	2.0	0.8	91.2	67.6





Vegetables
Most common activities, by number of affirmative responses
Top three most commonly indicated activities in each energy type category shown in green

ELECTRIC

Lighting	9
Ventilation	4
Communications/Computers	5
Electric fencing	2
Greenhouse heating	5
Dairy parlor heating	0
Heating other farm buildings	4
Incubators/Poultry brooders	0
Water heating	1
Water pumping	9
Irrigation	7
Drying	4
Pasteurizing	0
On-farm slaughter	0
Grinding/milling/threshing	0
Product cooling	6
Product freezing	2
Transportation	3
Other	3

PROPANE

Greenhouse heating	3
Dairy parlor heating	0
Heating other farm buildings	1
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
On-farm slaughter	0
Running a generator	0
Processing	0
Weed control	1
Other	1

HEATING OIL

Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	3
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

GASOLINE

Running a generator	2
Transportation of people	5
Transportation of supplies	8
Transportation of finished product	7
Running a tractor	6
Running other farm equipment	5
Other	1

DIESEL

Running a generator	0
Transportation of people	0
Transportation of supplies	1
Transportation of finished product	0
Running a tractor	6
Running other farm equipment	1
Other	0

WOOD

Greenhouse heating	1
Dairy parlor heating	0
Heating other farm buildings	1
Incubators, poultry brooders	0
Water heating	0
drying	0
Pasteurizing/boiling	0
Running a generator	0
Other	0
On-farm slaughter	0
Processing	0

APPENDIX C

Case Studies of Typical Small-Scale Farms of Western North Carolina

Identifying details of farms and farmers have been removed or changed to protect anonymity.

Cattle Farmers

Interview Farm Energy Use Statistics

ACRES	Ha	GJ	GJ/Ha		
42.0	17.0	144.6	8.5		
ELECTRIC	**PROPANE**	**HEATING OIL**	**GAS**	**DIESEL**	**WOOD**
$450	$0	$0	$300	$2,200	$0
7.4 MMBtu	-	-	15.8 MMBtu	113.3 MMBtu	-

Julius Ellis began Boondog Beef in 1999 as a supplemental income to a financial services company he runs in a small town to the southeast of Asheville. Julius runs about 100 head of cattle on 42 acres of land using rotational grazing techniques that keep the cattle moving once every few weeks. He sells beef to area restaurants and also participates in a local farmers market. All of his products reach end consumers within a 100-mile radius of the farm. The farm sells products year-round, and sales are in the range of $10,000-$50,000 per year.

A simple pole barn provides shelter for cattle and field equipment.

“It just makes the most sense,” Ellis says of his choice to get into a side business with cattle. “I don’t think anybody would really be able to do it on the scale I’m on, making a living on it, but it helps to have that revenue.”

A walk-in freezer is the primary user of electricity on the farm.

The biggest energy bill incurred by Ellis in 2015 was for diesel fuel, which was in part used for hauling materials on the farm and doing field work with a tractor, and partly used to haul cattle to processing facilities 90 miles away and—to a lesser extent—finished products to restaurants and markets less than 50 miles away. The transport to markets, however, was usually carried out in a gasoline-powered vehicle. Electricity was the second-highest-cost energy type on the farm, and its use was dominated by walk-in freezers used to store products. “I would love to have a smaller freezer with a faster turnover, but my butcher is far enough that I don’t need to be going there more than I need, if I can help it,” says Ellis. Other uses of electricity include water pumping for cattle drinking, electric fencing, and lighting in the barn.

Mr. Ellis said he would like to investigate using a grid-tie solar system that could generate some farm income, but that he’s not sure it would be a good financial decision and is not aware of the best way to get started. “It’s difficult to tell what [the local utility]’s policy is on it, and whether I could really make some income from it.”

Fruit and Nut Growers

Interview Farm Energy Use Statistics

ACRES	Ha	GJ	GJ/Ha		
4.0	1.6	105.4	65.14		
ELECTRIC	**PROPANE**	**HEATING OIL**	**GAS**	**DIESEL**	**WOOD**
$750	$0	$0	$600	$1000	$0
16.4 MMBtu	-	-	31.5 MMBtu	51.5 MMBtu	-

Roberta Brown has been operating Brown's Berry Farm since 1990. The farm sits along a creek 30 miles from Asheville, NC, and Brown keeps 4 acres in production. She produces a variety of blueberries and cane berries, selling them mostly through farmers' markets within 100 miles of the farm and U-pick harvesters throughout the sales season from May through September. About 20% of her harvest is processed into jams and is transported by Brown to small farm stores greater than 100 miles from the farm.

The farm sits on 4 acres of flat bottomland, a rarity for most rural property in the mountains of western North Carolina.

Only about a third of Brown's household income comes from the farm. She has not yet been able to retire from the local high school, where she works full-time as an information manager. "I would really like to be able to retire from the school system and do this full time. That is my goal." Raising a family as a single parent is another limit to being a full-time farmer with a farm business completely supporting the household. "I would love to expand, but I can't do it all. I'm just one person."

The berry house has two freezers for storing fruit, and provides a comfortable place for greeting U-pick customers

Brown reports that electric-powered irrigation is the highest energy user on the farm, but she does not keep precise records of energy use. Freezers in the house and in the berry house are the next biggest users by her estimate. Electric fencing keeps neighboring horses out of the production area. Diesel is primarily used for on-farm tasks with a tractor such as hauling products and amendments, maintaining alleyways, and minor soil preparation tasks. Gasoline is used to transport the products to markets.

The common thermal energy types (propane, natural gas, heating oil, wood) are not used on the farm, but electricity is used for water heating in jam processing stage from within Brown's home. She says that it would be impractical to do processing in the county extension office's commercial kitchen, which is a 30-minute drive. "When I fix jam it's usually a work all day, jam all night kind of day. To take everything down there would [not work]. Here, I get a load of jam going and go do a load of clothes or the wash and keep moving."

Irrigation water is drawn from the creek that runs the length of the production acreage.

Aside from basic bookkeeping at the end of the year, the only farm tasks that Brown performs outside the May-September sales season is pruning in February and March, which requires no energy beyond her own. During the season, customers come from all over the Southeast, mostly on the heels of visits to nearby Asheville by tourists who Brown describes as "health conscious people and people looking to do something outside." She cites visits from families coming from as far as Atlanta as having established annual traditions of visiting her farm.

Next year, Brown plans to buy a Heartland wood-fired cookstove to do all her processing using wood from her property, which she says is readily available on the 5 wooded acres of land she owns. In addition to providing process heat for jam-making, the stove would also provide supplemental heat to her home and her hot water tank through an exchange reservoir.

The old diesel pump, estimated at 80 years old.

The manure from horses next door provides free fertilizer to her crops ("the blueberries really like it"), but because the horses are pastured, the amount that is recoverable requires additional outside sources of fertilizer.

Brown is curious about renewable energy, but says that her lack of knowledge about different technologies—atop her already busy schedule—prevents her from investigating further. The technology that most piqued her interest was solar photovoltaics. "It'd be nice to put solar down there at the barn for the pump, and to run the freezer for the berry house," she said. "And I don't even know if it's practical to run solar panels for something like that. You don't know whether what you find in these stores is going to just run a light bulb or be something you can really depend on."

Brown found separating her personal transportation energy use from the farm's use to be difficult. "You have to combine so many different things. Or I do. It's hard to measure. Yesterday we were out on a pleasure ride to Greenville, and we're stopping by [looking at] farm equipment. It's like it never separates…I'll go to work, and then stop by and order tractor fuel or something. You've got to do it all at one time."

Goat and Sheep Farmers

Interview Farm Energy Use Statistics

ACRES	Ha	GJ	GJ/Ha		
10.0	4.1	334.3	82.6		
ELECTRIC	**PROPANE**	**HEATING OIL**	**GAS**	**DIESEL**	**WOOD**
$2,293	$0	$0	$4,800	$0	$0
63.1 MMBtu	-	-	252.3 MMBtu	-	-

Ed Fowler of Daniel's Ranch is fairly new to sheep farming. In 2011, he began developing his land that was previously in hay production for certified grass-fed sheep. Since then, he has steadily been growing his flock, which now consists of 40 lambs on 10 acres.

Daniel's Ranch, a 10-acre grass-fed certified sheep farm.

The farm is two hours from Asheville in the southwestern corner of North Carolina. All of Fowler's lamb meat is sold across the border in a Georgia farmers from March to November, with some sales coming from customer visits to the farm. Sales remain under $10,000 for Fowler, while getting the farm off the ground continues to present him with new infrastructure costs, largely in animal housing and water system development.

Fowler's main energy cost comes from gasoline used mostly to transport five lambs at a time to the nearest meat processor, which is a 200 mile round trip. This restricted capacity is due to Fowler's lack of a farm vehicle, meaning that he has to use his SUV to move supplies and lambs. "I'd like to get to tot where I take 10 at once," he says. "I'm just not there yet. Money's going to other things."

Freezer storage and water pumping are the major users of electricity, Fowler's second-highest farm energy cost. Fowler's home, which he shares with his partner and two children, also serves as the farm office and storage facility for processed meat, which consists of two large, residential chest freezers. "I used to keep them in the barn," he says, "but that didn't lend itself to happy customers, walking through the animal area."

No other energy types were used on the farm, though heating a greenhouse to eventually grow specialty crops is a near-term goal for Fowler, who says his limited acreage combined with his grass-fed certification prevents him from making a full living on the sheep alone. "I would love to have it be my primary income. We wouldn't be able to do this without [my partner's] employment off the farm."

Two freezers in the Fowler residence are used to store the farm's meat products.

After the purchase of a high-capacity farm vehicle and a tractor for improved pasture management, Fowler says he would like to run farm's electricity with a solar photovoltaics system. "I've looked into it," he says. "It's expensive, though. It would only make sense for us if we could run the house, too."

Horticultural and Nursery Plant Producers

Interview Farm Energy Use Statistics

ACRES	Ha	GJ	GJ/Ha		
40.0	16.2	232.2	14.3		
ELECTRIC	**PROPANE**	**HEATING OIL**	**GAS**	**DIESEL**	**WOOD**
$0	$0	$800	$1,000	$2,400	$0
-	-	42.9 MMBtu	52.6 MMBtu	123.6 MMBtu	-

Linda Noble of Red Rooster Nursery has been farming on her family's land 30 miles south of Asheville since the late 1970s. From hogs, to corn and hay, and now to nursery plants, she has stayed flexible to the shifting demands of a food system that is largely influenced by factors outside the orbit of western North Carolina farms.

Red Rooster Nursery has eight unheated greenhouses.

"Most people in this valley gave up crop farming back in the 70s," says Noble, largely due to a mix of environmental and economic factors. "Before, there were twelve places I could sell corn within an hour drive. By the 1980s, you can't sell corn. And now—anyone now has got to have tractor-trailers to haul it out of town."

Accordingly, Noble now uses her 40 acres to grow and pot up nursery plants. "I would say we're 50-50 with nursery stock for landscapers and with forestry products (maples, poplars, oaks of different varieties)." Livestake cuttings for streambank rehabilitation were also part of the business until general contractors began to outcompete small nurseries for plant material contracts in the last decade. The farm has sales exceeding $100,000 per year, with 80% of products being sold within 100 miles of the farm at trade shows, directly to small garden store resellers in the area, or to customers coming to the farm. The business is in operation year-round.

Livestakes, like corn and hay before it, are being phased out as an income stream.

Labor and material expenses are high, with slim margins on plants that usually take 2-5 years to be ready for sale. Energy costs are dominated by diesel for transporting supplies and plants around the farm, as well as off the farm for sales. Gasoline is used for transport as well, but it is mostly used for a gasoline-powered irrigation system. Heating oil is used for heating a small plant propagation room as well for the small nursery office on during two or three months of the year.

Noble would like to expand her propagation room to be the size of a 16'x48' greenhouse heated through a hydronic hot water system utilizing a wood boiler with on-site firewood. "We've got so much dead standing, and about 6 acres of nursery stock that just didn't get potted up when the economy crashed."

Vegetable Farmers

Interview Farm Energy Use Statistics

ACRES	Ha	GJ	GJ/Ha		
2.0	0.8	165.5	204.5		
ELECTRIC	**PROPANE**	**HEATING OIL**	**GAS**	**DIESEL**	**WOOD**
$2,746	$100	$319	$920	$200	$0
76.8 MMBtu	3.6 MMBtu	17.1 MMBtu	48.4 MMBtu	10.3 MMBtu	-

Phillip and Farren Carrow started Buffman Gardens in 2006. The farm produces microgreens and value-added products from vegetables they grown on the farm, including pickled beets, cucumbers, and peppers; soups; kimchi; and pesto. The farm began as an income-generating project that could take them into an active retirement. “We wish we had done it early, but there’s no way we could have. You have to build up a sum before you can do what you want,” says Phillip. “You could eke out a living, doing what we’re doing as a start-up without that cushion. I only know one couple who’ve done it.”

Buffman Gardens consists of a narrow, 2-acre strip of bottom land deep in a western NC mountain valley.

Buffman Gardens is located on a small acreage of land deep in a winding mountain valley about a 40-minute drive from Asheville. Only two acres are cultivated for the farm, and the growing season lasts from February to October, with sales continuing through November and December. A small house that was formerly a residence when the land was purchased is now solely used for product storage and processing. The Carrows consider their two acres to be the maximum acreage that the two of them can reasonably farm in vegetables without additional manpower.

A 1,000 sq. ft. former residence is now used exclusively for processing and storing vegetables, pickles, soups, kimchis, and pestos.

In the first years of their farm business, the Carrows sold to both farmers markets and restaurants in Asheville, but now they limit their sales to only restaurants. “Tailgate market takes an inordinate amount of time. Taking a day to get ready, and a day there. It was cutting into our days on the farm.” Now the Carrows drive into Asheville twice a week for shorter, direct transactions with restaurants, and combine those trips with personal or farm-related errands.

The Carrows keep meticulous energy expense records, thanks largely to the record-keeping requirements of their organic certification. Electricity is far and away the most expensive energy type for the farm, being used mostly for processing and storage, with irrigation also being fueled with electricity. Diesel is used only for the tractor, and gasoline is used for their twice-weekly trips to Asheville restaurants and farm errands. Heating oil is used to keep the processing and storage house heated during three to four months in the wintertime, and the small propane bill goes toward a small propagation house for plant starts in the first two months of the growing season.

The former residence's kitchen was approved for use as a commercial kitchen for value added products.

A room in the basement was converted into a walk-in cool room using a CoolBot controller, rigid insulation, and a window A/C unit.

While the Carrows consider the equipment on their operations to be maximally efficient in their energy use, they are interested in solar photovoltaics for generating electricity, specifically for running a fan in the greenhouse that currently has no power, and for their water pumping needs.

Vita

Alex Arnold was born in Washington, Indiana, USA, to Malcolm and Susan Arnold. He attended Purdue University, where he studied Industrial Management with a concentration in Earth and Atmospheric Sciences and was awarded a Bachelor of Science degree with highest distinction honors in 2008. After graduation, he spent two years serving as a Peace Corps Volunteer in Ghana, where he was an environmental educator. Upon returning to the U.S., he worked as an AmeriCorps service member, building houses with Habitat for Humanity in Lexington, Kentucky, and then as a finish carpenter in Asheville, North Carolina. In the fall of 2014, he began his studies of renewable energy technologies in the Department of Sustainable Technology and the Built Environment at Appalachian State University, where he received the Provost's Fellowship.

Mr. Arnold now lives in Marshall, North Carolina, with his wife and partner, Lauren, and two dogs, Dogjohn Robie and Solo the Eagle Dog, where he works as a nonprofit consultant helping farmers develop and fund renewable energy and energy efficiency projects.