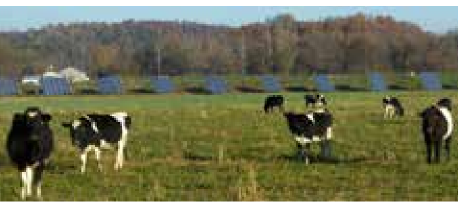
farm to plate

STRENGTHENING VERMONT'S FOOD SYSTEM

Chapter 4, Section 6

Food System Energy Issues



Vermont Sustainable Jobs Fund

A 10-YEAR STRATEGIC PLAN FOR VERMONT'S FOOD SYSTEM

Key Messages

In the United States, power is commonly inefficiently generated from nonrenewable sources; most of this power is lost as heat during generation, distribution, and consumption— and major environmental problems have developed as a result of these processes.

Nonrenewable energy **and** *industrial agriculture* **are the current paradigms of energy and food systems.** However, innovations in energy and food systems are rapidly providing new opportunities for saving energy, generating renewable energy, and strengthening local food systems. Distributed renewable energy systems and local food systems both emphasize sustainability during extraction/harvesting, production/generation, and consumption, as well as local control, and the importance of relationships. Federal and state policies, financing options, cultural norms, and business offerings are increasing the availability of renewable energy and local food.

For example, a *federal tax credit*, cheaper solar panels, and Vermont's net metering law and *SPEED program* have facilitated substantial growth in the number of large solar photovoltaic installations in the state. In 2015, the Vermont legislature passed the second strongest renewable portfolio standard in the country—*H.40 (Act 56) - RESET*, which requires utilities to purchase 55% of electricity from renewable sources (or renewable energy credits) by 2017 and 75% by 2032. *Vermont's Comprehensive Energy Plan* calls for 90% of the state's energy consumption to be derived from renewable sources by 2050 (up from 20% today—mostly renewable electricity from hydropower, biomass, and wind, followed by wood for heating and ethanol).

The local food movement reflects a growing preference for fresh, healthy food and direct connections with producers—and many Vermont businesses are stepping up to meet the demand. At the same time, Vermont's food system businesses are already contributors to renewable energy generation: from the siting of large solar and wind projects on agricultural land, to agricultural and woodland crops, animal waste, and food scraps that are used as feedstocks for electricity, heat, and liquid fuel. Vermont's food system consists of more than agricultural activities—large roofs at grocery stores and manufacturing facilities support solar installations, and several thousand buildings have made efficiency improvements.

The intersection of renewable energy systems and local food systems is fertile ground for developing sustainable solutions to pressing problems. Many food system businesses have already implemented energy saving and renewable energy producing technologies. But there is also the possibility of emerging conflicts over energy goals and food production goals. For example, many municipalities and Vermonters have expressed concern about the rapid development of larger solar PV installations around the state. Concerns have been raised about aesthetic issues, property values, development on agricultural and other land, and a perceived lack of sensitivity on the part of the Public Service Board during the *Section 248* process that issues "certificates of public good" for energy generation projects. In response, a *Solar Siting Task Force* was created "to study the design, siting, and regulatory review of solar electric generation facilities and to provide a report in the form of proposed legislation with the rational for each proposal."

How can we meet both Vermont's food and energy goals? This section of the Farm to Plate Strategic Plan provides a foundation for

1) improving understanding of food system energy issues (including food system organizations understanding energy issues better and energy organizations understanding food systems better);

2) identifying opportunities and strategies to help food system businesses reduce their reliance on nonrenewable energy sources and increase energy efficiency and the production of renewable energy; and

3) improving the delivery of energy related technical assistance to food system businesses.

CONTENTS

CROSS-CUTTING ISSUES

Food System Energy Issues

How can Vermont's food system accelerate the adoption of energy conservation and efficiency measures and renewable energy generation in order to reduce energy consumption, production expenses, and environmental degradation?

CURRENT CONDITIONS

In the 200 years since the Industrial Revolution, virtually every society on the planet has become dependent on nonrenewable energy for everything from electricity and transportation to plastics and food production.

"Energy flows through ecosystems into sociocultural systems as the fundamental stuff of life support."

Lee Freese, *Environmental Connections*, 1997: 84.

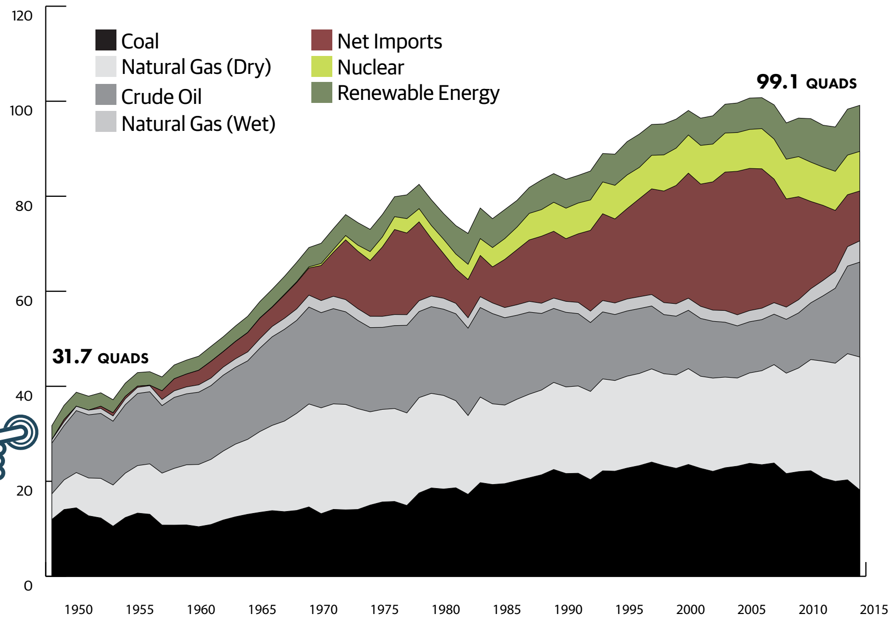
Over the last 65 years, total U.S. energy production (Figure 4.6.1) and consumption have increased, but the composition of energy sources has changed:

- **U.S. natural gas and crude oil production have increased:** Total domestic fossil fuel production has increased in recent years, mainly from natural gas and crude oil. As nuclear energy and renewable energy generation have come online, fossil fuels have dropped from 91% of U.S. energy production to 80%.

Photo credit: UVM Special Collections

Human and animal labor powered Vermont agriculture before World War II.

Figure 4.6.1. U.S. Primary Energy Production and Net Imports (Quadrillion BTUs), 1949-2015



Source: U.S. Energy Information Administration, Annual Energy Review, www.eia.gov/totalenergy/data/monthly. A quadrillion is one followed by fifteen zeroes. A BTU is the amount of energy required to heat or cool one pound of water by one degree Fahrenheit.

- **Coal production has decreased:** Proposed and/or finalized EPA regulations impacting coal-fired generation as well as low natural gas prices have led to the retirement—or planned retirement—of 42,192 megawatts (MW) of coal-fired generation by 2025 (equal to 13% of coal generating capacity).[1] Coal is now equal to about 23% of U.S. energy production.
- **Hydraulic fracturing has increased natural gas production:** The emergence of hydraulic fracturing (i.e., fracking) technology has allowed for the exploitation of tight oil formations and shale gas. As a result, the U.S. is now the *top* producer of petroleum and natural gas in the world.[2] Natural gas now accounts for about 30% of U.S. energy production—the highest amount of any U.S. energy source. Crude oil accounts for 20% of U.S. energy production.

ENERGY BASICS

Energy is the capacity to do work. Energy is not created or destroyed, it is converted from one form to another. Fuels are substances we use to transport energy from place to place that can readily be converted to usable work using machines or other devices. Energy is typically measured using heat units, such as British Thermal Units (BTU), Calories, or therms.[3] Since these are all units of heat, there are equivalencies between them that make unit conversions possible (Table 4.6.1). It's important to realize that a Calorie (with a capital 'C') does not represent the same amount of energy as a calorie, or "small calorie" (with a lowercase 'c'). A Calorie, often called a nutritional calorie or a kilocalorie, is equal to 1,000 small calories.

Table 4.6.1: Energy Equivalencies Among Several Common Units

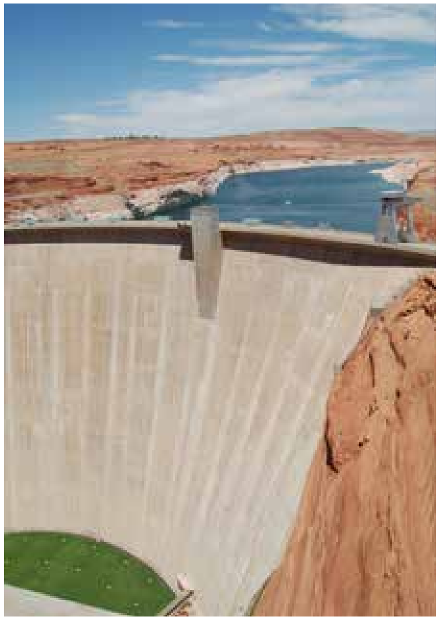
Unit	Conversion
1 Calorie (Cal or kcal)	= 3.968 BTUs
	= 0.00116 kWh
	= 1,000 small calories
1 kilowatt hour (kWh)	= 3,412 BTUs
	= 860 Cal
1 British Thermal Unit (BTU)	= 0.0252 Cal
	= 0.00029 kWh

Power is the rate at which energy is generated or used. For example, all things equal, a 4 kW solar PV system can generate 4 kW of power. Energy is equal to power x time (kWh = kW x hour). If the PV system generates 4 kw for 8 hours in a day, the total energy converted from the sun's radiation is 32 kWh.

- **Majority of U.S. energy supply is domestically produced:** In 2015, domestically produced energy accounted for about 89% of the total amount of power used in the U.S. Net imports, mainly crude oil, made up the remaining 11% (the combination of domestic energy production and imports equals U.S. energy production—99 quads in 2015). The Energy Information Administration (EIA) projects that the U.S. will soon eliminate net imports (i.e., U.S. energy exports will exceed imports by switching from being a net importer of natural gas to a net exporter of natural gas. The EIA predicts that the U.S. will remain a net importer of crude oil despite recent production increases).[4]

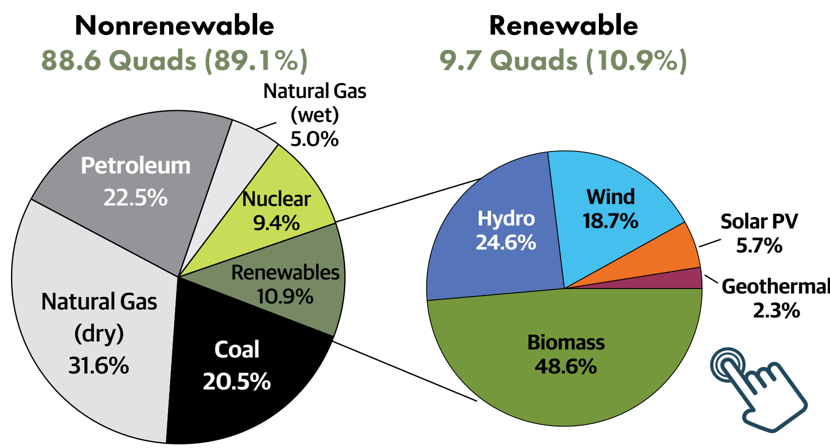
- **Nuclear energy facilities operating longer than originally licensed:** From 1960 to 2001, nuclear energy incrementally ramped up to a little more than 11% of U.S. energy production. Nuclear energy consistently generated 11% of U.S. energy from 2001 to 2011 but has dropped to about 10% since then. The average age of the 99 nuclear reactors operating in the United States is 34 years. The Nuclear Regulatory Commission licenses reactors for 40 years but has subsequently issued 20-year extensions to 74 of the plants. Reactors are not expected to operate past 60 years, meaning that by 2050 almost all reactors will start the decommission process or will have to receive a subsequent license extension.[5] The last commercial nuclear reactor to be built in the U.S. went online in 1996,[6] but the Tennessee Valley Authority's Watts Bar Unit 2 is expected to go online in 2016. In general, electrical capacity additions in recent years have been from renewable energy sources (e.g., wind, solar) and natural gas,[7] while continued operating costs, age, and safety concerns have led to the retirement of four reactors over the past few years, including Vermont Yankee (Vernon).[8]

- **Renewable energy production ramps up:** Overall, about 89% of U.S. energy production is generated from nonrenewable sources and nearly all energy imports come from non-renewable sources (Figures 4.6.1 and 4.6.2). Renewable energy accounts for a little more than 11% of U.S. energy generation, with hydroelectric power constituting the largest single source (25%). However, if the different types of biologically-derived energy sources—woody biomass, corn, grasses, oilseed crops, and waste—were combined then they would constitute the largest source of renewable energy (49%). Wind (41%) and solar (26%) made up nearly 70% of new electric generation capacity in 2015 (natural gas accounted for 30%). Texas (mostly wind) and California (mostly solar) accounted for the lion's share of new generation capacity.



Hydroelectric power is the single largest source of renewable energy in the U.S. Glen Canyon Dam in Arizona generates 3.46 billion kWh per year.

Figure 4.6.2: U.S. Energy Production (Quadrillion BTUs), 2015



Source: U.S. Energy Information Administration, www.eia.gov/totalenergy/data/monthly/pdf/sec1_7.pdf

Click on graphs for additional information.

- **Per capita energy consumption is flat:** Although total energy production, consumption, and the U.S. population have increased, per capita energy consumption has stayed essentially level over the past 40 years—an average of 336 million BTU per person. This is still quite high compared to most of the world. The EIA reports that reductions in energy consumption tend to result from the adoption of energy efficient technologies (e.g., the U.S. is only now in a period when Energy Star appliances that started rolling out in the 1990s are mainstream; fuel economy standards have incrementally increased) and structural changes in the economy (e.g., recovery from the Great Recession). The EIA expects energy demand in the residential and transportation sectors to be flat through 2040 and the commercial and industrial sectors to gradually increase energy consumption.[9]

- **Most power is lost:** The Lawrence Livermore National Laboratory estimates that more than 60% of U.S. energy production has not been leveraged for a useful purpose ("Rejected Energy," mainly heat, in Figure 4.6.3, page 5). Residential and commercial energy consumption is estimated to be 65% efficient (i.e., 35% of the power is lost), while the industrial sector is estimated to be 80% efficient and transportation is only 21% efficient.
- **Capacity factors of power generation facilities vary:** The *capacity factors*—the ratio of actual generation to potential generation—of electricity generating facilities vary quite a bit (Table 4.6.2). For example, nuclear facilities operated, on average, 92% of the time in 2015, while utility-scale solar PV facilities operated about 29% of the time, and wind facilities had an average capacity factor of 33%.

The Vermont Public Service Department created a helpful comparison[10] of different types of renewable generators based on capacity factors (note that they used different capacity factors than the national averages). Each of these generators can be expected to generate the same amount of energy, d*espite different peak power ratings due to their different capacity factors*:

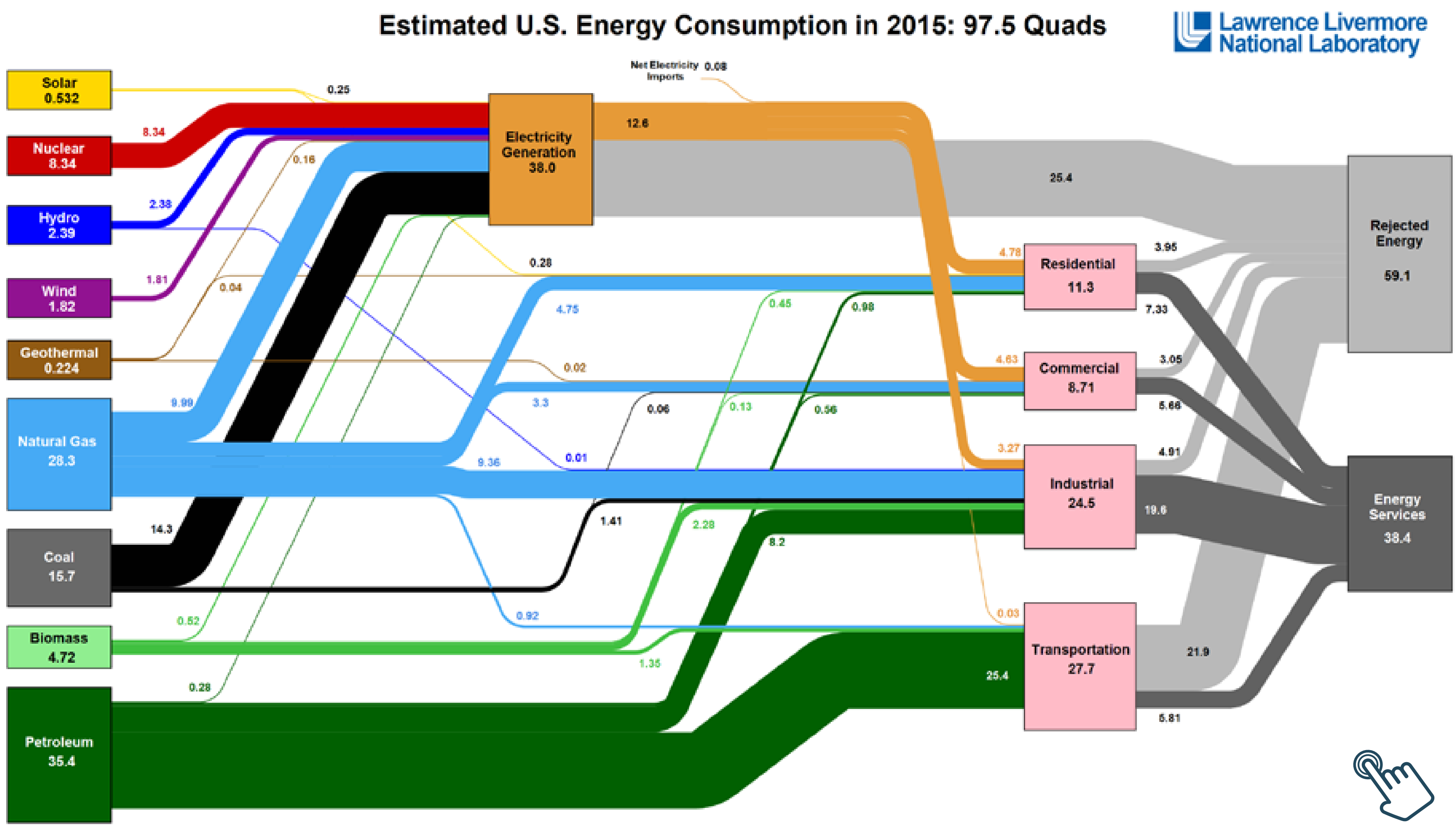
- **20 MW** wind project, eight 2.5 MW turbines (33% capacity factor)
- **44 MW** solar PV project, ~300 acres (16% capacity factor)
- **15 MW** hydroelectric generation (45% capacity factor)
- **9 MW** woody biomass electric generation (75% capacity factor)
- **7 MW** anaerobic digestion— more than currently exists in VT (95% capacity factor)

Table 4.6.2: Selected Capacity Factors for Utility Scale Electricity Generators

	2011	2012	2013	2014	2015
NONRENEWABLE ENERGY					
Coal	63.7%	56.7%	59.7%	61.0%	54.6%
Natural Gas (Fired combined cycle	43.6%	51.1%	48.2%	48.3%	56.3%
Petroleum (Steam turbine)	12.0%	12.8%	12.1%	12.8%	14.7%
Nuclear	89.1%	86.1%	89.9%	91.7%	92.2%
RENEWABLE ENERGY					
Hydropower	37.6%	45.9%	38.9%	37.3%	35.9%
Wind	29.8%	32.1%	32.4%	34.0%	32.5%
Solar PV	20.3%	19.1%	–	25.9%	28.6%
Solar Thermal	24.5%	23.9%	–	19.8%	22.7%
Landfill Gas	70.8%	70.0%	68.9%	68.9%	67.6%
Biomass	57.8%	56.3%	56.7%	58.9%	52.9%
Geothermal	71.9%	71.8%	73.6%	74.0%	71.7%

Source: U.S. Energy Information Administration, Table 6.7.A. Capacity Factors for Utility Scale Generators Primarily Using Fossil Fuels, www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_a. Table 6.7.B. Capacity Factors for Utility Scale Generators Not Primarily Using Fossil Fuels, www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_6_07_b.

Figure 4.6.3: U.S. Energy Flow, 2015



Source: Lawrence Livermore National Laboratory and the U.S. Department of Energy, https://flowcharts.llnl.gov/content/assets/images/energy/us/Energy_US_2014.png.

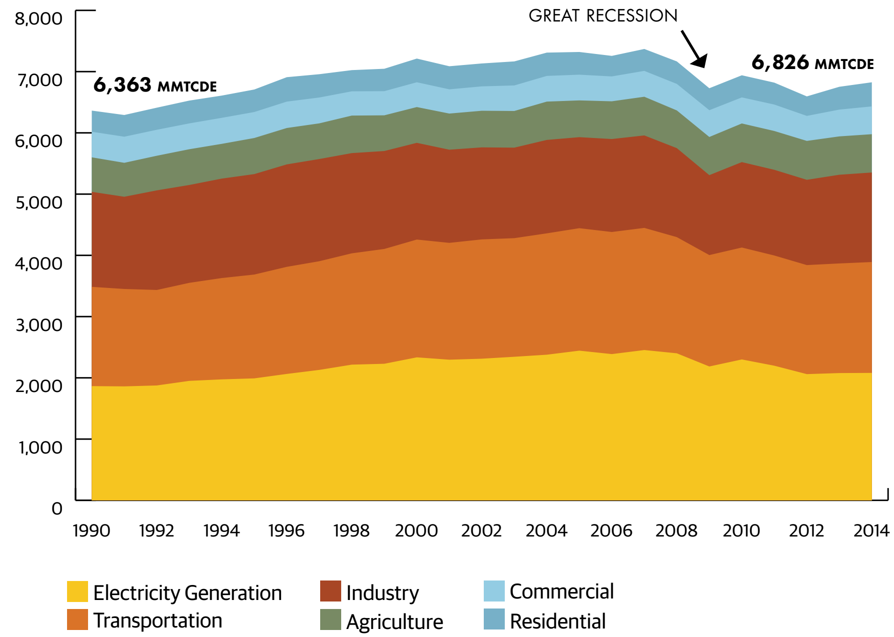
This figure illustrates the flow of energy in the U.S. Moving from energy sources on the left to end uses on the right, the graphic illustrates how different energy sources are split and used in different sectors. A summary of the total amount of energy consumed in useful services and the amount that is lost (i.e., "Rejected Energy") is provided on the far right. ***Note that agriculture and food systems are not specifically tracked in this format but they are components of all four end uses.***

- **Power generation creates many environmental problems:** The extraction of energy resources, their conversion into fuel, and their use creates a wide variety of environmental and health problems. With the combustion of fossil fuels to power societal development over the past 100 years, the atmospheric concentration of carbon dioxide has inched up to almost _400 parts per million_. From 1990 to 2014, U.S. greenhouse gas emissions generally increased in the electricity, transportation, agricultural, and residential sectors (with a decrease during the Great Recession), while decreasing in the industry and commercial sectors (Figure 4.6.4). However, a recent study estimates that methane leaks from fracking and the nation's natural gas infrastructure—which are not accounted for in Figure 4.6.4—may have increased 30% from 2002 to 2014. **In other words, the replacement of coal power plants with natural gas power plants may have increased America's greenhouse gas emisssions.**[11]

This increase in greenhouse gases is changing the Earth's climate, resulting in melting glaciers and ice sheets, rising ocean levels, altered weather patterns (e.g., increasing the frequency and severity of hurricanes), and changes in the composition of local plants, animals, and insects.

The _disposal/storage of high level nuclear waste_ remains a contentious and unresolved problem—radioactive waste is currently stored at sites in 35 states. The underground injection of wastewater during the fracking process has polluted groundwater resources and led to a dramatic increase in the number of _earthquakes in Oklahoma_.[12] Renewable energy generation poses its own problems, from siting controversies to, for example, the prospect of long-term drought conditions and less snowfall in the West reducing hydroelectric generation.

Figure 4.6.4: U.S. Greenhouse Gas Emissions (million metric tons of carbon dioxide equivalents), 1990-2014



Source: U.S. Environmental Protection Agency, Greenhouse Gas Inventory Data Explorer, _www.epa.gov/climatechange/ghgemissions/inventoryexplorer/#allsectors/allgas/econsect/all_.

In short, power is commonly inefficiently generated from nonrenewable sources; most of this power is lost as heat during generation, distribution, and consumption—and major environmental problems have developed as a result of these processes.

Energy systems—and food systems—develop slowly, and their development paths represent long sequences of investments in physical and social infrastructure and the development of consumer habits that can't easily be changed. As described in *Chapter 3, Section 2: Farm Inputs*, a major transition—from human and animal based labor—to fossil fuel based inputs over the past 200 years has changed the nature of global agricultural production: **substantial productivity gains in food systems have been made through the increased availability and use of nonrenewable energy sources.**

Today, food system activities consume large amounts of **direct** and **indirect energy**, "from the manufacture and application of agricultural inputs, such as fertilizers and irrigation, through crop and livestock production, processing, and packaging; distribution services, such as shipping and cold storage; the running of refrigeration, preparation, and disposal equipment in food retailing and food service establishments; and in home kitchens."[13] The USDA reports that food-related energy use increased from 12.2% of national energy use in 1997 to 14.4% in 2002, and was an estimated 15.7% of energy use in 2007 (*Unfortunately, updated information is not available and very limited food system-related energy information is available at the state level*).

We can't simply turn back the clock on the development of our energy and food systems—*Nonrenewable energy* and *industrial agriculture* are still the defining paradigms of both systems. However, in recent years, we have witnessed major changes in food and energy systems: The local food movement reflects a growing preference for fresh, healthy food and direct connections with producers. Innovations in energy systems are rapidly providing new opportunities for saving energy and generating renewable energy. *Major jumps* in solar photovoltaic and wind energy production have taken place over the past few years; *smart meters* and the *smart grid* are increasingly prevalent; *battery storage* and *distributed generation* systems are becoming a reality; hybrid, plug-in hybrid, and electric vehicles are more common; and the *first cellulosic ethanol plant* finally opened in Iowa.

The intersection of energy systems and food systems is fertile ground for developing sustainable solutions to pressing problems. Today, energy produced by food system businesses typically calls to mind corn grown for ethanol, which is blended with gasoline (over *14.3 billion gallons* of ethanol were produced in 2014). But food system energy production can take many forms that may be more scale appropriate for a small state like Vermont. For example, 19 *anaerobic digesters* (17 dairy farms, 1 at *Vermont Tech*, and 1 at Magic Hat brewery) in Vermont have nearly 6,000 kilowatts of installed electrical generating capacity. Anaerobic digesters turn the methane from animal manure into energy. Solids left over after anaerobic digestion can also be used as animal bedding, cutting down on another input cost. Farmers can replace petrodiesel with biodiesel made from oilseed crops such as sunflowers grown in Vermont. Animal feed imports can also be reduced by feeding livestock the meal left after oil is squeezed from oilseeds. Food system activities off the farm can also produce power: waste vegetable oil from fried foods can be turned into biodiesel, and food decomposing at landfills produces methane that can be captured to generate electricity. Wind turbines and large solar farms are increasingly common in Vermont, many food system businesses use biomass for heating, many food system businesses have installed efficiency improvements, and many others could be more energy efficient.

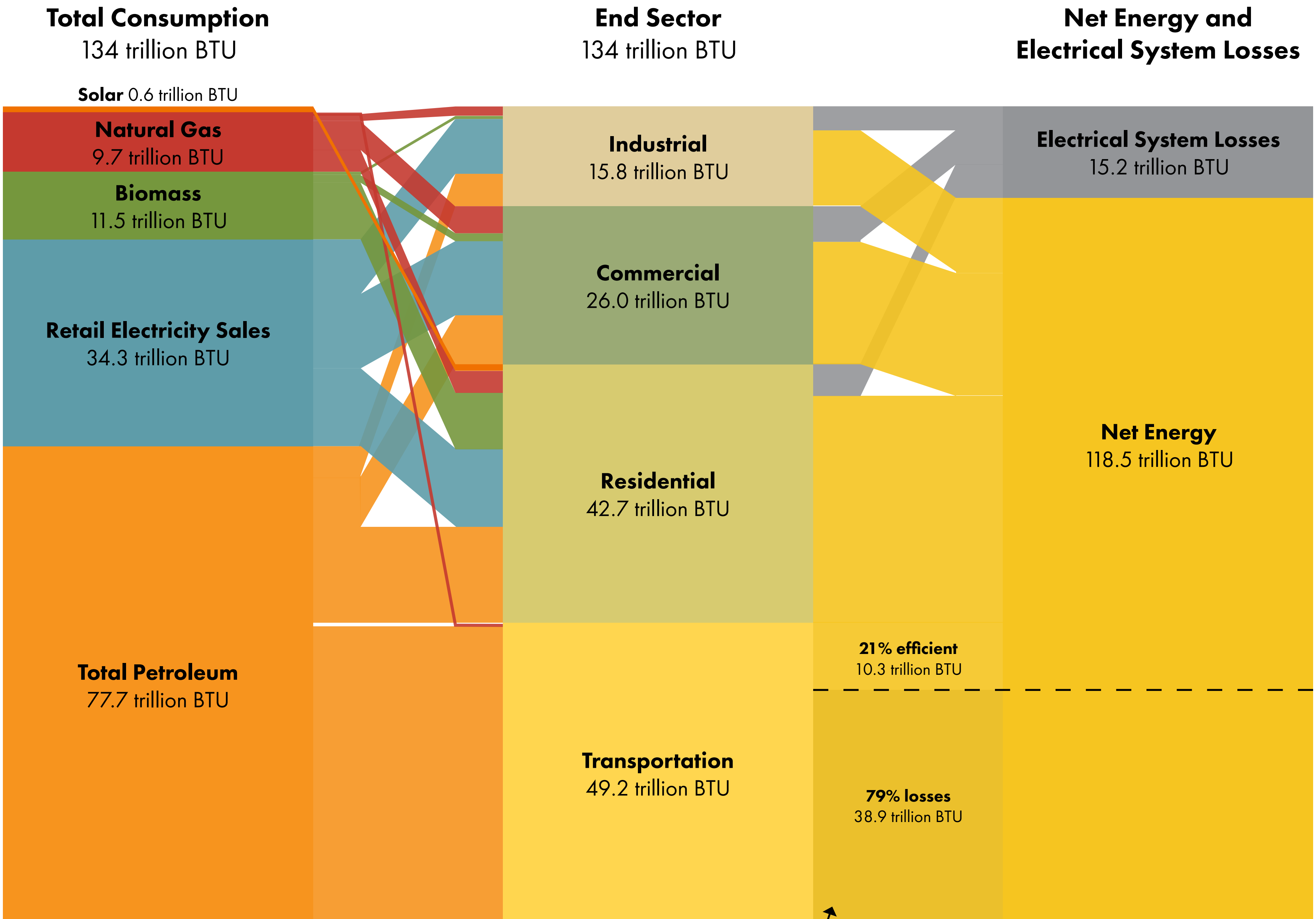
Goal 22 of the Farm to Plate Strategic Plan focuses on reducing overall energy consumption in Vermont's food system while increasing the amount of energy produced from renewable sources.

GETTING TO 2020

Food system enterprises will minimize their use of fossil fuels and maximize their renewable energy, energy efficiency, and conservation opportunities.

Click on Goal for additional information.

Figure 4.6.5: Vermont Energy Flow, 2013



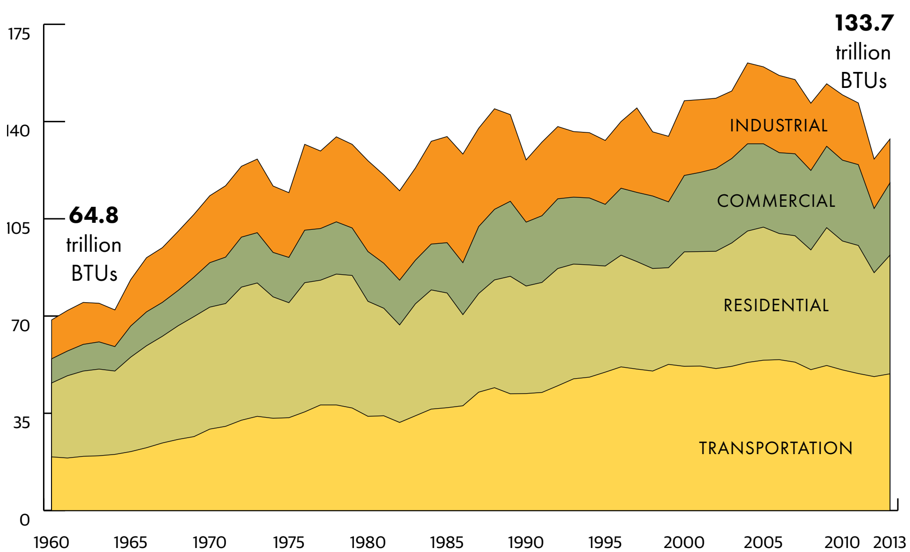
Source: U.S. Energy Information Administration, 2013, www.eia.gov/state/?sid=VT.

Note: EIA data does not delineate transportation system losses. If we apply the national statistic of 21% for transportation efficiency from Figure 4.6.3, then 10.3 trillion BTU were used for energy services and 38.9 trillion BTU were lost.

Vermont Energy Production and Consumption

Vermont produces and consumes a relatively small amount of energy: Vermont ranks 46th in energy production in the United States (84.2 trillion BTUs in 2013), equal to 0.1% of total national energy production. Vermont consumes the least amount of energy of any state (134 trillion BTUs in 2013, Figure 4.6.5, Figure 4.6.6)—in fact, less than the District of Columbia—equal to 0.15% of total national consumption (Vermont ranks 44th in energy consumption on a per capita basis).[14] Over the past 50 years, energy consumption in Vermont has increased about 100%, from about 65 trillion BTUs to 134 trillion BTUs. Transportation accounted for 36.8% (49.2 trillion BTUs) of total energy consumption in Vermont in 2013, and nonrenewable gasoline makes up 77% of energy consumption in the transportation sector. Homes in Vermont accounted for about 31.9% (42.7 trillion BTUs) of total energy consumption, and over 50% of that amount is for space and water heating from nonrenewable (e.g., distillates) and renewable (e.g., wood) sources. Vermont's commercial sector accounted for about 19.4% (26.0 trillion BTUs) of total energy consumption, and consumption is about evenly split between electricity sales and different fuels for space and water heating. Finally, Vermont's industrial sector consumed about 11.8% (15.8 trillion BTUs) of Vermont's energy from electricity sales and other mostly nonrenewable fuels for space and water heating and transportation.

Figure 4.6.6: Vermont Energy Consumption by End Sector, 1960-2013



Source: U.S. Energy Information Administration, 2013, *www.eia.gov/state/?sid=VT*.

Electricity

The shutdown of the Vermont Yankee nuclear reactor in 2014—equal to 604 megawatts of generating capacity, 5 million MWh of electricity production, 4% of New England electric generation, and more than 70% of generation in Vermont[15]—has meant that Vermont purchases more electricity from the New England grid, which has increased its reliance on natural gas generation.[16] **A significant portion of Vermont's electricity supply comes from renewable sources:** *Hydro-Québec*; local hydro, biomass, wind, solar, cow power, and landfill gas; market purchases that *may* include renewable energy (i.e., "System A" in the parlance of the Vermont Public Service Department); and in-state renewable generation where renewable energy credits have been sold to third parties (i.e., "System B").

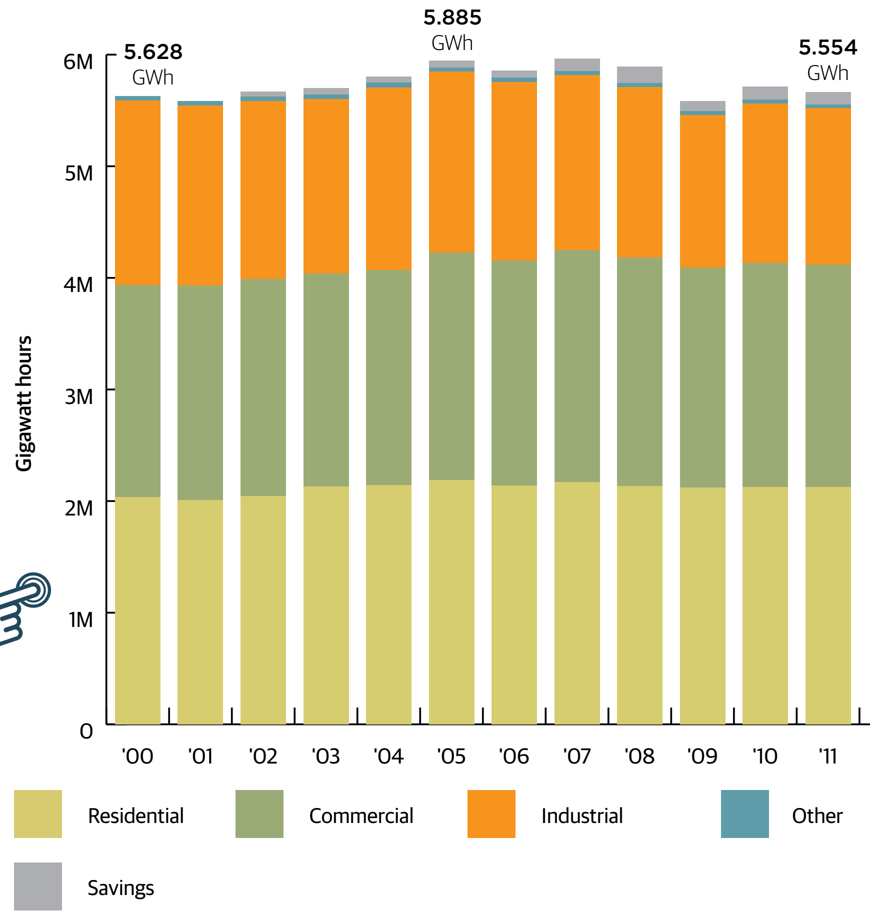
Electricity uses across the food system include lighting, equipment (e.g., reverse osmosis systems for maple syrup production, a wide variety of commercial kitchen equipment), refrigeration, motors, pumps, heating, ventilation, and air conditioning.

Unfortunately, we currently do not know how much energy Vermont's food system consumes. Efficiency Vermont roughly estimates that farms and food processing facilities consume over 290,000 MWh (equal to about 6% of total electricity consumption). A little over 3,200 dairies, dairy processing facilities, "other producers," breweries/wineries/distilleries, and meat processors account for the majority of this estimate. This is clearly an undercount, since there are about 12,000 food system businesses, but we do not have estimates for the overall food system, nor do we have food system thermal and transportation estimates beyond on-farm diesel fuel purchases.

Energy Efficiency

Energy *conservation* refers to reducing or going without a service to save energy. There is no source of information that captures energy conservation data about Vermont's food system, but examples include careful maintenance of tractors and vehicles, turning off machinery when not in use, no-till or minimum tillage practices, and properly insulating buildings.

Figure 4.6.7: Vermont Electricity Consumption by End Sector, 2000-2011



Source: Vermont Public Service Department, Utility Facts 2013, http://publicservice.vermont.gov/sites/dps/files/documents/Pubs_Plans_Reports/Utility_Facts/Utility%20Facts%202013.pdf. Note: electricity savings data is shown from 2002 through 2011.

Energy *efficiency* refers to expending less energy to perform the same end use services and more efficient production (e.g., avoiding heat lost). Electrical efficiency typically refers to equipment improvements (e.g., Energy Star appliances) and demand-side management (e.g., using energy during off-peak hours). Thermal efficiency typically refers to the weatherization of buildings (e.g., air sealing, insulation, and heating system replacements). Transportation efficiency typically refers to efforts to reduce vehicle miles traveled and single-occupant vehicle travel, and increase the adoption of electric vehicles. Vermont's total electricity consumption decreased 1.3% from 2000 to 2011 (Figure 4.6.7). Efficiency savings averaged over 86,000 MWh during that timeframe (e.g., efficiency savings ranged from a low of 0.8% of total consumption to a high of 2.6%). In fact, **total state electricity savings in 2011 were greater than the combined electricity consumption of Essex and Grand Isle counties.**[17]

Efficiency Vermont—Vermont's "efficiency utility" funded by a charge on electric customers' bills—is the main source of electric and thermal efficiency services, including many rebates for on-farm equipment and lighting improvements for Vermont's 7,300 farms (including about 870 dairy farm and over 1,800 maple producers), as well as services for manufacturing facilities, stores, and restaurants.

Energy can be a significant portion of operating costs for Vermont's over 700 food processors and manufacturers. "Financially speaking, managing our energy and reducing our usage is hugely important to the success of our company. Energy is one of the top, if not the top, overhead cost that we're faced with," says Commonwealth Dairy's (Brattleboro) CFO, Ben Johnson. "I know when I am starting any new project in the facility, trying to engage the Efficiency Vermont team to get a good review of what we're trying to do is part of the project kick off. This allows us to get good suggestions on something we could actually act on, if appropriate."

Vermont has about 1,000 grocery, convenience, liquor, specialty food, and country stores, including 15 food coops. The National Renewable Energy Laboratory developed an analysis that showed that grocery stores could achieve 50% energy savings in a cost-effective manner, mainly through lighting and equipment changes.[18] Vermont has over 2,000 food service and drinking places. According to Efficiency Vermont, restaurants use 2.5 times more energy per square foot compared to other commercial buildings. The [Food Service Technology Center](#) estimates that most of the energy bill in the commercial food service sector goes toward inefficient cooking, holding, and storage equipment.

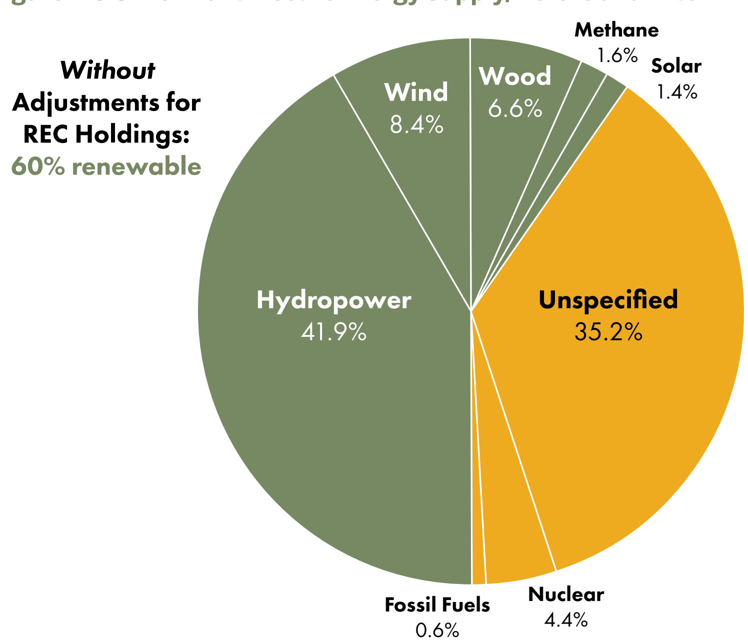
Renewable Electricity

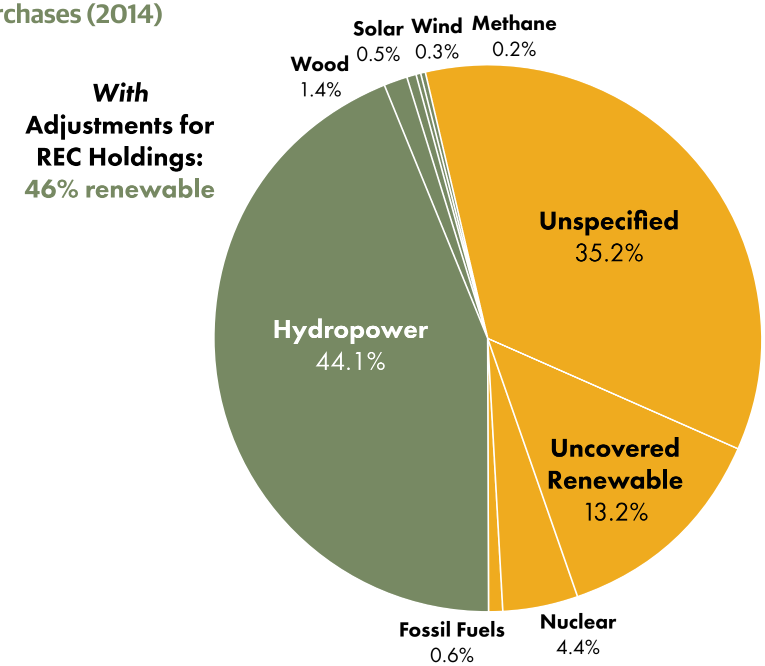
Counting renewable electricity installations in Vermont is necessarily a moving target as new projects, particularly solar PV projects, come online everyday. As of September 2015, many hydroelectric power plants, two wood-fired power plants, four large-scale wind projects, and a recent uptick in the number of large solar farms currently constitute the majority of renewable electricity generation capacity in Vermont (Figure 4.6.9), but there are also several thousand small, net metered solar sites (Figure 4.6.11). The PSD estimates that meeting expected energy demand and Vermont's 90% renewable by 2050 would mean that electric end use energy would still need to grow by about 75% for supplies to become virtually 100% renewable.

Note that the renewable energy credits (RECs) for most of Vermont's large renewable electricity generators are sold out of state (The exception appears to be the anaerobic digesters in *Green Mountain Power's Cow Power program*), and therefore cannot be claimed as renewable energy in Vermont (Figure 4.6.8).[19] Since electrons are indistinguishable on the grid, RECs were created to denote the environmental benefits associated with one megawatt-hour of renewable energy generated (i.e., 1 REC equals 1 MWh). Existing policy incentivizes selling RECs out of state. *H.40 (Act 56)—Renewable Energy Standard and Energy Transformation (RESET)* and a draft rule change to *Act 99 (net metering)* are meant to change REC incentives but it is currently unclear how this will unfold. **Broadly speaking, the selling of RECs means that Vermont will have a hard time reaching its goal of 90% renewable by 2050 without retiring more RECs in-state.**

For the purpose of this Plan section, we report the pre-REC installed capacity of renewable energy sites in Vermont in order to highlight what Vermont's portfolio could look like if RECs were retired in state.

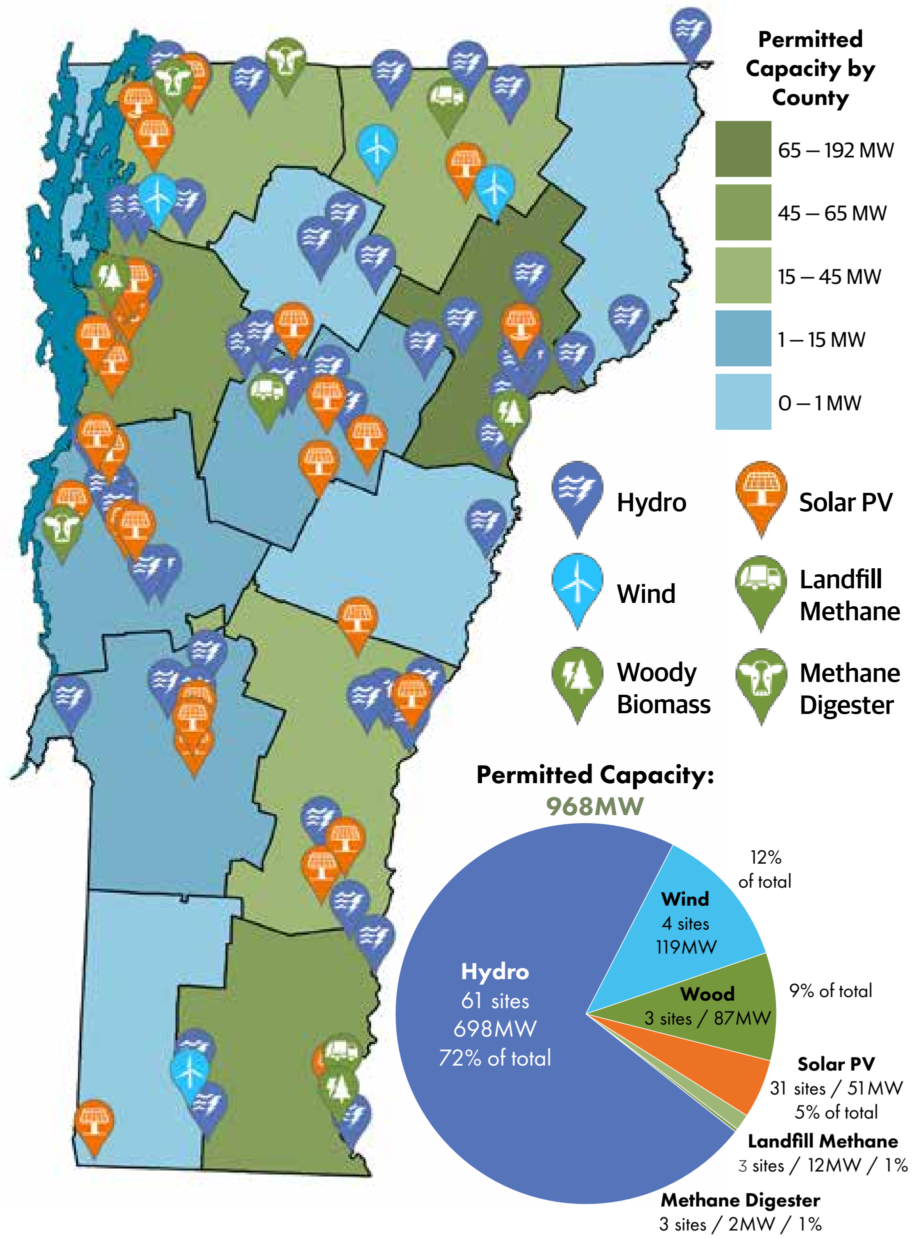
Figure 4.6.8: Vermont Electric Energy Supply, Before and After REC Sales and Purchases (2014)





Source: Vermont Public Service Department, 2016 Vermont Comprehensive Energy Plan, page 189, *https://outside.vermont.gov/sov/webservices/Shared%20Documents/2016CEP_Final.pdf*.

Figure 4.6.9: Vermont Renewable Electricity Generation Sites Over 500 kW*



Note: this map only depicts the location of generation sites and does not account for capacity factors, renewable energy credits sold, or ownership of systems. * As of September 2015.

Renewable electricity is disproportionately generated at large sites: In fact, 105 sites (2% of all sites) account for 94% (968 MW) of installed renewable electricity capacity (Figure 4.6.9), while 5,172 sites (98% of all sites) account for 6% of installed capacity (56 MW).

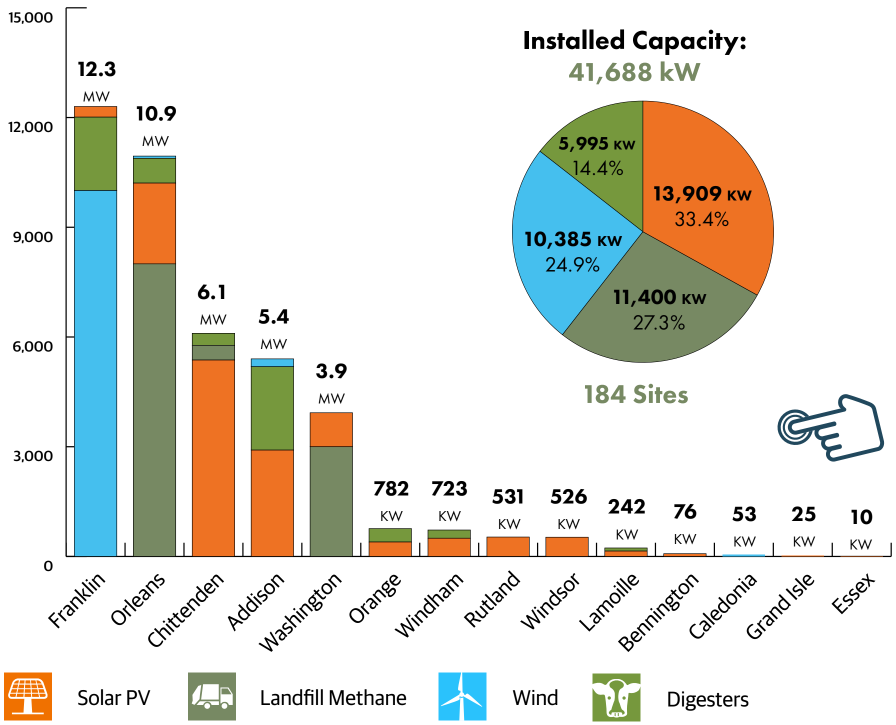
Solar energy, wind energy, and methane digesters are the most common type of energy installation at food system businesses. The Coventry Landfill is currently the largest food system business renewable energy generating site, with 8 MW of landfill methane and 2.2 MW of solar PV electricity generating capacity. Georgia Mountain Maples, a 4 wind turbine 10-megawatt electricity generating site is the second largest site, followed by several 2.2 MW solar farms on agricultural land. Vermont has at least 19 anaerobic digesters and many food system businesses have solar photovoltaic installations (Figure 4.6.10).

The pre-REC installed capacity of food system renewable electricity generators is equal to 4% of total installed renewable electricity capacity— surely an undercount but the best available information we have as of September 2015.

Solar Photovoltaics

Solar photovoltaics, also called solar PV for short, are made of a semiconductor material that directly turns the photons in sunlight into electricity. A complete solar PV system consists of four things: solar panels, a way to mount the solar panels (either on a roof or on the ground), the electronic conversion equipment (i.e., an inverter), and the electrical synchronizing and safety equipment to connect the electricity to the utility's network. According to the Energy Information Administration, the United States had a little more than 20 gigawatts (20,000 megawatts) of solar electricity generating capacity as of November 2015. California alone has nearly half that total, and most of the solar electricity generating capacity in the U.S. comes from utility-scale generation (e.g., generation from facilities with at least 1 MW of capacity).[20] **With about 5,000 installations (Figure 4.6.11), solar PV is far and away the most common type of renewable energy in Vermont and the biggest category of energy generation by food system businesses (Figures 4.6.10, 4.6.11, 4.6.12).**

Figure 4.6.10: Food System Renewable Electricity Production*



Source: Vermont Farm to Plate, *www.vtfarmtoplate.com/getting-to-2020/22-efficiency-and-renewable-energy*. * As of September 2015.

As shown in Figure 4.6.11 a small number of utility-scale solar electricity generators account for a significant percentage of total Vermont solar electricity generation: 30 ground-mounted sites (0.6% of solar PV sites) with >500 kW generating capacity accounted for 44% (41,593 kW) of total solar electricity generating capacity. Fifteen ground-mounted sites (0.3% of solar PV sites) with >1 MW of generating capacity accounted for 32% (30,700 kW) of total solar electricity generating capacity. Distributed generation (e.g., small-scale roof and ground-mounted PV systems) accounts for 99% of solar PV installations in Vermont but only 56% of generation— and that is rapidly changing as more and more larger systems comes online.

Net Metering

Most solar PV sites in Vermont—including most food system businesses with solar PV— are *net metered*. A net metered project means that the renewable electricity generated by the consumer is applied as a credit—which for most utilities is capped at $0.19 per kilowatt-hour—to offset electricity that would normally be purchased from the utility. Electricity generation in excess of the consumer's use during a billing period is credited to their account for future use. Solar energy generators in *Green Mountain Power* territory can receive a "Solar Adder" which is added to the highest residential rate of $0.15 per kilowatt-hour. This adder is $0.053 credit per kilowatt-hour. Group net metering, including "community solar arrays" allows energy generators to share their credits across multiple meters at the farm, or they can be set up by a group of people, businesses, or nonprofits to share the production of a single system and benefit from the economy of scale provided by a larger solar array. The only requirement is that all the group beneficiaries are in the same utility service area. Net metered projects can be built up to a capacity of 500 kW.

Vermont SPEED

Although solar PV systems are the most common type of renewable energy installation in Vermont, they only account for a small percentage of the installed capacity of all renewable electricity systems. This is rapidly changing, however. The Vermont *Sustainably Priced Energy Development* (SPEED) program provided long-term contracts at fixed prices for qualified projects that triggered a wave of large solar installations, including 38 SPEED-approved solar projects equal to 59 MW of generating capacity. From 2010 to 2011, the SPEED program offered contracts of $0.30 per kWh for 25 years for solar projects before dropping prices in each subsequent year (e.g., SPEED offered prices of about $0.11 to $0.12 per kWh in 2015).

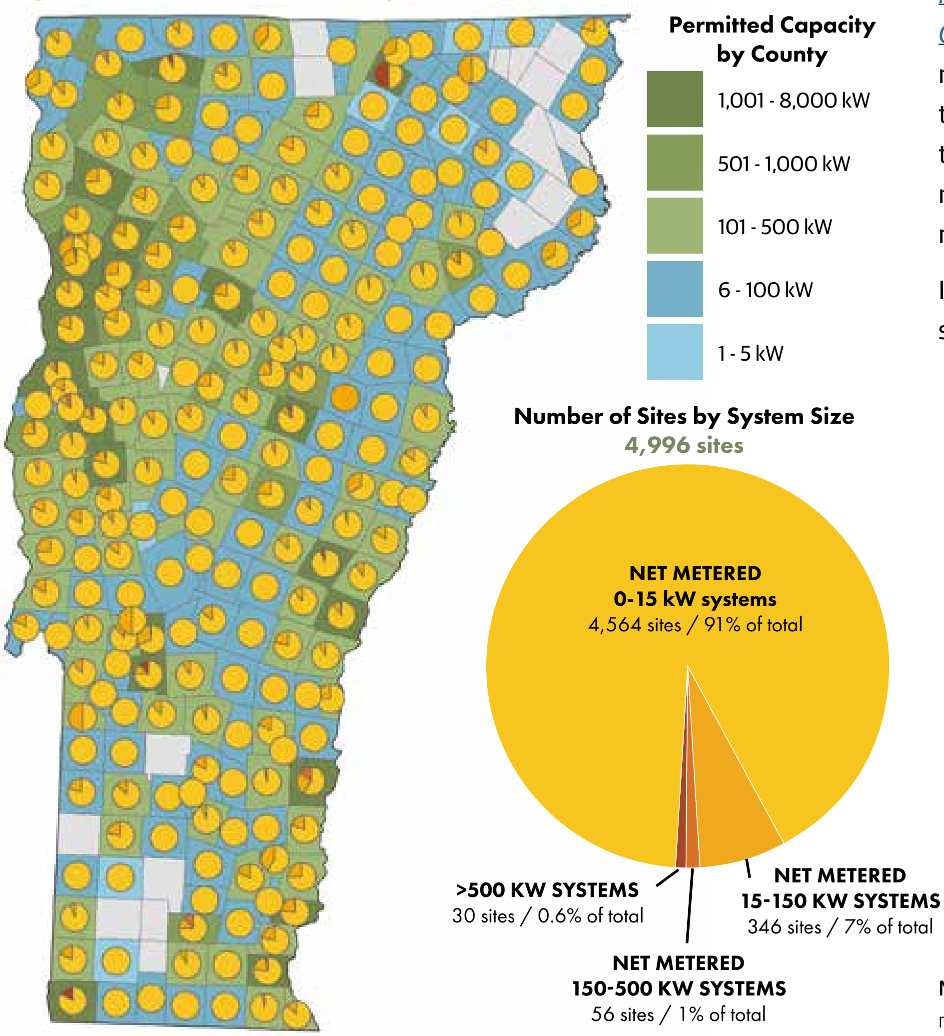
Currently, 30 large solar installations (equal to less than 1% of solar installations) account for 44% of installed solar capacity, while over 4,500 small net metered sites account for 27% of installed capacity (Figure 4.6.11). Four large solar installations account for less than 1% of solar installations at food system businesses but 63% of installed capacity. Note that renewable energy installation data is always a moving target: Many more solar projects—representing thousands of kilowatts— have been permitted but not yet built.

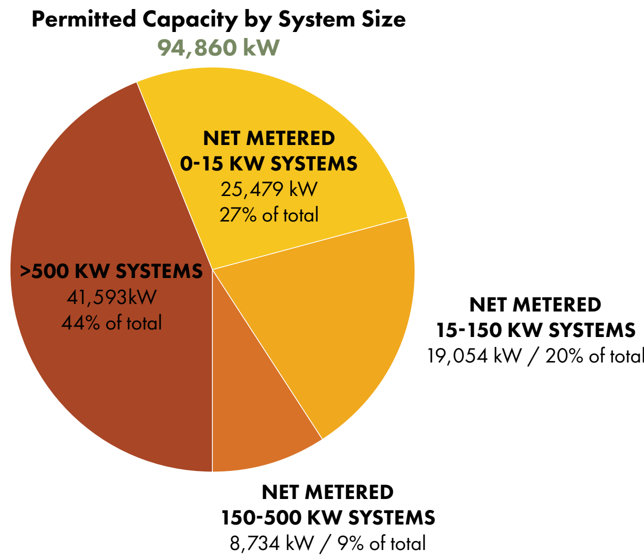
Although the SPEED program led to many large renewable energy installations, it was controversial as Vermont utilities sold renewable energy credits (RECs) out of state that were also used to count toward Vermont's renewable energy goals. The RESET program supercedes the SPEED program in 2017 and requires increasingly larger percentages of local renewable distributed generation and alignment with regional RECs trading standards.

Many municipalities and Vermonters have expressed concern about the rapid development of larger solar PV installations around the state. Concerns have been raised about aesthetic issues, property values, development on agricultural and other land and a perceived lack of sensitivity on the part of the Public Service Board during the [Act 248] process. For example, in testimony to the [House Committee on Natural Resources and Energy], the [Vermont League of Cities & Towns] reports that 38 towns adopted a resolution "to instruct their state representatives and senators to develop amendments to the statutes that concern the siting and approval of renewable energy projects, and to the procedures of the PSB in order to ensure that Vermont municipalities have a more meaningful role in the CPG process and to require compliance with appropriately-developed municipal siting standards."

In response, RESET also established a [Solar Siting Task Force] "to study the design, siting, and regulatory review of solar electric generation facilities and to provide

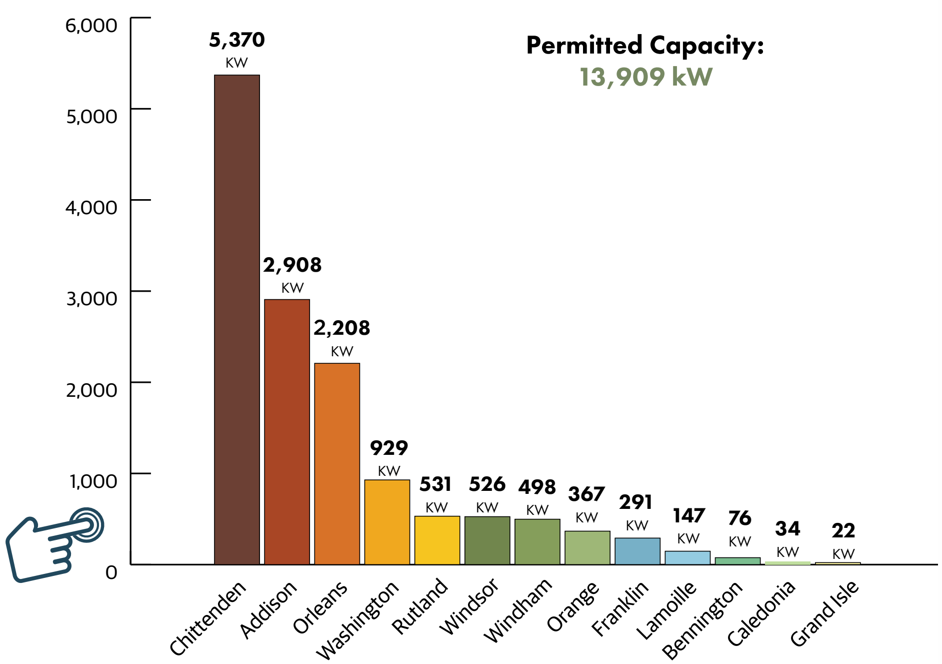
Figure 4.6.11: Vermont Solar PV by Town*





Note: this map only depicts the location of generation sites and does not account for capacity factors, renewable energy credits sold, or ownership of systems. * As of September 2015.

Figure 4.6.12: Solar PV Generating Capacity from Food System Businesses



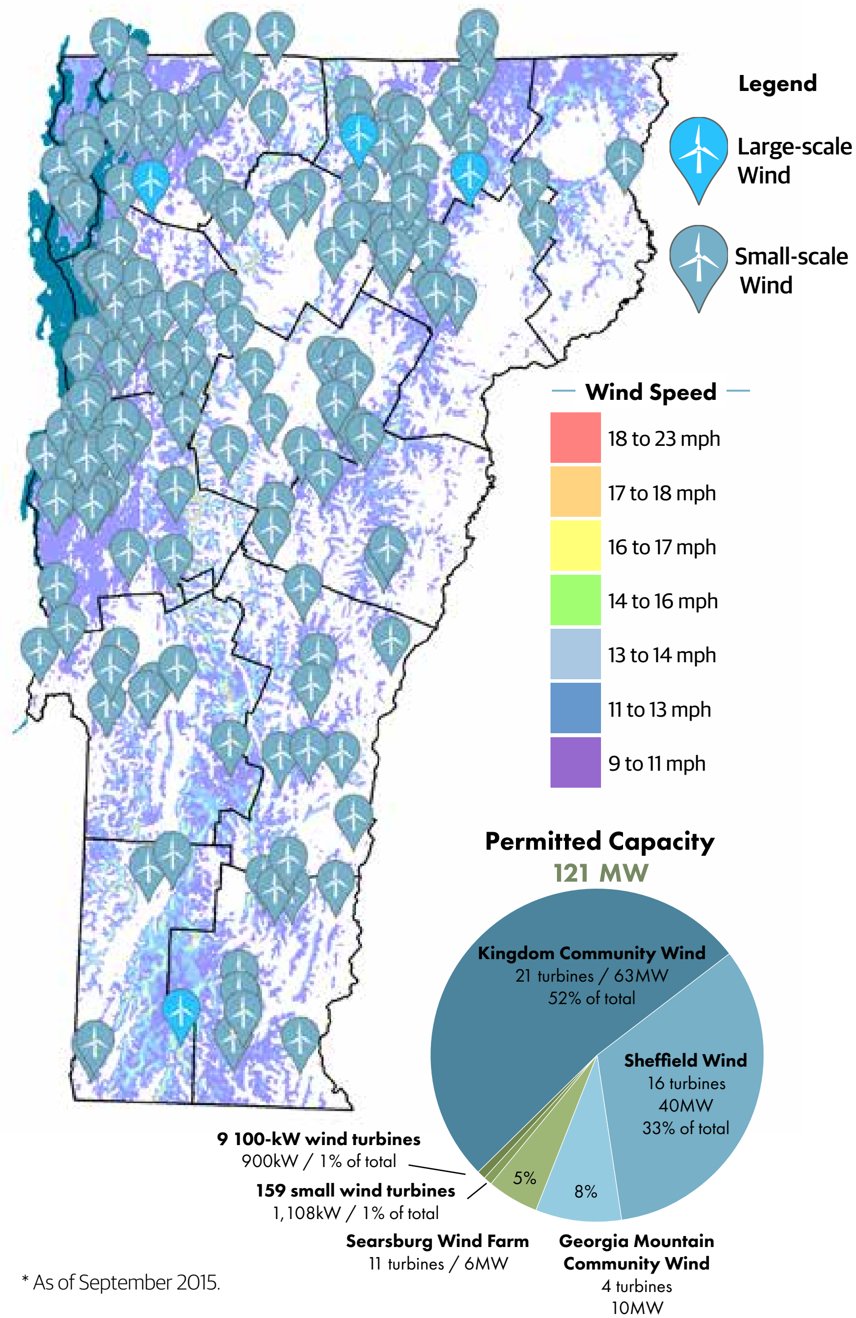
Source: Vermont Farm to Plate, *www.vtfarmtoplate.com/getting-to-2020/22-efficiency-and-renewable-energy#indicator-population-indicator-4*.

a report in the form of proposed legislation with the rational for each proposal." In 2015, the *Solar Siting Task Force* released its *final report* of recommendations for the Vermont Legislature. The report outlines recommendations for planning, incentives, the regulatory process, and aesthetics/environment that, for example, strengthen the capacity of regional planning commissions and municipal planning commissions to plan for solar facilities and incentize development in preferred areas.

Wind Energy

Vermont's wind resource varies a lot from one place to another due to wind direction, ground obstructions, surface roughness, as well as elevation in relation to the surrounding topography. The strongest wind resources are generally located at higher elevations and that is where Vermont's four commercial

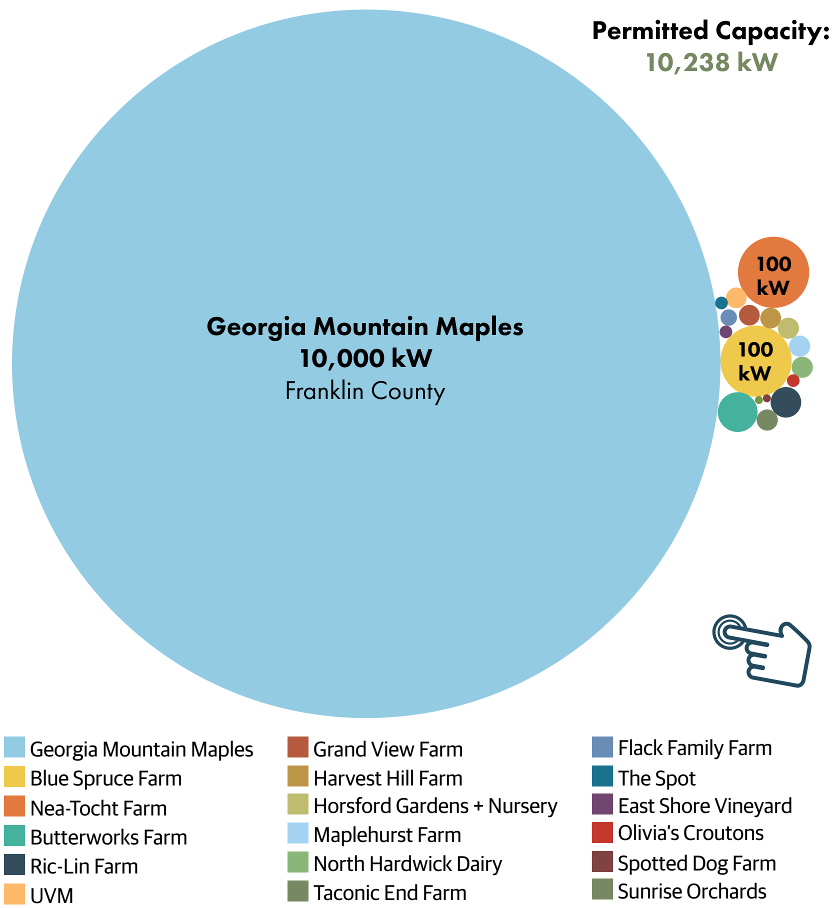
Figure 4.6.13: Vermont Wind Installations*



* As of September 2015.

installations—Kingdom Community Wind, Sheffield Wind, Georgia Mountain Community Wind, and Searsburg Wind Farm—are located. These four sites account for 98% of Vermont's wind installed capacity. Vermont also has at least 159 small-scale net metered wind projects—ranging in size from 0.95 kilowatts (kW) of generating capacity to 99 kW—and nine 100 kW turbines that are powering homes, schools, businesses, and farms (Figure 4.6.13).

Figure 4.6.14: Wind Generating Capacity from Food System Businesses



Source: Vermont Farm to Plate, www.vtfarmtoplate.com/getting-to-2020/22-efficiency-and-renewable-energy#indicator-population-indicator-2.

Large-scale wind development in Vermont has seemingly stalled, with Deerfield Wind (30 MW) the only facility currently in permitting. Vermont's Comprehensive Energy Plan recommends focusing on small- and medium-scale and community-directed wind projects. The 2015 SPEED program request for proposals incentivized small-scale wind projects (less than 100 kW) by setting aside 1.5 MW of possible development at a rate of $0.2520 per kilowatt-hour. Eight proposals representing 652 kW were received.

One site, Georgia Mountain Community Wind—owned by Georgia Mountain Maples, accounts for 98% of the installed capacity of wind energy at food system businesses (Figure 4.6.14). Two 100 kW wind turbines at Blue Spruce Farm and Nea Tocht Farm—both using Northern Power NP 100 turbines installed by Aegis Renewable Energy and owned by Green Mountain Power. In exchange for hosting the wind turbine the farmers get a 10% of the output of the wind turbine as a lease payment. This structure provides a zero risk opportunity for farms to incorporate renewable energy while having a very small footprint.

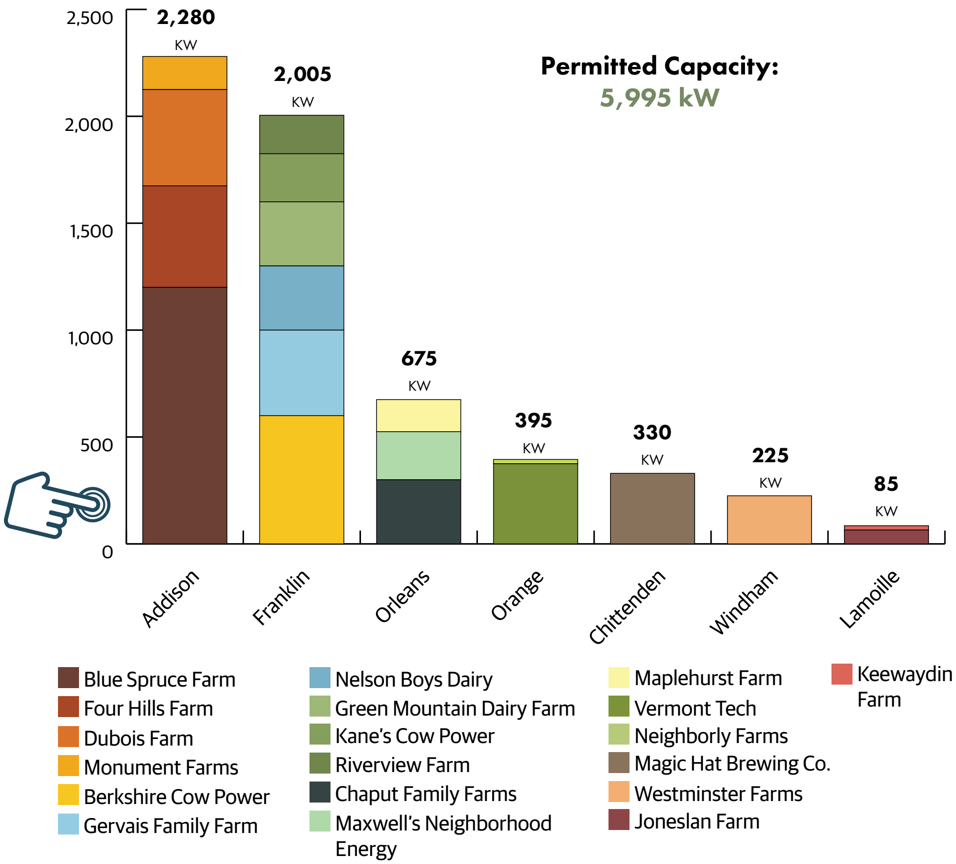
Photo Credit: Vermont Agency of Agriculture

Just after Memorial Day in 2013, the Audet family hosted a community celebration of the installation of a 100-kilowatt wind turbine at Blue Spruce Farm. A portion of the electrical output of the turbine is allocated to the local school.

Anaerobic Digesters

Anaerobic digesters are oxygen-free tanks or containers that use microorganisms (i.e., different types of bacteria) to transform biomass like cow manure into "biogas" (e.g., methane and carbon dioxide), while retaining the manure slurry. This biogas can then be fed to a gas engine to generate electricity, or to a boiler to generate heat. There are currently 19 digesters in Vermont (Figure 4.6.15): 17 on dairy farms, 1 at Magic Hat Brewing Company, and 1 at Vermont Tech. [Green Mountain Power's Cow Power] program enables customers to buy RECs from 12 participating dairy farms.

Figure 4.6.15: Anaerobic Digester Generating Capacity from Food System Businesses



Source: Vermont Farm to Plate, www.vtfarmtoplate.com/getting-to-2020/22-efficiency-and-renewable-energy#indicator-population-indicator-3.

The [Vermont Tech community anaerobic digester] uses farm manure and food residuals to generate electricity, heat, and recycled nutrients.

As of 2015, Vermont has about 870 dairy farms milking a total of about 134,000 cows.[21] Most of the millions of tons of cow manure produced in Vermont does not go through a digester. Despite the potential of this resource, digester development in Vermont has nevertheless stalled.[22] The PSD attributes this to the high cost of digester development compared to other dairy farm investments, a lack of financing vehicles today compared to when the majority of digesters in Vermont were constructed, permitting challenges, and a variety of technological and equipment challenges.

Heat

According to the *Vermont Public Service Department* (PSD), heating fuels that are not regulated—such as fuel oil, kerosene, propane, and wood (biomass)—account for 27% of Vermont's total energy demand, 27% of the state's greenhouse gas emissions, and 82% of Vermont's space-heating and industrial process heat requirements. The residential sector accounts for 65% of unregulated fuel consumption, nearly double the combined usage of the commercial (21%) and industrial (14%) sectors. About 72% of distillate consumption in Vermont is for heating applications. The PSD reports that all uses of wood for fuel (e.g., cords, pellets) in 2009 totaled 1.5 million tons. Over the past 50 years, liquefied petroleum gas (LPG) consumption has increased over 492%, from 5% to 16% of total petroleum consumption. Natural gas consumption in Vermont has increased 822% from 1966 to 2012.[23]

Unfortunately we do not have much information about how and where renewable heat options (e.g., wood chip/pellet furnaces or boilers, solar hot water) are being used by food system businesses. Heat uses across the food system include air heating in greenhouses, barns, and other buildings, soil heating, boiling sap, heating hot water, drying crops, and a wide variety of commercial kitchen equipment.

Biomass Fuels

A *recent study* conducted by the *University of Vermont Extension*, provides insights into the adoption of biomass fuels at vegetable greenhouses. Greenhouse production in Vermont covers 2.6 million square feet and produces $24.5 million in crops, of which about $5 million are fruits and vegetables. This translates to 60 acres of covered production with gross revenues of $408,000/acre overall

Table 4.6.3: Renewable Heating Fuel Summary

Fuel	BTU Content	Cost	Delivered Heat Cost (per million BTU)	Pros	Cons
CORD WOOD	18-20 million BTU/cord	$160 – 200/ cord	$11.1 @ 85% efficiency	Readily available & familiar; can generally be sourced on farm.	Manual handling; batch loading
WOOD PELLETS	8,600 BTU/lb	$294/ton	$20.1 @ 90% efficiency	Automated feeding with auger and bin; available in bags and (in some locations) bulk delivery.	Higher cost per BTU than cord wood; limited bulk delivery options currently
WOOD CHIPS	9.9 million BTU/ ton	$56/green ton	$15.9 @ 65% efficiency	Inexpensive.	Generally high moisture compared to other fuels; limited small scale appliance availability.
CORN	8,500 BTU/lb	$300/ton	$23.9 @ 90% efficiency	Can be grown on farm; automated feeding with auger and bin.	Can form clinkers more easily than other biomass fuels.
GRASS PELLETS	8,600 BTU/lb	$250/ton	$16.1 @ 90% efficiency	Can be grown on farm; automated feeding with auger and bin when densified.	Relatively high ash content, needs automated removal system; clinkers possible.
PROPANE	92,000 BTU/gal	$2.80/gal	$33.8 @ 90% efficiency	Common, easy to use; no ash.	Not renewable; net CO_2 and greenhouse gas contributor.
FUEL OIL	129,500 BTU/gal	$4.00/gal	$34.3 @ 90% efficiency	Common, easy to use; no ash.	Not renewable; net CO_2 and greenhouse gas contributor.
BIODIESEL	118,296 BTU/gal	$4.18/gal	$39.3 @ 90% efficiency	Fuel oil replacement can be sustainably produced.	Some seals and materials may need to be changed.

Source: Chris Callahan, UVM Ag Engineering and $224,000/acre for fruits and vegetables. Growing crops under cover in greenhouses and high tunnels provides a more protected and controlled environment compared to field production. This protection has become increasingly important to Vermont farmers as the incidence of extreme weather events has increased in recent years. At the same time, Vermont farmers are expanding their greenhouse and high tunnel production in order to meet the growing demand for local food, which continues even when crops are 'out of season'.

However, the production of greenhouse crops often requires the addition of heat in early spring and late fall to protect against cold temperatures. That heat is generally derived from nonrenewable fossil fuels such as propane and fuel oil. **From 2008 through 2015, 25 growers received cost-share funds for greenhouse biomass heating systems. wood pellets or corn, cord wood, or solar.**

The total installed cost of these systems was $312,766; the average cost per system was $12,511 and the average cost-share (i.e., sponsor funding) on these projects was 44% of the total cost. The growers installed a variety of system types depending on desired fuel, heating load and method of heat distribution (i.e., hot air or hot water). The project started in 2008 and the systems have operated for the equivalent of 96 growing seasons in total with an average of 3.8 growing seasons per system, an average net fuel savings of $2,696 per system per year, and an average payback of 4.8 years (at full cost). From 2008 through 2015 a total of 15.3 trillion BTU of biomass energy was provided to these greenhouses, equivalent to 167,000 gallons of propane. The cumulative equivalent carbon dioxide emissions avoided by this substitution of fuel is estimated to be 2.14 million pounds. This is roughly equivalent to the annual emissions from 204 cars, or 2.3 million miles of car travel.

Researchers found that growers were more interested in biomass heat when the cost of fossil fuels were high. When fossil fuel prices stabilized or declined then growers' receptivity to change also dropped. A few growers found that if the systems were tied into other heating loads (e.g., residential heating, pack-shed heating, winter storage heating), then the systems were used for a longer period of time each year and their investment payback period was reduced.

The *Vermont Sustainable Jobs Fund*, through its *Vermont Bioenergy Initiative*, made a series of grants in the area of grass bioenergy (e.g., switchgrass) focused on research and development, systems feasibility, and education and outreach. Results include:

Switchgrass trial conducted by UVM Extension at Borderview Farm.

Fuel "pucks" or "briquettes" made from Switchgrass by Renewable Energy Resources for combustion testing.

- Grass biomass crops trials have demonstrated 3 to 6 tons per acre yields with annual production costs averaged over 10 years—including prorated establishment costs of $250 to $300 per acre per year—resulting in farm gate biomass costs of $50 to $80 per ton depending on annual biomass yield.
- The key factors supporting success of grass biomass crops in the region are species and variety selection, soil fertility, successful establishment including weed management, and soil productivity class.
- Grass biomass crops are aligned with the region's historical production and use of hay and other grass forages. Grass biomass crops can be harvested using equipment that already exists in the region.
- Grass biomass crops can be densified in smaller forms more suitable for storage, transportation, delivery and combustion in appropriately-sized

heating appliances for on-farm heating at a conversion cost of $49 to $148 per ton. Grass biomass fuels can be delivered with production cost of $85 to $228 per ton ($5.2 to $$14.4 per million BTU).

- Grass biomass fuels can be combusted in small commercial boilers intended for wood chips with a 3 to 5 year simple payback period and emissions comparable to wood pellets.
- Recent advances in boiler design such as improved combustion air controls and automated ash removal have helped address earlier issues with the use of these newer, high-ash fuels.

Grass pucks being fed into an EvoWorld HC100 Eco boiler at Meach Cove Trust in Shelburne, VT.

Compost Powered Heat

One Vermont company, [Agrilab Technologies](#) (Enosburgh Falls) has developed a compost processing and heat recovery technology system to heat buildings and warm water. Agrilab has several projects in Vermont and across the country, including the [City of Boston's Composting Facility](#).

Heat Pumps

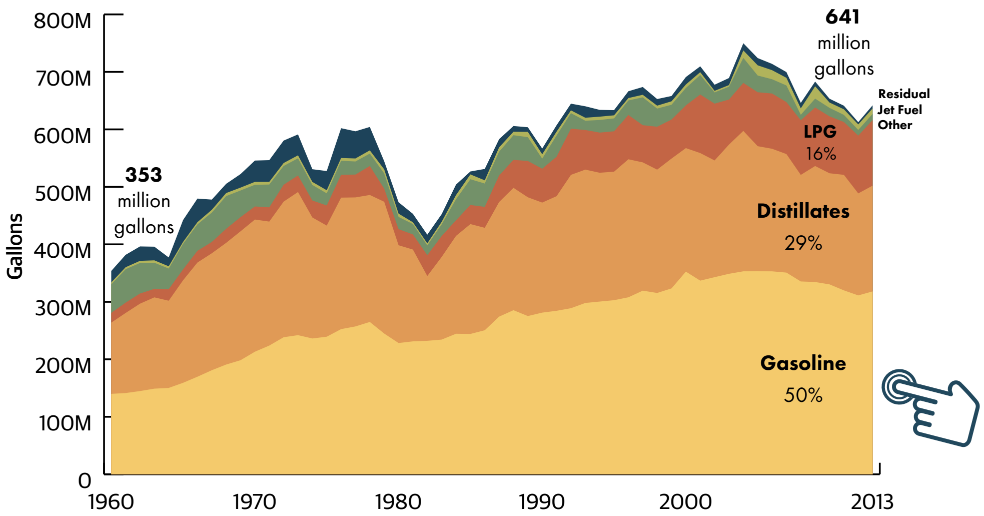
Heat pumps are expected to play a major role in heating and cooling Vermont in the years ahead. Unfortunately, we currently do not have data on the number of heat pumps installed at food system businesses.

Transportation

Liquid fuel consumption in Vermont (i.e., petroleum products) increased by about 74% from 1960 to 2012 (Figure 4.6.16). However, Vermonters have reduced total petroleum consumption by about 108 million gallons from the highest year of consumption on record, 2004 (749,868,000 gallons), to 2013 (641,886,000 gallons). Gasoline consumption increased 127% from 1960 to 2013 and is equal to 50% of total petroleum consumption. The majority of the gasoline consumed in Vermont is for transportation (98%). Distillate consumption increased 48% from 1960 to 2013 and is equal to 29% of petroleum consumption. About 28% of distillate consumption in Vermont is for transportation, with the rest used for heating.

Except for on-farm diesel use, we do not have data on food system business liquid fuel consumption, but we assume that most of it is used in vehicles. Ethanol—a biofuel usually derived from corn—is blended into gasoline by federal law. The [Energy Information Administration](#) estimates that Vermont consumed 713,000 barrels (about 30 million gallons) of ethanol in 2013, the lowest amount

Figure 4.6.16: Vermont Liquid Fuel Consumption, 1960-2013



Source: Energy Information Administration, [www.eia.gov/state/seds/data.cfm?incfile=/state/seds/sep_use/tx/use_tx_VT.html&sid=Vermont](#)

of any state except Alaska. Vermont does not produce ethanol but does produce a small amount of biodiesel from oilseed crops and waste vegetable oil for on-farm use.

Biodiesel

The *Vermont Bioenergy Initiative* (VBI) funded very early stage, farm-based demonstration projects, including several on-farm biodiesel production facilities. The VBI showed that oilseed crops can be produced and processed in the Vermont to make biodiesel. Even at relatively moderate yields and at small scales of production, farm-based biodiesel enterprises are producing can produce fuel from these crops at a cost of $2.30-2.50 per gallon, with a net energy return ratio of between 3.6 and 5.9 to 1, and with net carbon avoidance of 1,984 to 3,227 pounds per acre per year.

With support from the U.S. Department of Energy (DOE), the VBI was a steady, stable source of foundational support for nearly 10 years that has helped some of the early bioenergy pioneers work on challenges with sustained effort. Results include:

- Oilseed crops can be successfully grown in the Vermont and the Northeast. Researchers and growers in Vermont have successfully produced sunflower, canola, winter rapeseed, flax, safflower and camelina.
- Production guidance from other, high-volume production areas is generally not well-aligned with our growing region due to soil fertility, pest management and weather differences.
- Researchers in Vermont have compiled and published regionally-specific production guidance based on the crop research done locally.
- Yields are highly variable from year to year with the main depressive pressure being from pests and disease.
- Harvester (combine), drying, cleaning, and storing capacity are critical barriers to entry in adoption of oilseeds as a revitalized crop in the Northeast.
- Oilseed presses, though commercially available, are not well specified by manufacturers and require nuanced expertise to operate.
- Researchers in Vermont and Pennsylvania compiled and published oilseed press best practices and reviews to assist with more expedient adoption of the practice.
- Multiple scales of biodiesel production from seed oil have been demonstrated on farms in Vermont including self-built and commercially available systems.
- A regulatory review of on-farm biodiesel production was conducted by researchers at Vermont Law School which explored a wide range of regulatory hurdles and requirements that farm-based fuel enterprises would face.

With DOE funding for the VBI ending in 2015, it's unclear where new biodiesel projects will receive financial support.

Black Bear Biodiesel (Plainfield) collects waste cooking oil from hundreds of restaurants throughout Vermont and then processes it into biodiesel.

Sunflowers at Ekolott Farm.

State Line Biofuels in Shaftsbury has been a pioneer in biodiesel development in Vermont.

Electric Vehicles

Electric vehicles figure prominently in Vermont's Comprehensive Energy Plan. A major shift is expected to take place as electric vehicles and plug-in hybrids are expected to grow from over 1,000 vehicles in Vermont today to several hundredthousand by 2050. It is unclear how this will impact food system businesses. We may still be several years away from seeing a proliferation and diversification of electric vehicles for farm equipment and fleets.

ANALYSIS

The following sections review the intersection of opportunities in energy generation from food system organizations and meeting the goals of Vermont's Comprehensive Energy Plan; food system energy issues (e.g., farm production expenses); and utilizes the insights of the Farm to Plate Network *Energy Cross-Cutting Team* to identify ongoing market development needs (e.g., research needs, technical assistance needs).

Food System Energy Issues

Direct and Indirect Energy

Direct energy use refers to fuels that are purchased and used directly by farmers, food processors, distributors, and members of households. This class of energy use includes diesel and gasoline purchased to run farm machinery or vehicles, electricity purchased to run machinery, or propane, natural gas, or wood used to generate space or process heat.

Indirect energy refers to the energy needed to manufacture, deliver, and maintain key pieces of food system infrastructure including farm machinery, agricultural inputs like fertilizer and pesticides, buildings, roads, tools, packaging supplies, and other equipment and appliances.

The wide variety of direct and indirect energy uses across the food system means that fluctuations in energy availability and prices can have a significant impact on all Vermonters. For instance, the metal, glass, plastic and rubber used to build a tractor all require energy to mine or extract the raw materials from which they are made and in their manufacture, and the tractor requires further investment of fuel to transport it from its place of manufacture to where it is sold, then to deliver it to the farm where it will be used. Once on the farm, the farmer must continue investing energy in the tractor in the form of maintenance to keep it running, including lubricant and new parts. The actual diesel fuel used to run the tractor represents a direct fuel cost on top of all of the indirect energy costs associated with the tractor and, if the total indirect energy costs associated with the tractor throughout its useful life are divided among each year of use, it is entirely possible that the annualized indirect energy costs are actually larger than the energy value of the diesel fuel the farmer buys for it in a given year. While purchasing diesel fuel can be a substantial cost for farmers due to the rising price of petroleum-derived fuels, a segment of the purchase and maintenance costs of a piece of machinery also originate in the fuels needed to manufacture it.

Per capita energy use in the United States declined 1.8% from 1997 to 2002, but per capita food-related energy use increased by 16.4% during that timeframe. Much of this increase reflects the historic trend of energy-based products and services replacing human labor. For example, the USDA attributes much of this growth in energy consumption to the outsourcing of food preparation activities at home and within the food service industry to automated food processing. That is, **increased consumption of prepared foods and more eating away from home appear to be the driving force behind the growth in food system energy consumption.** Additionally, energy used for farm inputs and to run equipment on the farm equaled 14.4% of food system energy consumption in 2002, and it grew about 5% from 1997 to 2002, the third largest increase after food processing and food services.[24]

A starting list of direct and indirect energy uses across the food system includes:[25]

Lighting	Ventilation	Refrigeration
Milk Harvesting	Controllers	Other Motors/Pumps
Water Heating	Cooking	Drying
Waste Handling	Air Cooling	Transportation
Crop / feed / food storage	Water management	Material handling
Irrigation	Air heating / Building environment	Cultural Practices - planting, tilling, harvesting, engine driven equipment

An example of the practicalities of indirect energy may be helpful. Take for instance a tractor, in this case a New Holland TM135, model year 2001. This tractor weighs about 13,500 pounds, and if we translate its physical mass to embodied energy using a standard conversion factor of 35,000 BTU/pound this gives us an estimate of indirect energy use for the tractor's manufacture of 475 MMBTU. If the tractor's useful life was a single year, all of this embodied energy would be counted against its use for that year. If 1,000 gallons of diesel were used over that year to fuel the tractor, equating to 140 MMBTU of energy, the indirect component of energy use outweighs the direct component of energy use for that year.

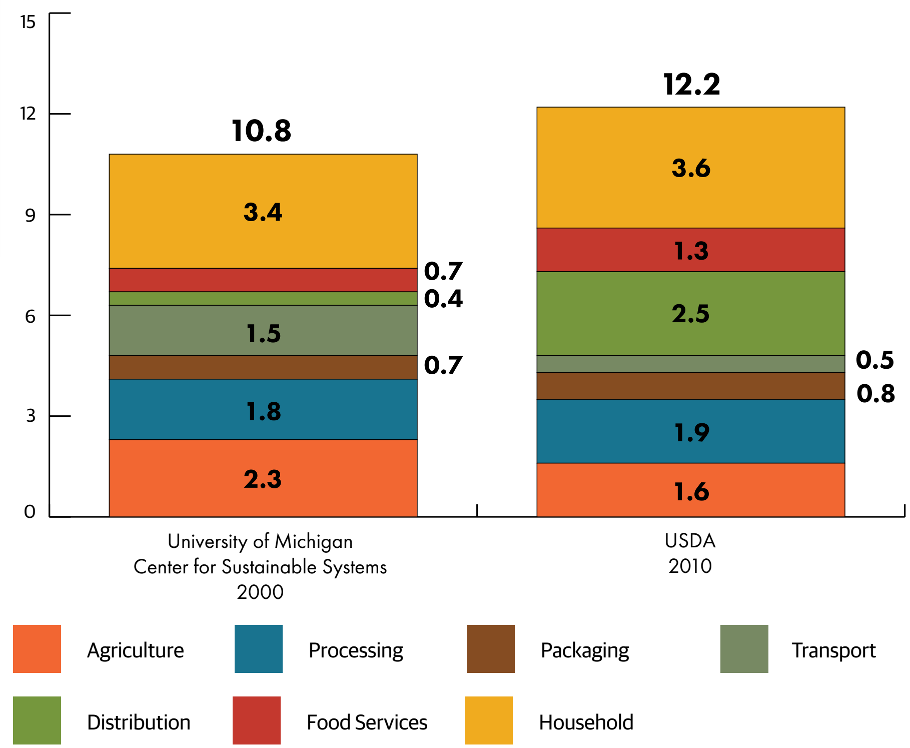
In actuality, the tractor's useful life will be spread over several years, so the total indirect energy use for this tractor apportioned to any individual year will depend on how long the tractor lasts. It's common to assume lifetimes for tractors and other farm machinery in the range of 15-20 years, so if we assume a lifetime of 20 years the amount of indirect energy attributed to each year would be 24 MMBTU. It's also common to add 10 % of this amount to account for indirect energy use associated with maintenance, which would add another 2.4 MMBTU for a total of 26 MMBTU per year. Now the embodied energy of the tractor attributed to a single year of use is far smaller than its direct fuel use. If the farmer used the tractor less and only burned 200 gallons of diesel in it per year, the direct and indirect energy associated with the use of this tractor would be roughly equivalent at 28 and 26 MMBTU per year.

Data specific to Vermont's food system isn't available but, since most of Vermont's food is imported from outside the state, a look at energy use in the U.S. food system is a useful proxy. However, analyzing energy use in the U.S. food system is not as straightforward as one might expect, as no agency within the federal government (or state governments) tabulates these statistics.

For example, researchers from the University of Michigan's Center for Sustainable Systems and analysts from the United States Department of Agriculture's Economic Research Service estimated the energy use in the U.S. food system for the year 1996 (Figure 4.6.15).[26] **Researchers at the University of Michigan Center for Sustainable Systems estimate that it takes 10.8 Calories (i.e., 42.9 BTUs) of energy to deliver one Calorie of food once wastage and spoilage are accounted for throughout the food system. Analysts at the USDA's Economic Research Service put the figure a bit higher at 12.3 Calories (i.e., 48.8 BTUs) of energy to deliver that same Calorie of food.** These figures differ by several percent in their estimate of the total amount of energy needed to deliver a Calorie of food, and also differ importantly in how they divide the energy used among the different sub-systems within the food system.

While the 10-12 input Calories per Calorie of food in 1996 might seem high, in fact both studies define the U.S. food system quite narrowly. They both leave out the embodied energy of imported foods and the energy demands associated with food waste disposal, water treatment associated with food systems, research

Figure 4.6.17: Two Estimates of the Energy Required to Deliver One Calorie of Food in the U.S. (Food System Wastage and Spoilage Already Taken into Account), 1996

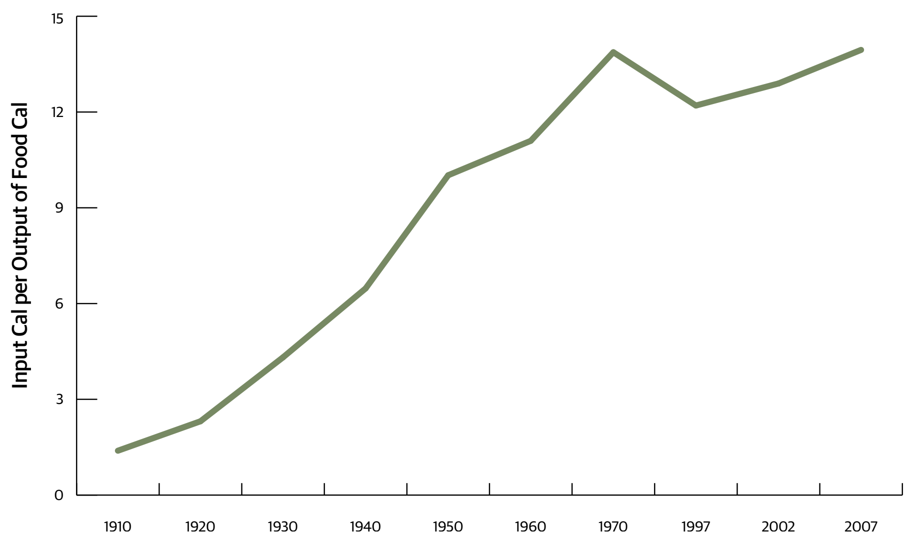


and development within the food system,[27] the energy costs of food system governance, and the energy costs associated with delivering healthcare and other services to those who suffer poor nutritional outcomes due to poor dietary choices or lack of sufficient food access. Beyond this, the data is almost 20 years out-of-date, and the energy intensity of food production has trended upwards since 1996 so that, **in 2015, it is likely that delivering a Calorie of food requires 15-20 Calories of energy inputs once wastage and spoilage are accounted for.**

Put another way, the energy needed to deliver the average Vermonter's daily food intake equates to roughly 1.2 gallons of gasoline, which is slightly less gasoline per day than the average Vermonter uses in their car.[28]

Food production in the United States has not always been so energy intensive. **Historical data show that the energy costs of food production are higher today than they have ever been**, and not only were the energy costs of the U.S. food system radically lower in the past but they were low enough that the food system probably delivered roughly 1 Calorie of food for each Calorie of energy input around the year 1900 (Figure 4.6.18).[29] Changes in the system come from many sources, including the mechanization of farming and food processing, the development

Figure 4.6.18: Energy Use in the U.S. Food System, 1910-2007



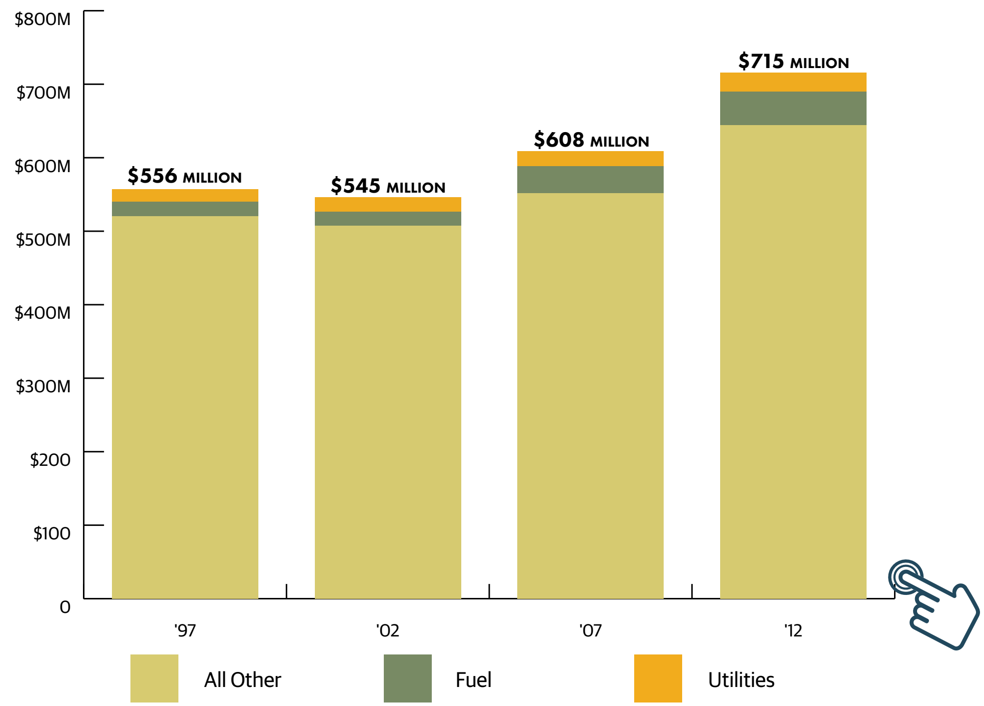
Source: Calculated by Eric Garza based on Steinhart and Steinhart (1974) and Canning et al., (2010).

of mass-distribution of food, the adoption of refrigeration and freezing as modes of food storage, an increased reliance on and preference for highly processed foods, the increasing importance of food services such as restaurants and catering services to consumers' methods of accessing food, and the adoption of energy intensive methods of food storage and preparation within the home.

Farm Production Expenses

Vermont farm production expenses increased 28% from 1997 to 2012 (+$159 million, Figure 4.6.19). **From 1997 to 2012, the amount of money Vermont farmers spent on fuel increased 132%, from $19.7 million to $45.8 million. Fuel expenses increased from 3.5% of total expenses in 1997 to 6.4% of total**

Figure 4.6.19: Vermont Farm Production Expenses, 1997-2012

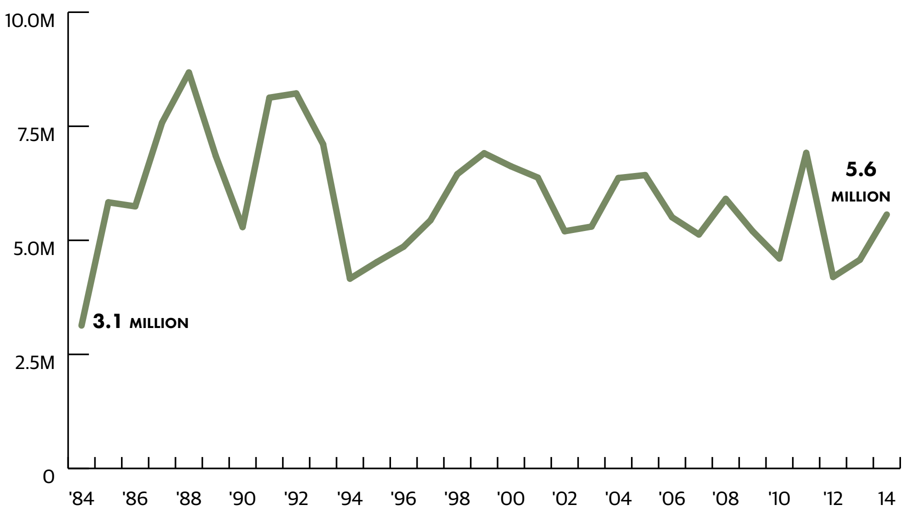


Source: USDA Census of Agriculture, multiple years, www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Vermont/, adjusted for inflation to 2012 dollars.

purchases in 2012. From 1997 to 2012, utility expenses increased 54%, from $16.6 million to $25.6 million. Utility expenses increased from 3.0% of total expenses to 3.6% of total expenses in 2012.

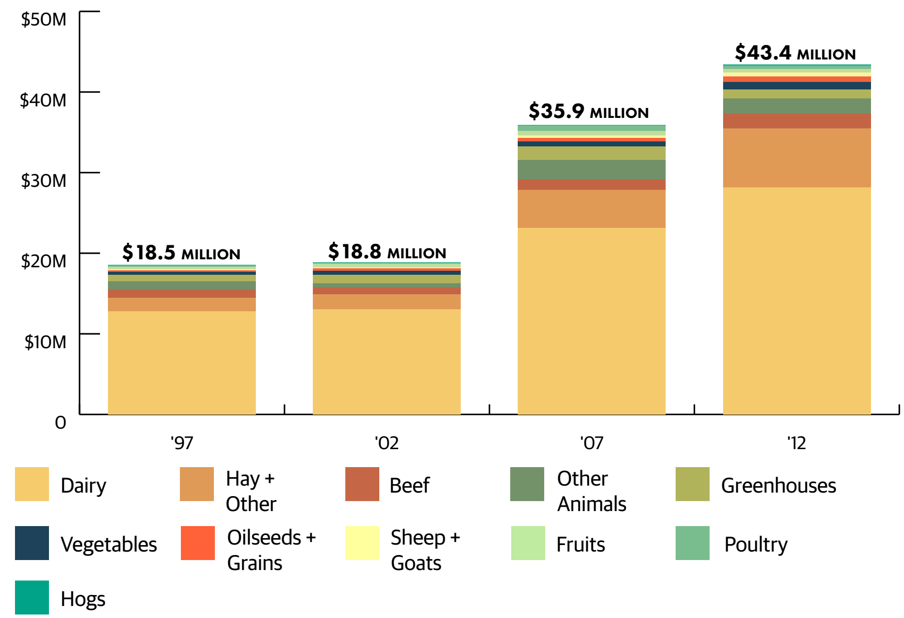
Between 1984 and 2014, Vermont farmers purchased an average of about 6 million gallons of diesel fuel per year (Figure 4.6.20). Data about on-farm electricity and thermal energy consumption are not readily available. Dairy farms have the highest energy expenses of any farm type in Vermont, and energy expenses increased even as the number of dairy farms in Vermont decreased (Figure 4.6.21).

Figure 4.6.20: Vermont Farm Distillate Sales, Gallons, 1984-2014



Source: Energy Information Administration, www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=KDOVAFSVT1&f=A.

Figure 4.6.21: Vermont Fuel Expenses by Farm Type, 1997-2012



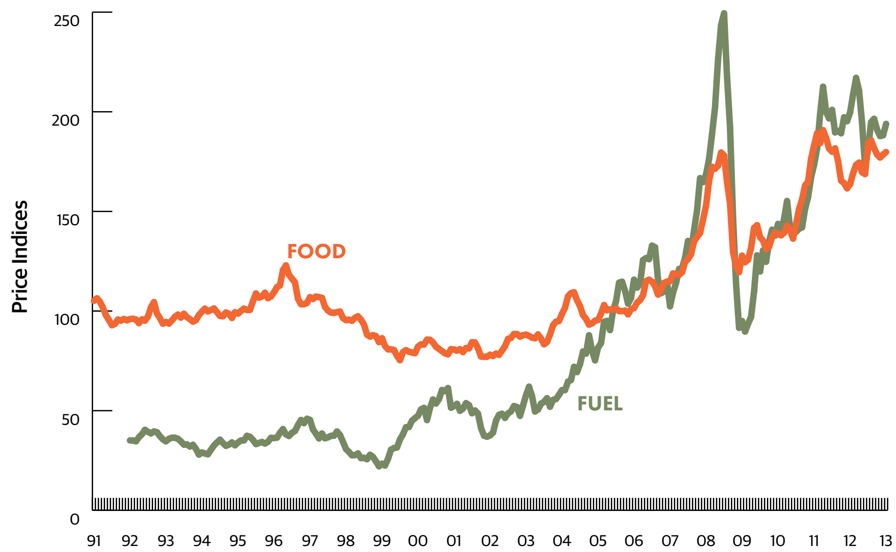
Source: USDA Census of Agriculture, multiple years, www.agcensus.usda.gov/Publications/2012/Full_Report/Volume_1,_Chapter_1_State_Level/Vermont/, adjusted for inflation to 2012 dollars.

Energy and Food Costs

Although Americans spend less of their income on food than citizens of most other Western nations, rising food prices contribute substantively to food insecurity. Food price trends are driven by many factors, including changing weather and climate patterns, the cost of labor, land, machinery and other infrastructure, and fuel.

Food prices rose gradually after the year 2000, and have spiked twice since 2005. These trends mirror those seen in global fuel prices, which have seen substantial and sustained price increases since 2000 (Figure 4.6.22). An important goal in the provision of food security is to sever the ties between fuel prices and food prices so that the price of food is no longer contingent on the price and availability of fossil fuels. To accomplish this, the energy needed to deliver food to Vermonters' plates must fall dramatically and/or we need to further develop local sources of energy.

Figure 4.6.22: Trends in Food and Fuel Price Indices, 1990-2013



Source: International Monetary Fund

Agriculture and Climate Change

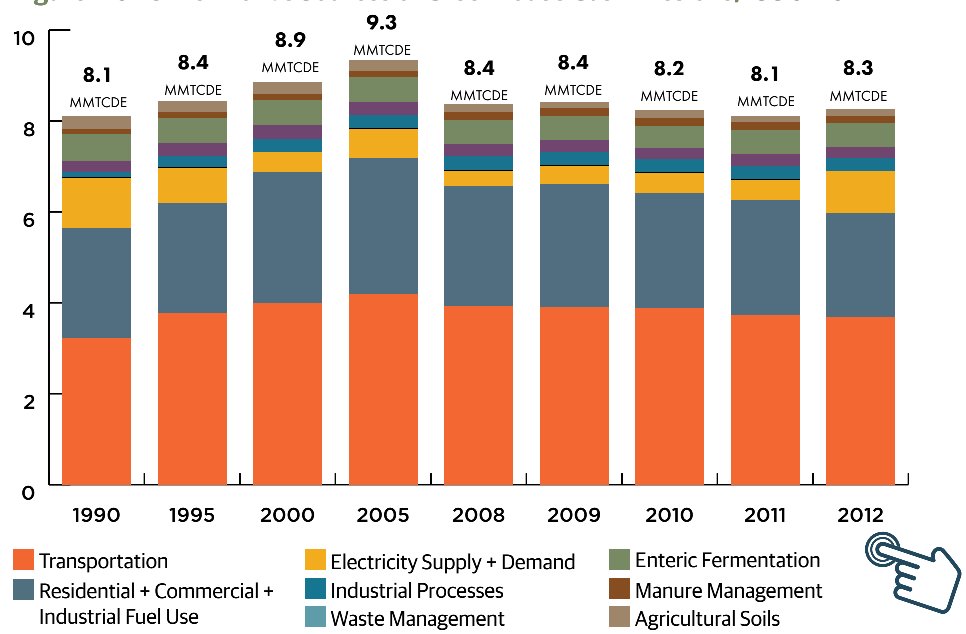
Total U.S. greenhouse gas emissions from all sources increased 5.9% from 1990 (6,267 million metric tons) to 2013 (6,638 million metric tons). Emissions from mobile and stationary energy sources accounted for 85.7% (5,745.7 million metric tons) of total U.S. emissions in 2011, up 9.1% (5,267.3 million metric tons) from 1990 levels. The biggest sources of emissions are transportation, industry, and electricity generation (i.e., from coal).

Emissions from agricultural sources—which includes *enteric fermentation* in domestic livestock, livestock manure management, rice cultivation, agricultural soil management, and field burning of agricultural residues—are the fourth largest source of U.S. emissions at 8.8% (587 million metric tons). Agricultural emissions increased 19% from 1990 to 2013.[30] Sinks (e.g., forests) sequester about 13% of total U.S. emissions on an annual basis.

From 1990 to 2012 Vermont's greenhouse gas emissions essentially stayed the same— a little over 8 million metric tons (Figure 4.6.23).[31] Vermont's emissions are equal to 0.1% of total U.S. emissions. **Agricultural activities in Vermont—enteric fermentation (cow digestion), manure management, and agricultural soils—accounted for about 10% of total emissions in 2012.** According to the Vermont Agency of Natural Resources, "both carbon storage and uptake were adversely affected by the 1998 ice storm, which covered nearly a million acres of forestland." That is, the 1998 ice storm contributed to slower carbon storage in the years following the event. Furthermore, "acres of forestland started to decline, resulting in a substantial increase in the carbon flux (reduced carbon uptake) before rebounding to the current level of -1.61 million metric tons carbon per year, and carbon storage increased to over 370 million metric tons of stored carbon."

Food system activities, particularly farming, are vulnerable to the fluctuations of weather: climate change means increased precipitation and extreme weather events in Vermont; as well as alterations in the composition of crops, forests,

Figure 4.6.23: Vermont's Sources of Greenhouse Gas Emissions, 1990-2012



Source: Vermont Agency of Natural Resources, http://anr.vermont.gov/sites/anr/files/specialtopics/climate/documents/emissions/Vermont%20GHG%20Emissions%20Inventory%20Update%201990-2012_June%20-2015.pdf.

and land cover. Climate change will also directly impact the availability and cost of ingredients for Vermont's food processors and manufacturers. Two reports from the U.S. Department of Agriculture (USDA) and a report from the U.S. Global Change Research Program indicate detrimental effects on most crops, livestock, and ecosystems that will vary somewhat by region:

- Rising temperatures and altered precipitation patterns will affect agricultural productivity. Crop sector impacts from weather are likely to be greatest in the Midwest, and these impacts will likely expand due to damage from crop pests.
- Livestock production systems are vulnerable to temperature stresses.
- Climate change will exacerbate current stresses from weeds, diseases, and insect pests on plants and animals; it will also alter pollinator life cycles, which will impact all types of crop and livestock production in Vermont.
- Ecosystem services (e.g., maintenance of soil and water quality, flood control) that food systems depend on will be damaged.
- Increased incidences of extreme weather events will impact food production around the world. Tropical Storm Irene—viewed as a harbinger of things to come—flooded 20,000 acres of farmland and impacted 463 Vermont producers when it struck in 2011.[32]

University of Vermont researchers note that an increase in average annual precipitation, including very heavy precipitation events, have increased in Vermont. Climate change projections for Vermont include increases in average annual precipitation, the length of the growing season, and the heat index, and a decrease in maple sap production.

The cost of energy impacts the cost of food and overall farm viability. Agricultural activities both contribute to and will be impacted by climate change.

Vermont's Comprehensive Energy Plan

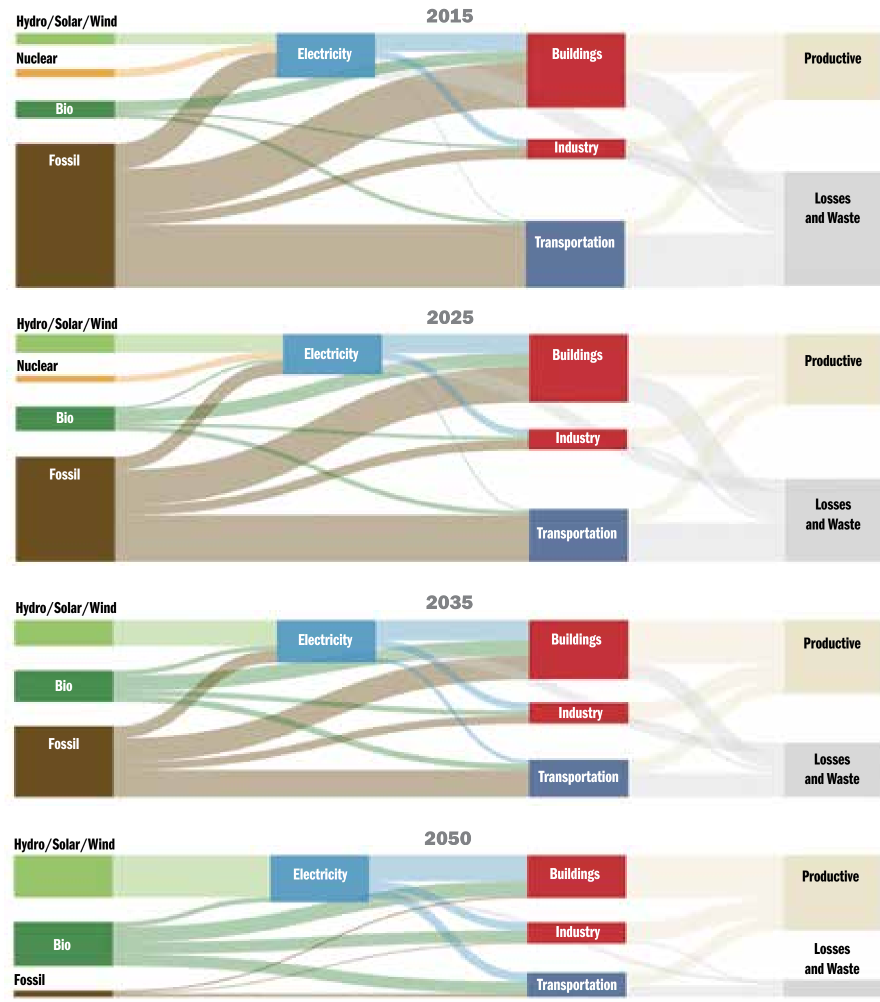
Vermont's 2011 Comprehensive Energy Plan **(CEP) and** *2016 update* **call for obtaining 90% of the state's energy from renewable sources by 2050 and reducing greenhouse gas emissions 50% from a 1990 baseline.** Vermont produces and consumes a comparatively small amount of power, and generates a small percentage of greenhouse gas emissions compared to the rest of the nation. Today, **Vermonters consume over 5 billion kilowatt-hours (i.e., 5 million megawatt-hours or 5,000 gigawatt-hours, Figure 4.6.7) of electricity and over 600 million gallons of petroleum for transportation and heating per year** (Figure 4.6.16). As a follow-up to the CEP, the Vermont PSD developed a "*Total Energy Study*" (TES) to identify the most promising technology and policy pathways to accomplish the plan. Through the CEP and the Total Energy Study, the PSD identified efficiency, solar, wind, hydro, biomass, and methane capture as the most likely technological solutions, noting that each technology has strengths and weaknesses. The TES suggests five policies that could achieve the goals of the CEP:

1. **Total Renewable Energy and Efficiency Standard:** This standard would require all providers of energy in Vermont to meet a fraction of their sales with renewable energy or energy efficiency. The required clean energy fraction would be the same for all fuels, and would rise over time. Obligations would be met by "retiring" tradable certificates corresponding to a certain amount of renewable energy or efficiency.

2. **Carbon Tax Shift:** DPS suggests creating an economy-wide carbon tax, a tax levied on the carbon content of fuels. In this option, other taxes would be cut by an amount equal to or close to the amount of revenue raised by the carbon tax. The idea is that a carbon tax sends a price signal that is much closer to the true costs of emissions (e.g., the impacts of air pollution and climate change).

3. **Renewable Targets with Carbon Revenue:** Under this policy, Vermont would set a target for the renewable energy content of all fuels, placing a non-binding obligation on energy suppliers. If the target is not met within a given sector the obligation would become mandatory within that sector

Figure 4.6.24: Vermont Energy Flows, 2015, 2025, 2035, and 2050



Source: Vermont Department of Public Service, *2016 Vermont Comprehensive Energy Plan*, http://publicservice.vermont.gov/publications-resources/publications/energy_plan/2015_plan.

The PSD created data visualizations (Figure 4.6.24) for the transformation of Vermont's energy system. Over the next 30 years, Vermont's energy system is anticipated to use less energy, waste less energy, and derive most of energy generation from renewable sources.

or that sector's carbon tax would be increased. This policy would be paired with the carbon tax shift noted above to raise revenue for programs that help obligated parties meet their target obligations.

4. **Sector-specific Policies:** Sector-specific policies would be tailored to address known challenges or market failures within a given portion of the state's energy economy.
5. **New England Regional Policy Focus**: Policies adopted at the regional level or coordinated with our neighboring states may be more effective than policies adopted by a single state. This reflects understanding that the six New England states are served by an electric grid with a single regional operator and markets, and that biomass is commonly used in a state different from the state in which it is harvested. There is also a potential that the combined market power of New England or Northeast states (and potentially including neighboring Canadian provinces) can move markets and bring new technologies to scale in a way that no single state can do.[33]

A 2013 report summarizing policy options for achieving the Total Energy Study, *Policy Options for Achieving Vermont's Renewable Energy and Carbon Targets*, suggests that "the existing building stock will probably require new heating technologies and energy sources, and Vermont may need a significant electrification of the light duty vehicle fleet, coupled with a virtually complete shift from fossil fuel to biofuels for the remaining light vehicles using internal combustion engines."[34]

Several policies and recommendations have been enacted since 2011. Policy 1 of the Total Energy Study, a renewable portfolio standard, was enacted during the 2015 Vermont legislative session. *H.40 (Act 56)—Renewable Energy Standard and Energy Transformation (RESET)*—requires utilities to purchase 55% of electricity or renewable energy credits from renewable sources by 2017 and 75% by 2032. **Vermont now requires the second highest renewable portfolio standard target (75%) after Hawaii (100%) in the U.S.**[35] RESET requires utilities to purchase a small but increasing percentage of renewable electricity from distributed energy sources, including net metered sources; establishes a system of tradable renewable energy credits; delineates solar setbacks and screening requirements and called for the creation of a *solar siting task force*. **The PSD estimates that more than 400 MW of renewable energy projects will come online in Vermont to meet RESET.**[36]

Additionally, *Energy Independent Vermont*—a coalition of environmental organizations, town energy committees, businesses, and other associations—encouraged the state to adopt a carbon pollution tax (Policy 2 of the Total Energy Study) in 2015 but no legislative action was taken. Revisions to the *Residential Building Energy Standard* took effect in 2015 and include additional "stretch code" requirements such as electric vehicle charging stations for multifamily developments of 10 or more dwellings. Finally, *RPCs* are increasingly working with the PSD to develop energy plans for municipalities and regions.

When the PSD analyzes *sector-specific policies* (TES Policy 4) they are referring to the electricity, heat, and transportation sectors rather than broader economic sectors and industry sub-groups. But there is also a strong case to be made for focusing on the barriers and opportunities to energy efficiency and renewable energy *within* specific industries or systems (e.g., forest products, computer and electronic product manufacturing, food systems). For example, competing values and priorities might pit energy production and food production against each other in some areas of the state. In other cases, energy projects might move forward at a faster pace if developers and advocates had a clearer sense of the needs and desires of food system businesses.

The size of Vermont's food system (e.g., land in agriculture is equal to a little more than 20% of Vermont's land area) and the scale of energy system development necessary to meet RESET and the CEP means that both systems will invariably intersect: from the siting of large solar and wind projects on agricultural land, to agricultural and woodland crops, animal waste, and food scraps that are used as feedstocks for electricity, heat, and liquid fuel. Of course, Vermont's food system consists of more than agricultural activities— large roofs at grocery stores and manufacturing facilities can support solar installations, several thousand buildings can be more energy efficient, and many dozens of delivery vehicles can be more fuel efficient. **The intersection of energy systems and food systems is truly fertile ground for developing sustainable solutions to pressing problems.**

Food System Energy Market Development Needs

Consumers, governments, businesses, nonprofits, educational institutions, and farmers, continuously make and reshape markets for goods and services. For many years now, a wide variety of technical assistance providers, renewable energy businesses, financing sources, and policy-makers have helped farmers and other food system businesses install renewable energy systems and become more energy efficient. For example, in 2007 the *Vermont Environmental Consortium* developed a "Farm Energy Handbook" that covered such topics as biodiesel production and wind power and distributed it to 1,200 farmers. The *Rural Energy Council*, convened by the *Vermont Council on Rural Development* from 2006 to 2007, identified 18 key recommendations for advancing renewable energy production and efficiency, including on-farm energy recommendations. *Efficiency Vermont* has worked with most of the state's dairy farms to install energy-saving devices and offers an agricultural equipment rebate program for lighting, plate coolers for dairies, and other types of equipment. The *Clean Energy Development Fund*, *Vermont Agency of Agriculture, Food and Markets*, VEDA's *Vermont Agricultural Credit Corporation*, *USDA Rural Development*, *USDA Natural Resource Conservation Service*, and Vermont's biggest utility, *Green Mountain Power*, have provided funding for the development of anaerobic digesters and other renewable energy projects.

This Farm to Plate analysis of the intersection of renewable energy systems and local food systems focuses on ten market development needs that are important for the success of individual energy efficiency, renewable energy, and food system businesses and other organizations, and also for the development of Vermont's food and energy systems. These market development needs focus attention on outstanding or emerging questions that can be addressed by the collective efforts of the Farm to Plate Network and the wider network of energy efficiency and renewable energy organizations. As a practical matter, not all of these market development needs have to be addressed at the same time, in a particular sequence, or at all. For example, *Vermont Tech* offers a variety of *renewable energy*, agricultural, engineering, and automotive degrees and we might consider the education needs of energy and food systems to have been met.

Market Development Needs

- **Research** *(e.g., identifying outstanding research questions)*
- **Natural Resource, Physical Infrastructure, and Technology** *(e.g., addressing energy siting and land access issues; sharing knowledge of emerging technologies)*
- **Sales and Distribution** *(e.g., connecting energy efficiency and renewable energy companies with food system businesses)*
- **Marketing and Public Outreach** *(e.g., building food system business awareness of energy efficiency and renewable energy options)*
- **Technical Assistance and Business Planning** *(e.g., connecting food system businesses with energy efficiency and renewable energy technical assistance providers)*
- **Financing** *(e.g., connecting food system businesses with energy efficiency and renewable energy financing providers)*
- **Network Development** *(e.g., connecting the Farm to Plate Network with energy efficiency and renewable energy networks)*
- **Education** *(e.g., identifying energy efficiency and renewable energy educational programs for food system businesses)*
- **Workforce Development** *(e.g., identifying energy efficiency and renewable energy labor needs at food system businesses)*
- **Regulation and Public Policy** *(e.g., understanding regulations or policies that impact energy efficiency, renewable energy, and food system businesses)*

ENERGY EFFICIENCY MARKET DEVELOPMENT NEEDS

With *Efficiency Vermont*, nearly 12,000 food system businesses have access to the preeminent energy efficiency technical support and financing organization in the country. Since this is the case, **energy efficiency technology, technical assistance, and financing market development needs are fairly well addressed in Vermont.** One opportunity is for the Energy Cross-Cutting Team and Farm to Plate Network to encourage more food system businesses to take advantage of these resources.

Research

One of the outstanding food system energy efficiency research needs is a lack of benchmarks or common understandings of what makes a particular food system business type energy efficient. We also have very little information on thermal and transportation efficiency in Vermont's food system. Efficiency Vermont should investigate the possibility of creating and sharing an inventory/database of food system businesses it has worked with so that food system and energy system technical assistance providers can understand 1) where action has already taken place and 2) what efficiency looks like at specific businesses. For example:

- How much energy does an "efficient" maple producer use per gallon of syrup produced?
- How much energy does an "efficient" dairy farmer use per hundredweight of milk produced?
- How much energy is used by an "efficient" greenhouse per square foot of growing space?
- How much energy is used by an "efficient" meat processor per square foot of refrigerated space?

Efficiency Vermont and other food system energy service providers should also consider how to codify thermal and transportation efficiency issues, opportunities, and best practices.

Natural Resource, Physical Infrastructure, and Technology

Many types of energy saving technologies and applicable rebates for food producers, manufacturers, stores, and restaurants are identified on the Efficiency Vermont website.

TECHNOLOGY FOR FARMS

Fans: Proper ventilation from energy efficient fans can improve air quality for people and animals in barns and greenhouses.

www.efficiencyvermont.com/rebates/list/ventilation-fans-agriculture

LED Lighting: Energy efficient vapor-proof lighting provides better light distribution.

www.efficiencyvermont.com/rebates/list?cat=Lighting&type=

Reverse Osmosis Systems: Can remove 75% or more of the water content from maple sap, cutting boiling time by 50–75% and reducing fuel consumption by up to 66%.

www.efficiencyvermont.com/rebates/list/maple-reverse-osmosis-systems

Maple Sap Vacuum Pumps Variable Frequency Drive Controllers: Allows the pump to run at different speeds depending on actual need. When not running at full capacity, less electricity is used.

www.efficiencyvermont.com/rebates/list/variable-frequency-drives-maple-sap-vacuum-pumps

Heat Recovery Units: for dairy farms. Uses waste heat from milk bulk tank compressor to preheat water so that the hot water heater doesn't have to work as hard. Can reduce expenses by up to 50%.

www.efficiencyvermont.com/rebates/list/heat-recovery-units-agriculture

Variable Speed Milk Transfer Systems: Regulates the flow of milk through plate coolers.

www.efficiencyvermont.com/rebates/list/variable-speed-milk-transfer-systems

Plate Coolers: Plate coolers are heat exchangers that use water to precool milk, reducing the energy required by the refrigeration system to cool the milk in the bulk tank. Can save up to 50% on milk cooling costs.

www.efficiencyvermont.com/rebates/list/plate-coolers-agriculture

Milk Vacuum Pump Variable Frequency Drive Controllers: Allows the pump to run at different speeds depending on actual need. When not running at full capacity, less electricity is used.

www.efficiencyvermont.com/rebates/list/variable-frequency-drives-milk-vacuum-pumps

» ***AFTER REVIEWING YOUR OPTIONS, DOWNLOAD THE EFFICIENCY VERMONT REBATE FORM:***

www.efficiencyvermont.com/docs/for_my_business/rebate_forms/AgricultureRebateForm.pdf

The EcoVap electric evaporator, an all-electric evaporator that eliminates the need for heating fuel or cord wood fuel, may become a cost-effective alternative with certain fuel cost scenarios (e.g., high fossil fuel prices and low electricity prices). Two installations are currently operating in Vermont.

TECHNOLOGY FOR MANUFACTURERS

Motors, Drives, and Pumps: Variable frequency drives adjust the amount of electricity used to power motor speeds.

www.efficiencyvermont.com/products-technologies/industrial-special-equipment/pumps-motors-drives

Compressed Air: Air compressors can account for 10% of electricity use. Efficiency Vermont provides rebates to businesses installing new, energy efficient compressed air equipment.

www.efficiencyvermont.com/products-technologies/industrial-special-equipment/compressed-air-systems

Lighting Equipment, Controls, and Design: Outdoor and indoor lighting can account for about 10% of facility electricity use. Efficiency Vermont provides rebates to businesses installing energy efficient lighting and controls.

www.efficiencyvermont.com/products-technologies/lighting/lighting-controls-sensors

Heating, Ventilation, and Air Conditioning: HVAC costs make up a large part of operating expenses for Vermont businesses. Efficiency Vermont provides rebates to businesses installing energy efficient HVAC equipment.

www.efficiencyvermont.com/products-technologies/heating-cooling-ventilation

Refrigeration and Controls: Refrigeration can account for nearly 50% of energy costs at food processing facilities. Efficiency Vermont provides rebates to businesses installing energy efficient compressors, evaporator fan motor controls and other equipment.

www.efficiencyvermont.com/products-technologies/refrigeration-commercial-kitchens/commercial-refrigeration

Commercial New Construction: Efficiency Vermont offers technical support and financial incentives for all types of commercial projects.

www.efficiencyvermont.com/services/renovation-construction/commercial-new-construction

Insulation and Air Sealing: Some small businesses are eligible for an Efficiency Vermont rebate to work with a Building Performance Institute certified contractor to perform energy audits and building improvements.

www.efficiencyvermont.com/products-technologies/insulation-windows-doors

TECHNOLOGY FOR RETAIL STORES

Lighting Equipment, Controls, and Design: Outdoor and indoor lighting can account for about 10% of facility electricity use. Efficiency Vermont provides rebates to businesses installing energy efficient lighting and controls.

www.efficiencyvermont.com/products-technologies/lighting/lighting-controls-sensors

Heating, Ventilation, and Air Conditioning: HVAC costs make up a large part of operating expenses for Vermont businesses. Efficiency Vermont provides rebates to businesses installing energy efficient HVAC equipment.

www.efficiencyvermont.com/products-technologies/heating-cooling-ventilation

Refrigeration and Controls: Refrigeration accounts for a considerable amount of energy costs at grocery stores. Efficiency Vermont provides rebates to businesses installing energy efficient compressors, evaporator fan motor controls and other equipment.

www.efficiencyvermont.com/products-technologies/refrigeration-commercial-kitchens/commercial-refrigeration

New Construction and Major Renovation: Efficiency Vermont offers technical support and financial incentives for all types of commercial projects.

www.efficiencyvermont.com/services/renovation-construction/commercial-new-construction

Insulation and Air Sealing: Some small businesses are eligible for an Efficiency Vermont rebate to work with a Building Performance Institute certified contractor to perform energy audits and building improvements.

www.efficiencyvermont.com/products-technologies/insulation-windows-doors

TECHNOLOGY FOR RESTAURANTS

Commercial Kitchens: Food preparation can account for 35% of restaurant energy costs. Efficiency Vermont offers rebates for fryers, griddles, convection ovens, and steam cookers.

www.efficiencyvermont.com/products-technologies/refrigeration-commercial-kitchens/commercial-cooking-equipment

Refrigeration & Controls: Save money by retrofitting existing walk-in coolers and freezers with efficient fan motors, economizers that use “free” outdoor air for cooling, and more. ENERGY STAR qualified ice machines are on average 15% more energy efficient than standard machines.

www.efficiencyvermont.com/products-technologies/refrigeration-commercial-kitchens/commercial-refrigeration

Lighting Equipment, Controls & Design: Efficient lighting also gives off less heat, reducing the need for air conditioning. Occupancy sensors save money by turning off lighting in occasionally used spaces like rest rooms, storage areas, and walk-in coolers.

www.efficiencyvermont.com/products-technologies/lighting/lighting-controls-sensors

Heating, Ventilation & Air Conditioning (HVAC): Energy-efficient and optimized HVAC equipment and controls can reap significant long-term cost savings, increase equipment reliability, and create a more comfortable restaurant.

www.efficiencyvermont.com/products-technologies/heating-cooling-ventilation

New Construction & Major Renovation: Efficiency Vermont offers financial and technical assistance to help businesses increase the comfort of building occupants and optimize the efficiency of both large and small new construction and major renovation projects.

www.efficiencyvermont.com/services/renovation-construction/commercial-new-construction

Energy Star is a voluntary program that helps businesses and individuals save energy through third-party certified Energy Star products. Energy Star has compiled many resources for saving energy at *manufacturing facilities*, *grocery stores*, and *restaurants*.

Technical Assistance and Business Planning

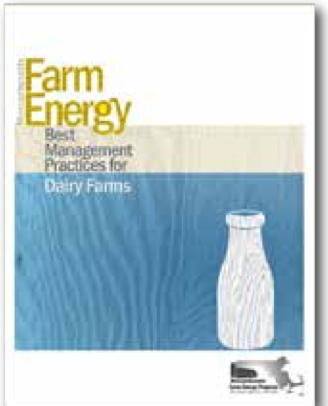
Although Efficiency Vermont is a fairly prominent organization, we don't know how aware food system businesses are of the services offered by Efficiency Vermont or of financing resources for efficiency projects offered by service providers like *Vermont Economic Development Authority*, *USDA Rural Development*, or *USDA Natural Resources Conservation Service*. Nor do we have a sense of how best to integrate energy considerations into other enterprise planning discussions (e.g., farm transfer, farm viability planning, business expansion, diversification, and so on). Food system energy service providers should work with other food system technical assistance providers, including the *Production and Processing Working Group* and *Financing Cross-Cutting Team* to ensure that energy issues are more "top of mind" or at least a part of these considerations. To ensure that food system businesses and technical assistance providers have up-to-date and convenient access to energy efficiency and renewable energy information, the Energy Cross-Cutting Team could develop resource sheets and an online database of financing and technical assistance resources.

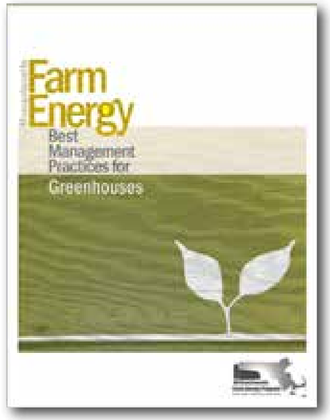
Many energy efficiency technical assistance resources for food system businesses are available online.

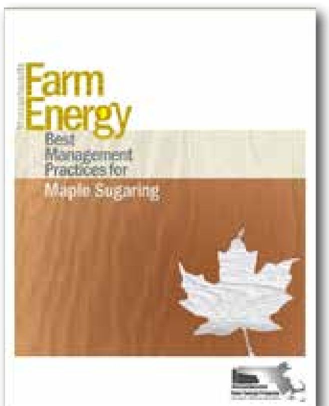
eXtension **is a clearinghouse of learning resources— including videos and photos— generated by the land-grant university system, including** ***efficiency resources*****.**

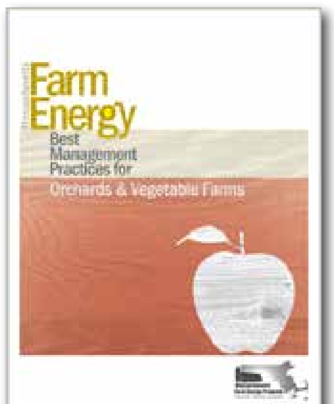
The ***National Sustainable Agriculture Information Service*****—ATTRA—provides many helpful energy efficiency reports for free or a small fee.**

The Berkshire-Pioneer Resource Conservation and Development Area developed a series of Farm Energy Best Management Practices that cover energy efficiency considerations for dairy farms, greenhouses, maple sugaring, orchards, and vegetable farms.









Click on Tiles for additional information.

The Food Service Technology Center provides education and resources for achieving substantial energy savings at commercial food service businesses.

Food Service Technology Center PG&E

Financing

In addition to rebates offered through Efficiency Vermont, many additional energy efficiency financing resources are available in Vermont.

ORGANIZATION: PROGRAM	PURPOSE OR USE OF FUNDS
NRCS Natural Resources Conservation Service	The NRCS EQIP On-Farm Energy Initiative provides energy audits and financial assistance for qualifying farms.
USDA Rural Development Committed to the future of rural communities.	USDA Rural Development offers guaranteed loan financing and grant funding for energy efficiency improvements.
VEDA Vermont Economic Development Authority	VEDA's Agricultural Energy Loan Program offers loans up to $1,355,000 for energy efficiency improvements.

VEDA — Vermont Economic Development Authority	VEDA's commercial financing programs offer a variety of loans for business energy efficiency improvements.
Yankee Farm Credit — Building Relationships That Last Generations	Yankee Farm Credit offers loans for machinery, equipment, and improvements.
FOOD, FARMS & FORESTS	The Vermont Community Loan Fund's Food, Farms & Forests Fund offers loans for facility construction or improvement and equipment.

Marketing and Public Outreach

The Energy Cross-Cutting Team developed a series of *Farm to Plate Energy Success Stories* to showcase farms, businesses, vendors, installers, and technical assistance providers that have made a difference with energy efficiency savings and renewable energy production. Two success stories focused on energy efficiency on a dairy farm (Brace Farm, page 35) and at a dairy processor (Commonwealth Dairy, page 37).

Efficiency Vermont also developed a series of customer stories that feature food system businesses on their website:

Efficiency Vermont worked with Northshire Brewery (Bennington) to save $12,000 and 54,000 kWh annually.

Efficiency Vermont worked with King Arthur Flour (Norwich) to save $27,000 and 114,000 kWh annually.

Efficiency Vermont worked with The Woodstock Inn & Resort (Woodstock) to save over $15,000 annually.

Efficiency Vermont worked with Sterling Market (Johnson) to save $12,000 and over 85,000 kWh annually.

Efficiency on a Dairy Farm

Brace Farm Inc.

Ferrisburgh, VT

Highlights: $7,600 in first year savings ▪ $94,000 in lifetime savings ▪ 58,300 kWh in annual electricity savings ▪ Close relationship with the equipment vendor and Efficiency Vermont led to major cost savings and business improvements

Brace Farm Inc. is a small dairy that has been owned and operated by the Brace family since 1984. The current owners, Alex and Michelle Brace, took over operations from Alex's father in 2006. Brace Farm consists of two main buildings, including a tie stall barn where the cows are milked and a separate free stall barn that houses the dry cows. Twice per day, 140 head of Holsteins are milked, and over four million pounds of milk per year are shipped via the St. Albans Cooperative Creamery.

Collecting, cooling, and shipping this volume of milk is an energy-intensive process, and keeping the barns lit and properly-ventilated also adds to the energy requirements of the farm. However, **Alex Brace has taken significant steps to manage his energy use and to use energy more efficiently, all while maintaining milk production and preserving the longevity of his equipment.**

Plate Cooler Saves Energy by Precooling Milk

One of the first energy efficiency projects that Alex implemented was the installation of a plate cooler, which is a heat exchanger that uses water to precool milk, reducing the energy required by the refrigeration system to cool the milk in the bulk tank. This project, as with many others involving his milking equipment, was a collaborative effort between Alex and his equipment vendor, Todd Reed of Reed's Equipment (Vergennes). Todd helped size the plate cooler properly and worked with Efficiency Vermont, which helped cover a portion of the equipment costs. By installing this plate cooler, the Brace Farm is now saving 13,811 kWh annually, which amounts to approximately $1,750 per year.

Alex and his son Dustin in the barn.

Project Summary

	Annual kWh Savings	Customer Savings in First Year	Customer Savings Over Life of Project
2010			
Plate Cooler	13,811	$1,747	$18,663
2011			
Ventilation	4,339	$550	$5,502
Vapor Proof Lights	26,246	$3,482	$52,223
2012			
Milk Pump Variable Frequency Drive	7,658	$1,008	$10,078
Heat Recovery Unit	6,287	$827	$8,273
GRAND TOTAL	**58,341**	**$7,614**	**$94,739**

Heat Recovery Unit Saves Energy by Capturing Waste Heat

Every dairy farmer knows that proper sanitation and high milk quality go hand-in-hand. In order to ensure that his milking equipment is sanitized properly, Alex has to have a constant supply of hot water. To reduce the energy required to heat his 120 gallon hot water tank, Alex purchased a new heat recovery unit. This unit captures the waste heat from his bulk tank compressor to pre-heat the water so that the hot water heater doesn't have to work as hard. Alex replaced his old tank (which had sprung a leak), and Efficiency Vermont helped subsidize the cost with a $1,000 rebate on the cost of the equipment. "This equipment is a no-brainer," says Alex, "and it's very cost-effective."

Energy Efficient Exhaust Fan Improves Ventilation

To ensure his cows were comfortable and the air in the barn was being exchanged properly, Alex determined that one section of his barn needed to exhaust more air. He purchased an energy efficient exhaust fan for the tie stall barn, and Efficiency Vermont was able to provide some financial assistance to purchase a more efficient fan model. With his barn properly ventilated, his herd is exposed to less heat stress, which keeps his milk production more stable through the summer months.

Alex explaining how the variable frequency holds the vacuum level on his milk pump.

Variable Frequency Drive Decreases Electricity Use

More recently, Reed's Equipment helped install a variable frequency drive (VFD) on the milk pump at Brace Farm, which allows the pump to run at different speeds depending on actual need. When not running at full capacity, less electricity is used. Efficiency Vermont helped subsidize the cost of this installation, as well. This new VFD holds the vacuum level better, which allows for milking times to be faster—and is better for the cows, too.

New vapor-proof lighting in the dry cow barn.

Photo credits: Gregory Nesbit Photography

Durable Vapor-Proof Lighting Provides Even Light Distribution

Alex also took advantage of the rebates that Efficiency Vermont offers for agricultural lighting. He installed energy efficient vapor-proof lighting that was both more efficient than his old lighting and provided better light distribution. "The light output is great," says Alex. He also changed out the older, less-efficient lighting in his shop.

Looking to the Future

Alex and Reed's Equipment are discussing the installation of a variable speed milk transfer unit, which will slow the flow of milk through the plate cooler in order to maximize the heat exchange and will further reduce the burden on the compressors cooling the bulk tank.

Efficiency at a Dairy Processor

Commonwealth Dairy

Brattleboro, VT ▪ www.commonwealthdairy.com

Highlights: $150,000 in first year savings ▪ $2.1 million in lifetime savings ▪ 1.5 million in annual kWh savings ▪ Refrigeration system, compressed air system, motors, lighting, heating, and ventilation optimized

When German Company Ehrman AG partnered with *Commonwealth Yogurt, LLC* to expand to New England, they were impressed by Vermont's approach to energy efficiency. That, coupled with a wealth of dairy farms and yogurt enthusiasts, was enough to convince them to break ground in Brattleboro in 2009. Today, the Ehrmann Commonwealth Dairy team sells yogurt under the local brand name *Green Mountain Creamery* and they also make private label yogurt products for retailers throughout the region and beyond. **A major overhead expense is energy, including propane and electricity. Maintaining an energy efficient facility is imperative for any manufacturer and has become even more important in the increasingly competitive yogurt market.**

Laying the Groundwork Early for Maximum Energy Savings

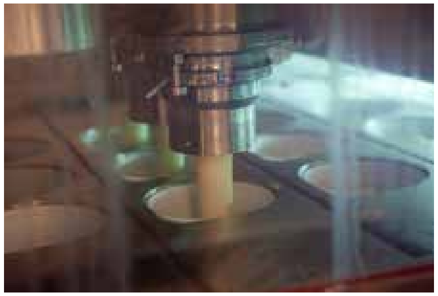
By consulting with *Efficiency Vermont* from the beginning, Commonwealth was able to make strategic choices that continue to benefit them today—and they haven't stopped there. Though their facility is widely considered to be state of the art due to their extensive control systems and the latest in processing equipment, Commonwealth continues their pursuit of efficiency.

One notable improvement was catalyzed by working with their Efficiency Vermont account manager to assess and adjust their compressed air system, which yielded an annual savings of $22,300. Commonwealth was in need of a backup compressed air system, and after an analysis, recognized that their existing compressed air system was oversized. They purchased a smaller compressed air system for their daily operation and were able to use the existing larger system as the backup. Commonwealth uses compressed air for many parts of their process

Commonwealth employees in front of the milk storage silo.

Project Summary

	Annual kWh Savings	Customer Savings in First Year	Customer Savings Over Life of Project
2011			
New Construction *(HVAC, lighting, motors, occupancy sensor, variable frequency drive)*	1,203,328	$116,649	$1,684,489
2012			
Compressed Air System	232,332	$22,296	$285,325
2013			
Facility Expansion *(HVAC economizer, lighting, occupancy sensor, variable frequency drive motor control)*	7,658	$1,008	$10,078
GRAND TOTAL	**1,525,181**	**$150,698**	**$2,112,033**



Filling Greek yogurt containers.

such as their pneumatic valve clusters—these move product from one point in the process to another—and they pressurize all of their tanks with clean, filtered air in order to keep the product as fresh as possible.

Another notable component of Commonwealth's efficiency projects was the inclusion of a water-cooled chiller system with variable speeds. This more efficient refrigeration system allowed Commonwealth to meet the requirements of their processes all while using less energy. Other energy efficiency efforts that were undertaken include efficient motors, lighting, heating, and ventilation. **Regardless of the size of the operation, employing energy efficiency strategies at a dairy processing facility is most effective when implementing energy saving techniques across various levels of production.**

From Overhead to Investment—Putting Energy to Work, Wisely

These ongoing efficiency measures have opened up significant cash flow for Commonwealth, enabling them to expand their operations, distribute more yogurt, and hire more people. Commonwealth is also collaborating with other businesses to ship whey byproducts as biofuel. The byproducts are being used as animal feed for a nearby farmer and in a local biodigester. This effort not only decreases the pressure on the local wastewater treatment facility but it also helps reduce the waste stream and increases the sustainability of their business operations.

> *"Balancing energy efficiency and capital expenditures is a challenge, which is why the Efficiency Vermont team is such a valuable resource. Efficiency Vermont understands that businesses must realize a payback on their capital investments and they do a great job of laying out the data and presenting the payback realistically."*
>
> —Ben Johnson, CFO, Commonwealth Dairy

Commonwealth's Clean In Place (CIP) process.

Photo credits: Gregory Nesbit Photography

Energy can be a significant portion of operating costs for dairy processors and using this energy more efficiently can have a great impact on a processor's bottom line. "Financially speaking, managing our energy and reducing our usage is hugely important to the success of our company. Energy is one of the top, if not the top, overhead cost that we're faced with," says Commonwealth Dairy's CFO, Ben Johnson. "I know when I am starting any new project in the facility, trying to engage the Efficiency Vermont team to get a good review of what we're trying to do is part of the project kick off. This allows us to get good suggestions on something we could actually act on, if appropriate."

SOLAR ENERGY MARKET DEVELOPMENT NEEDS

A *federal tax credit*, cheaper solar panels, and Vermont's net metering law and *SPEED program* have facilitated substantial growth in the number of large solar photovoltaic installations—and solar PV sector jobs—throughout Vermont. *H.40 (Act 56) - RESET*, Vermont's renewable energy law, calls for utilities to own renewable generation (or renewable energy credits) equal to 10% of electricity sales by 2032. If, for example, Vermont utilities met this requirement solely through distributed generation solar PV (which the law defines as 5 MW or less), then the PSD estimates that 400-500 MW would need to come online by 2032. With an estimate of 8 acres per MW of solar PV, this would mean more than 3,300 acres devoted to solar electricity generation. On the longer time horizon of Vermont's Comprehensive Energy Plan, the PSD estimates that solar PV installations could range from 1,500 to 2,250 MW by 2050 and require 8,000 to 13,000 acres.[37]

In conjunction with the growth in solar PV development, many municipalities and Vermonters have expressed concern about the rapid development of larger solar PV installations. Concerns have been raised about aesthetic issues, property values, development on agricultural and other land and a perceived lack of sensitivity on the part of the Public Service Board during the *Act 248* process that issues "certificates of public good" for energy generation projects. A *Solar Siting Task Force* met 10 times from July 2015 to January 2016 and developed a set of recommendations for the Vermont Legislature to consider.

Given A) the rapid growth of solar development; B) mounting resistance to solar development; C) the possibility that large-scale solar projects might pit energy production and food production against each other in some areas of the state; and D) multiple stakeholder-driven processes that have developed siting recommendations, the biggest market development need for solar energy projects located at food system businesses in Vermont may be network development to build trust and mutual understanding.

Natural Resource, Physical Infrastructure, and Technology

Germany, which lies at a more northern latitude than Vermont, leads the world in solar PV installations. And it is clear that Vermont has the sunshine to develop solar electricity projects: with well over 5,000 solar PV installations, it is the most common type of renewable energy generation in the state.

Vermonters can find estimates of solar energy generation for their property using the *National Renewable Energy Laboratories PVWattts Calculator*. The *Energy Action Network's Community Energy Dashboard* provides Vermont specific information on installed renewable energy sites by town, county, and regional planning commission boundaries. Community Energy Dashboard users can also turn on additional map layers (e.g., deer habitat) to facilitate conversations around siting.

Food system businesses can use PVWatts to estimate solar PV energy generation based on their location.

Food system businesses can use the Community Energy Dashboard to analyze existing and potential renewable energy locations.

Roof and ground-mounted solar PV installations have taken place at all types of food system organizations in Vermont (Table 4.6.4). The choice between roof and ground-mounted systems is context specific.

For example, at *Ayers Brook Goat Dairy* the quality of the bottomland, a conservation easement, and a new 14,000 square-foot, south-facing barn roof all pointed to a roof-mounted solar array. A barn roof is perfect for solar PV if there is enough space, a south-facing orientation, and a strong enough structure. *Aegis Renewable Energy* worked with structural engineers to analyze the roof structure and develop a simple modification to the trusses to bring the roof into code compliance for the added load of the array. To mount the solar panels, Aegis designed a roof-mounted metal frame to span the 12-foot distance between each rafter. To account for the additional roof load of five pounds per square foot, the barn designer, with the builder reinforced a small section of truss near the peak of the roof.

Ground-mounted systems are increasingly common and are generally of two types: trackers or fixed racks. Trackers (e.g., *AllSun Trackers*) are poles that support a set of panels and a mechanism that continually moves the panels to point directly at the sun during the course of a day. Trackers generate more electricity, especially later in the day, but generally require more land, have a higher maintenance expense, and may cost more. Farmers should weigh cost, conversion efficiency, land access, geographical factors (e.g., soil type), and other concerns when making a decision. Fixed racks consist of steel posts which are typically driven into the ground, forming fixed rows of panels angled at 30 degrees and generally facing due south. To date, all SPEED projects except the South Burlington Solar Farm are fixed rack systems, but hundreds of net metered trackers are also generating electricity across Vermont.

Table 4.6.4: Solar Installations by Food System Category

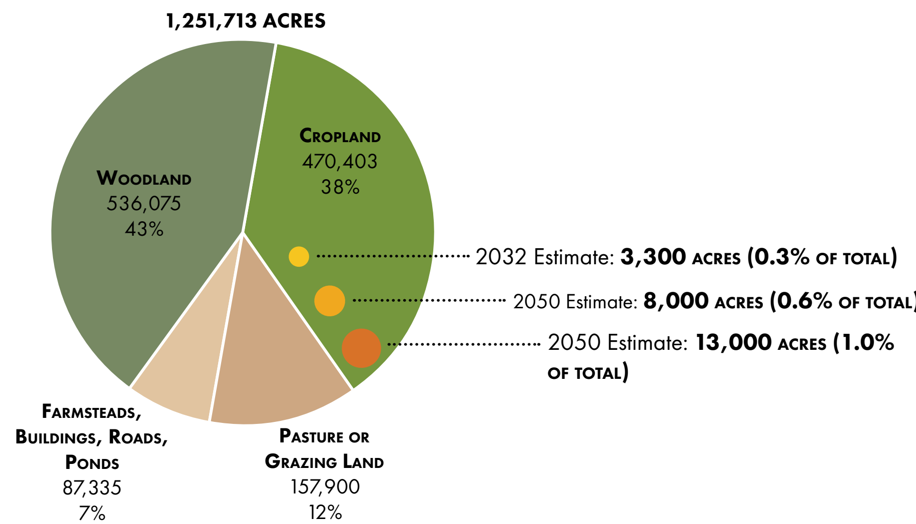
Organization Type	# of Sites	Solar Type	Installed capacity (kW)	% of Total kW
FARM	44	Roof	792.9	5.7%
	46	Ground	7,926.4	56.9%
PROCESSING	3	Roof	266.8	1.9%
	4	Ground	590.7	4.2%
DISTRIBUTOR	1	Roof and ground	382.8	2.7%
RETAIL	12	Roof	323.9	2.3%
	2	Ground	208.4	1.5%
NUTRIENT MANAGEMENT	1	Ground	2,200	15.8%
FOOD SHELF	1	Roof	14.3	0.1%
EDUCATIONAL INSTITUTION	8	Roof	69.2	0.5%
	7	Ground	516.7	3.7%
SUPPORT ORGANIZATION	6	Roof	217.1	1.5%
	1	Ground	399.4	2.9%
TOTAL	**136**		**13,908.5**	**100%**

Source: Farm to Plate analysis.

Much of the concern about the rapid pace of solar development in Vermont reflects the larger size and visibility of more than 30 ground-mounted systems larger than 1 MW (sometimes called solar farms). **Larger solar PV systems are evident across Vermont's food system businesses. Forty-six ground-mounted systems on farms and 1 large system at Coventry Landfill accounted for 35% of installations but 73% of installed capacity (Table 4.6.4).**

Land in agriculture is equal to 20% of Vermont's total area (1,251,713 acres out of 6,158,720 acres). Woodland makes up the largest percentage (43%) of land in agriculture, followed by cropland (38%), pasture or grazing land (12%) and farm infrastructure (7%). Dairy farms operate about 60% of the total cropland in Vermont. Figure 4.6.25 allocates 2032 (i.e., 3,300 acres) and 2050 solar acreage estimates (8,000 to 13,000 acres). **The three estimates are equal to 0.3%, 0.6%, and 1.0% of land in agriculture in Vermont in 2012.**

Figure 4.6.25: Land in Agriculture in Vermont (2012), with Solar Estimates



Source: Vermont Farm to Plate, www.vtfarmtoplate.com/getting-to-2020/5-land-in-agriculture#population-indicator-2

Producing Food and Energy

Whether using trackers or fixed racks, it is possible to use the area around the panels for farming if you plan ahead. For cropping or hay, consider the spacing and height necessary to run your planting and harvesting equipment. For pasture, consider the strength of the poles when livestock might rub against them, and consider the necessary height to avoid damage from grazing sheep, cows, horses, or other livestock.

Siting

In 2013, an *Energy Generation Siting Policy Commission* released a report providing guidance and recommendations on best practices for the siting approval of electric generation projects larger than the net metering threshold. The Commission identified five broad recommendations:

1. **Regional Planning:** Increase emphasis on planning at state, regional, and municipal levels, such that siting decisions will be consistent with Regional Planning Commission (RPC) plans.
2. **Tiered Siting:** Adopt a simplified tiered approach to siting to achieve a quicker, more efficient review of a greater number of small or less-controversial projects while focusing the bulk of Public Service Board time and effort on the evaluation of larger or more complex projects.
3. **Public Participation:** Increase the opportunities for public participation at municipal and regional levels.
4. **Predictability:** Implement procedural changes to increase transparency, efficiency, and predictability in the siting process.
5. **Environmental and Health Guidelines:** Update environmental and health protection guidelines for energy generation technologies and make easily available.[38]

In 2014, the *Vermont Housing and Conservation Board*—which administers conservation easements for farm and forestland—published a set of *Interim Guidelines for Renewable Energy Production on Conserved Lands*. The guidelines establish a set of general criteria to be applied to renewable energy development on conserved land (e.g., "Preference is given to locating these facilities on less productive portions of working lands (but not in sensitive natural areas or wetlands)" as well as specific criteria for solar development:

1. Installations should not require permanent concrete or paved areas, but should use posts inserted into the ground without concrete or set on top of the surface with floating ballasts to avoid long-term impact to soils.
2. Installations that allow certain agricultural practices to occur within and underneath the solar arrays (such as animal grazing, bee yards, or growing crops) are encouraged.
3. Solar projects should be designed to minimize impacts on scenic resources including open spaces, distant views, distinct natural features, and cultural resources (e.g. historic structures) by using natural screening, setting installations back from the roadside or other vantage points when not near existing structures, and placing them on less scenically important lands.
4. Solar arrays should be sited close to existing structures or with a backdrop of vegetation if possible.
5. Any associated project infrastructure (e.g. inverter and monitoring equipment) should be located and organized to be as unobtrusive as possible.
6. Roof-mounted panels should recognize and reflect the architectural lines and features of historic structures.

In 2015, the *Solar Siting Task Force* released its *final report* of recommendations for the Vermont Legislature. The report outlines recommendations for planning, incentives, the regulatory process, and aesthetics/environment that:

- strengthen the capacity of regional planning commissions and municipal planning commissions to plan for solar facilities;
- incentize development in preferred areas;
- create pathways for mediation of concerns, including giving the Vermont Agency of Agriculture, Food and Markets "party status" during the *Section 248* process for ground-mounted solar installations that would impact agricultural soils;

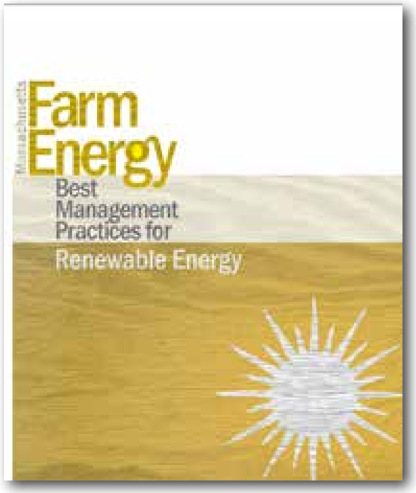
- develop solar siting best practices that address aesthetic issues, including identifying all visible structures for installations bigger than 50 kW.

Network Development

At the heart of our food system is a desire to trust the people, places, practices, and products that nourish us. In its first five years, the Farm to Plate Network has worked to build and strengthen relationships across the state. In order to meet the requirements of Vermont's renewable energy law, mitigate tension between solar energy proponents and stakeholder concerns, and move the consensus based recommendations of the Solar Siting Task Force forward, the Farm to Plate Network should work with renewable energy networks—such as Renewable Energy Vermont and the Energy Action Network—regional planning commissions, state agencies, and municipal governments to find common ground for solar development at food system businesses.

eXtension is a clearinghouse of learning resources— including videos and photos— generated by the land-grant university system, including solar energy resources.

The National Sustainable Agriculture Information Service—ATTRA—provides many helpful solar energy reports for free or a small fee.



The Berkshire-Pioneer Resource Conservation and Development Area developed a series of *Farm Energy Best Management Practices* that cover renewable energy options such as solar PV and solar hot water.

Technical Assistance and Business Planning

Technical assistance related to solar PV development is readily available through the list of solar consultants and installers maintained by Renewable Energy Vermont.

Financing

The Database of State Incentives for Renewables and Efficiency is the most convenient source of financing vehicles for renewable energy projects. DSIRE identifies 68 funding programs for Vermont organizations.

Marketing and Public Outreach

The Energy Cross-Cutting Team developed a series of Farm to Plate Energy Success Stories to showcase farms, businesses, vendors, installers, and technical assistance providers that have made a difference with energy efficiency savings and renewable energy production. Two success stories focused on ground-mounted PV at McKnight Farm (page 43) and a roof-mounted system at Ayers Brook Goat Dairy (page 45).

Solar PV on a Dairy Farm

McKnight Farm

East Montpelier, VT ▪ www.facebook.com/McKnightFarmVT

Highlights: 95 kW (AC) of installed capacity ▪ ≈120,000 kWh generated annually ▪ Payback period = 6 years ▪ Fixed rack solar PV systems and trackers are common throughout Vermont

McKnight Farm, an organic dairy that milks more than 200 cows and sells beef, requires a lot of electricity to make compressors, refrigeration, water pumping, and ventilation systems work. To eliminate this significant recurring expense, owner Seth Gardner invested in a solar photovoltaic project that would meet all of his farm's electricity needs.

McKnight Farm solar array in East Montpelier, showing about one quarter of the 1.5-acre array, which is rated at approximately 95 kilowatts power output. The system was built by Catamount Solar.

Photo Credit: Catamount Solar

Solar photovoltaics, also called panels or PV for short, are made of a semiconductor material that directly turns the photons in sunlight into electricity. A complete solar PV system consists of four things: solar panels, a way to mount the solar panels (either on a roof or on the ground), the electronic conversion equipment (i.e., an inverter), and the electrical synchronizing and safety equipment to connect the electricity to the utility's network. With well over 2,000 installations, solar PV is far and away the most common type of renewable energy installation in Vermont. Farmers have two ways to be compensated for the electricity generated by their solar PV systems: the Sustainably Priced Energy Development (SPEED) Program and net metering.

Vermont SPEED

Solar PV systems are the most common type of renewable energy installation in Vermont, but they only account for 4-5% (> 40 megawatts) of the installed capacity of all renewable electricity systems. This is rapidly changing, however, as Vermont SPEED incentives for solar PV projects—$0.257 per kilowatt-hour for 25 years—have triggered a wave of "solar farms," including 21.4 megawatts (MW) of SPEED-approved projects on 10 solar farms in 2013 alone—with another 40 MW in applications that did not receive approval. Since dairy farms have about 60% of the total cropland in Vermont, many farmers are investigating larger solar PV systems on a portion of their land.

Net Metering

Although SPEED does allow projects of 150 kilowatts or lower, as a practical matter most SPEED solar projects are rated at over 2 MW. Farmers can pursue small and medium-sized projects via net metering. A net metered project means that the renewable electricity generated by the consumer is applied as a credit—capped at $0.20 per kilowatt-hour—to offset electricity that would normally be purchased from the utility. Electricity generation in excess of the consumer's use during a billing period is credited to their account for future use. Solar energy generators in Green Mountain Power territory can receive an additional $0.06 credit per kilowatt-hour.

Gardner began planning his solar PV project for offsetting his farm's electricity use in spring 2012, and received a certificate of public good from the Public Service Board in September 2012. McKnight Farm benefitted from something that's uncommon in most states: "group" net metering. Group net metering allows energy generators to share their credits across multiple meters at the farm, or they can be set up by a group of neighbors or relatives to share the production of a single system. The only requirement is that all the group beneficiaries are in the same utility service area.

Siting Considerations

In some instances, a barn roof is perfect for solar PV if there is enough space, a south-facing orientation, and a strong enough structure. Ground-mounted systems are increasingly common and are generally of two types: trackers or fixed racks. Trackers (e.g., AllSun Trackers) are poles that support a set of panels and a mechanism that continually moves the panels to point directly at the sun during the course of a day. Fixed racks consist of steel posts driven into the ground, forming fixed rows of panels angled at 30 degrees and generally facing due south. The choice between trackers and fixed racks is context-specific. For example, trackers generate more electricity, especially later in the day, but generally require more land and may cost more. Farmers should weigh cost, conversion efficiency, land access, geographical factors (e.g., soil type), and other concerns when making a decision. To date, all SPEED projects except the South Burlington Solar Farm are fixed rack systems, but hundreds of net metered trackers are also generating electricity across Vermont.

Working with Catamount Solar, Gardner chose a site with good access to the sun and that was already maintained as a buffer between organically managed acreage and the adjoining conventional acreage. Gardner chose a fixed rack ground-mounted system because fixed racks are simpler and lower cost than trackers. To have enough area of solar panels to be able to generate the equivalent of his farm's total annual electricity usage required 1.5 acres of land for 416 panels. Because the site selected had very thin soil cover—with ledge only inches below ground—Catamount and Gardner chose to pour concrete blocks and mount the racks with the panels by drilling into the concrete. All of this work was completed between early November and the end of December.

Steers on pasture underneath solar panels mounted on livestock-tough poles in South Deerfield, MA.

Photo Credits: Hyperion Systems, LLC

The dual land use pole and spline mounting system patented and installed by Hyperion Systems, LLC, Amherst, MA, demonstrates the possibility of baling hay between rows of solar panels on a farm in South Deerfield, MA.

To pay for this project, Gardner received a $255,000 loan from VEDA's agricultural loan organization, the Vermont Agricultural Credit Corporation and a $36,000 rebate from the State of Vermont. The system is also eligible for a $85,620 federal tax credit. According to Catamount, the system is expected to produce about 120,000 kWh annually, valued at $25,200. Including the tax credits and depreciation value, the system payback is expected to be 6 years. Most of the electricity generated is allocated to the meter for the milking barn, with about 20% going to the freestall area, and the rest to the house.

Energy Success Stories

Solar PV on a Dairy Barn

Ayers Brook Goat Dairy

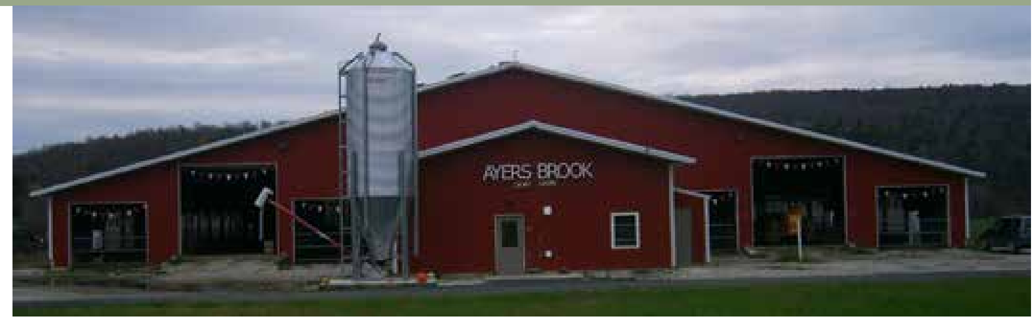
Randolph, VT ▪ www.vermontcreamery.com/ayers-brook-goat-dairy

Highlights: 150 kW (AC) of installed capacity ▪ ≈200,000 kWh generated annually ▪ Minimal changes to the roof structure required ▪ Largest PV installation on a barn in Vermont

Upon retirement, Carol and Perry Hodgdon sold their 116-acre Randolph cow dairy farm to Evergreen Conservation Partners—a partnership of the *Castanea Foundation*, *High Meadows Fund*, and the *John Merck Fund*. Evergreen Conservation Partners then leased the land to *Vermont Creamery*, Vermont's largest goat cheese producer.

The vision of Vermont Creamery co-founders, Bob Reese and Allison Hooper, is for the new *Ayers Brook Goat Dairy* to serve as a catalyst for growing Vermont's goat dairy industry. Ayers Brook milks about 230 goats in season—and has a goal of milking 500 goats—to supply the Vermont Creamery facility in Websterville with a steady supply of local goat milk. The number of farms raising goats and selling goat products in Vermont has increased 106% over the past 15 years, from 221 in 1997 to 457 in 2012. The vision for Ayers Brook also included permanently protecting the land with a conservation easement with the *Vermont Land Trust*, providing a national venue for teaching and training, and offering high-quality replacement stock to the region's goat farms.

Large *solar photovoltaic* arrays on barns are unusual in Vermont because there is typically room on the ground that can be re-purposed for solar panels. Large ground-mounted solar PV systems (e.g., fixed rack systems like *McKnight Farm* has, or trackers) are increasingly common on land owned by Vermont farmers. For some projects, this means that the land is taken out of agricultural uses for the lifetime of the project. For others, the ground-mounted solar PV arrays are developed in a way that allows livestock to graze under and around the installation (e.g., sheep graze around the *Ferrisburgh Solar Farm*).



Ayers Brook Goat Dairy's new barn in Randolph, central Vermont, is designed to house 500 goats, including state-of-the-art facilities for milking, breeding, and for raising goats for the dairy and for the region's goat farmers.

The 572 solar panels, here shown almost fully installed, use the one-third-acre south-facing roof, mounted on a frame designed by Aegis Renewable Energy.

Photo Credit: top- Vermont Agency of Agriculture; bottom- Aegis Renewable Energy

At Ayers Brook, the quality of the bottomland, the conservation easement, and the new 14,000 square-foot, south-facing barn roof all pointed to a roof-mounted solar array. With the *federal tax credit*—equal to 30% of expenditures—set to expire in 2016, Bob and Allison decided to move forward with the project and hired Aegis Renewable Energy (Waitsfield). However, the barn roof structure was designed to minimize roosting places for birds, and consists mostly of widely spaced rafters rather than trusses and purlins. Aegis worked with structural engineers to analyze the roof structure and develop a simple modification to the trusses to bring the roof into code compliance for the added load of the array. To mount the solar panels, Aegis designed a roof-mounted metal frame to span the 12-foot distance between each rafter. To account for the additional roof load of five pounds per square foot, the barn designer (Lester Buildings), with the builder (BCI Construction, Inc. of Orwell, Vermont) reinforced a small section of truss near the peak of the roof. **The Ayers Brook 150-kilowatt array, installed in July 2014, is the largest barn-mounted solar project in Vermont.**

Siting Considerations

When considering a new barn project, or even a significant expansion, you can work with structural specialists and the solar installer to find out what it would cost to make the roof's supporting structure "solar ready." Sometimes all it takes is putting the relevant people in touch early enough in the project. In general, if you are building a new barn you should try to have a clean, unpenetrated roof surface with good southern exposure and orientation.

For large projects over 100 kW you should consider bringing three-phase power to the site since it can maximize the investment in the solar array and will benefit the farm with all other electrical needs such as vacuum pumps and manure pumps.

In this case, payments on the loan are more than paid for by the savings. Some of the power is net metered to the adjoining farmhouse meter, and the rest goes to the Vermont Creamery facility in Websterville. **The total cost of the project was $525,000, and that was reduced by 30% using the federal investment tax credit and by 7.2% by the Vermont business investment tax credit. Payback period is about 11 years.**

Solar Energy and Energy-Efficiency — a Happy Marriage

Ayers Brook scoped out options for efficient lights and ventilation. With technical assistance and financial incentives from Efficiency Vermont, they installed LED (light-emitting diode) fixtures in the freestall and elsewhere, and incorporated as much natural light as possible. Over half of the estimated electricity savings will

Miles Hooper, crop and operations manager of Ayers Brook Goat Dairy, shows off the solar roof, along with some of the dairy's goats. On this fall day, the insulated curtains are about half-way open.

come from the lighting design. The other big savers are automated, insulated side curtains, along with "chimneys" that are weather-controlled and exhaust air out of the building. Altogether, compared to a typical barn scenario, **this energy-efficient equipment and design is estimated to save Ayers Brook over $10,000 per year.**

As with anything the Ayers Brook does, the point is to make the goats comfortable, with as much natural light as possible, and optimal temperatures, year-round. Ayers Brook found a way to marry this goal to state-of-the-art energy systems.

Photo Credits: top- Vermont Agency of Agriculture; kid - Aegis Renewable Energy.

WIND ENERGY MARKET DEVELOPMENT NEEDS

Vermont's Comprehensive Energy Plan suggest that if 55% of the wind energy serving Vermont is located here by 2050, then 36 to 106 additional 2.75 MW turbines would be required depending on the scenario (Vermont currently has 52 large-scale wind turbines). If 100% of the wind energy serving Vermont in 2050 was located here, then an additional 67 to 194 2.75 MW turbines would be required depending on the scenario.[39] By way of comparison, one 2.75 MW wind turbine is equal to 27 of the 100 kW wind turbines seen on Blue Spruce and Nea Tocht Farm.

However, large-scale wind development in Vermont has seemingly stalled, with Deerfield Wind (30 MW) the only facility currently in permitting. The Comprehensive Energy Plan recommends focusing on small- and medium-scale and community-directed wind projects. The *2015 SPEED program request for proposals* incentivized small-scale wind projects (less than 100 kW) by setting aside 1.5 MW of possible development at a rate of $0.2520 per kilowatt-hour. Eight proposals representing 652 kW were received. Going this route would mean that many more smaller systems (e.g., *Northern Power Systems*, a wind turbine manufacturer based in Barre, sells 100 kW wind turbines) would be necessary.

Natural Resource, Physical Infrastructure, and Technology

Vermont's wind resource varies a lot from one place to another due to wind direction, ground obstructions, surface roughness, as well as elevation in relation to the surrounding topography. When thinking about wind resource it is important to understand that every time your wind speed is doubled you get roughly 8 times more energy. The strongest wind resources are generally located at higher elevations and that is where Vermont's four commercial installations—*Kingdom Community Wind*, *Sheffield Wind*, *Georgia Mountain Community Wind*, and *Searsburg Wind Farm*—are located. These four sites account for 98% of Vermont's wind installed capacity. Vermont also has at least 159 small-scale net metered wind projects—ranging in size from 0.95 kilowatts (kW) of generating capacity to 99 kW—and nine 100 kW turbines that are powering homes, schools, businesses, and farms (Figure 4.6.13).

One site, Georgia Mountain Community Wind—co-owned by *Georgia Mountain Maples*, accounts for 98% of the installed capacity of wind energy at food system businesses (Figure 4.6.14). Two 100 kW wind turbines at Blue Spruce Farm and Nea Tocht Farm—both using *Northern Power NPS 100* turbines and installed by *Aegis Renewable Energy*—are indicative of the way that small-scale wind turbines can be developed on farm property.

BrighterVermont
CommunityEnergyDashboard
BUILDING A BETTER ENERGY FUTURE. TODAY.

Food system businesses can use the Community Energy Dashboard to analyze existing and potential renewable energy locations.

Wind speed maps and the locations of existing sites are available on the Community Energy Dashboard. Many of the siting guidelines outlined in *Solar Energy Market Development Needs* are applicable for wind development. For example, several regional planning commissions have further refined Vermont's wind speed maps to show non-ridgeline, more suitable locations for wind turbines. Wind turbines are very common on farmland throughout the world and it may be the case that community-scale wind turbines are increasingly installed on farmland in Vermont. For example, Blue Spruce Farm in Bridport partnered with *Green Mountain Power* (GMP) to host a 100 kW wind turbine under a unique arrangement that required no cost from the farm. In exchange for locating the wind turbine on their farm, the Audets receive 10% of the electricity, while the remaining 90% is sent on to the grid. As GMP focuses on building small-scale renewable energy projects in their service territory it may be possible for more Vermont farmers—who own a significant amount of Vermont's land area—to partner with the utility.

Wind turbine on farm in Strathroy, Ontario, Canada.

Network Development

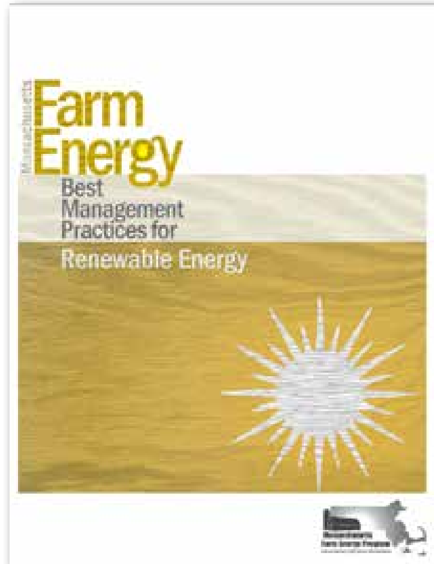
As with solar energy development located at food system businesses, the Farm to Plate Network should work with renewable energy networks—such as Renewable Energy Vermont and the Energy Action Network—as well as regional planning commissions, state agencies, and municipal governments to find common ground for wind development.

Technical Assistance and Business Planning

Technical assistance related to wind development is available through the list of wind consultants and installers maintained by Renewable Energy Vermont.

eXtension is a clearinghouse of learning resources— including videos and photos—generated by the land-grant university system, including wind energy resources.

The National Sustainable Agriculture Information Service—ATTRA—provides many helpful wind energy reports for free or a small fee.



The Berkshire-Pioneer Resource Conservation and Development Area developed a series of Farm Energy Best Management Practices that cover renewable energy options such as wind.

Financing

The Database of State Incentives for Renewables and Efficiency is the most convenient source of financing vehicles for renewable energy projects. DSIRE identifies 68 funding programs for Vermont organizations.

Marketing and Public Outreach

The Energy Cross-Cutting Team developed a series of Farm to Plate Energy Success Stories to showcase farms, businesses, vendors, installers, and technical assistance providers that have made a difference with energy efficiency savings and renewable energy production. One success story focused on a wind turbine at Blue Spruce Farm (page 49).

Energy Success Stories

Wind Energy on a Dairy Farm

Blue Spruce Farm

Bridport, VT ▪ www.bluesprucefarmvt.com

Highlights: 100 kW of installed capacity ▪ ≈150,000 kWh generated annually ▪ Unique partnership with Green Mountain Power facilitates community-scale wind energy installation

The Audet Family has operated Blue Spruce Farm since 1958 and currently milk about 1,500 cows that produce over 30 million pounds (3.6 million gallons) of milk per year. Dairy operations consume quite a bit of electricity. To offset this cost, Blue Spruce Farm was the first participant in the *Green Mountain Power* (GMP) *Cow Power program*, which uses anaerobic digestion to turn manure generated on the farm into about 2.4 million kilowatt-hours of electricity per year. Additionally, in 2013 the Audets partnered with GMP to host a 100 kW wind turbine under a unique arrangement that required no cost from the farm. In exchange for locating the wind turbine on their farm, the Audets receive 10% of the electricity, while the remaining 90% is sent on to the grid. As GMP focuses on building small-scale renewable energy projects in their service territory it may be possible for more Vermont farmers—who own a significant amount of Vermont's land area—to partner with the utility.

Vermont's Wind Resource

Vermont's wind resource varies a lot from one place to another due to wind direction, ground obstructions, surface roughness, as well as elevation in relation to the surrounding topography. The strongest wind resources are generally located at higher elevations and that is where Vermont's four large installations—*Kingdom Community Wind*, *Sheffield Wind*, *Georgia Mountain Community Wind*, and *Searsburg Wind Farm*—are located. But Vermont also has nearly 200 small-scale net metered wind projects—ranging in size from 0.95 kilowatts (kW) of generating capacity to 100 kW—that are powering homes, schools, businesses, and farms. Farmers can get a first approximation of average annual wind speed on their land using the *Community Energy Dashboard*.

Photo Credit: Vermont Agency of Agriculture

Just after Memorial Day in 2013, the Audet family hosted a community celebration of the installation of a 100-kilowatt wind turbine. A portion of the electrical output of the turbine is allocated to the local school.

Installers may also put up an *anemometer tower* to measure wind speed at the eventual height of the blades, but this can cost upwards of $30,000. For the Blue Spruce Farm wind turbine, contractor *Aegis Renewable Energy* (Waitsfield) used a wind site analysis tool developed by *AWS Truepower*. This analysis tool is based on decades of data collection and predicted an average annual wind speed of 11.5 miles per hour (5.14 meters per second) at 120 feet (37 meters) above the ground.

Because of Vermont's abundant hills and trees, it pays to have a tall wind turbine (i.e., the taller the turbine, the stronger and smoother the wind). At 120 feet tall, the *Northern Power Systems* wind turbine model NPS 100-24—manufactured in Barre— is well-suited to this moderate wind resource. Each of the three blades is almost 40 feet long, and the turbine includes a mechanism to detect the wind speed and direction in order to face the blades into the wind. The generator for this turbine starts generating power at seven mph (or three m/s), but wind speeds of 10-20 mph are the bread and butter of this turbine's output profile.

The NPS 100-24 is designed for low maintenance. It is gearless and the generator uses permanent magnets to create the electrical field. No gear box also means the NPS 100-24 is very quiet. Maintenance personnel climb a ladder inside the turbine to access the generator and blades.

Erecting the turbine was a three-stage process: beginning in early February 2013, Aegis Renewable Energy broke ground for the foundation and began digging trenches for underground electrical service. The contractor first excavated a 15-foot deep hole for the foundation, built the bolt cage assembly and forms for the concrete, and then poured the foundation, which required about 30 yards of concrete.

A below-ground pad of reinforced concrete is connected to a ring of rods (the "bolt cage"), visible in the photo, that rise to a few inches above ground level. This ring will also be encased in concrete, except for the top few inches, onto which the tower is bolted. Also shown are the electrical conduits, which will come up through the concrete floor inside the tower.

The concrete foundation cured for 28 days, after which assembly and erection of the tower, nacelle (generator housing), and rotor were completed in two days. Finally, commissioning and utility interconnection took another day and a half. In its first six months, the turbine has operated without interruption. Aegis estimates the turbine will produce about 150,000 kilowatt-hours per year—enough electricity for about 20 Vermont homes.

Blue Spruce Farm also operates one of the first manure digesters in Vermont, under a separate limited liability corporation. Marie Audet is an active advocate of on-farm energy production.

Photo Credits: Aegis Renewable Energy

ANAEROBIC DIGESTER MARKET DEVELOPMENT NEEDS

Vermont currently has 19 digesters (17 on-farm digesters, 1 digester at Magic Hat Brewing Company, and 1 at Vermont Tech). Consumers can enroll in Green Mountain Power's Cow Power program to support 12 of the 17 dairy farms. As of 2015, Vermont had about 870 dairy farms remaining, with a total of about 134,000 cows. **However, anaerobic digester development has stalled in Vermont with no on-farm digesters currently under development.**[40]

Two projects that would use manure from farms are underway: Green Mountain Power is proposing to build a three-farm 450 kW digester in St. Albans Town. The project would produce electricity using manure from three farms and approximately 2,000 cows. Two of the farms adjoin the site and would deliver manure by pipe, and receive liquid from the digester by pipe as well. The other farm would use trucks. Lincoln Renewable Natural Gas, LLC proposes to build a three-tank, 1.3 million gallon digester that includes equipment to purify the biogas for use in a pipeline, and has a long-term agreement to sell the gas to Middlebury College. The project incorporates manure from three farms, totaling 2,400 cows.[41]

The last digester to come online was the Community Anaerobic Digester at Vermont Tech (VTCAD). At full power, VTCAD uses 16,000 gallons of manure and organic residuals to produce 8,880 kWh of electricity per day, 'waste' heat that will be used to heat four campus buildings, bedding material for the college dairy herds and recycled nutrients used as crop fertilizer. VTCAD uses a mixture of manure from co-managed farms and organic residuals collected from the community. Feedstock materials include brewery residuals, the glycerol by-product of biodiesel production from waste cooking oil, grease trap waste, and waste paper and, soon, locally collected pre- and post-consumer food residuals.

Technical Assistance and Business Planning

Developing a new anaerobic digester can be a long and costly process. For example, the VTCAD was conceived by a partnership of educational, agricultural, waste management and environmental groups and funded by the U.S. Department of Energy. The first round of funding for the project was received in 2008 but the VTCAD was not operational until 2014. The VTCAD identified the following hurdles to more widespread development of anaerobic digesters in Vermont:

- Lack of incentives for the production and use of renewably produced heat;
- Lack of clarity about the types of permits required to accept food waste as AD feedstock;
- Ambiguity about the necessity of pasteurizing food waste prior to anaerobic digestion;
- No specific regulations governing land application of digester effluent as a soil amendment;
- Ambiguity concerning a farm's ability to sell separated solids if food waste feedstock included beef as the prions that cause bovine spongiform encephalopathy ('mad cow disease') are not inactivated by Pasteurization; and
- Lack of incentives for capture and mitigation of methane (or other greenhouse gases) and for recycling of waste nutrients back into the agricultural production cycle.

Additionally, the construction firm building the digester, Bio-Methatech, underwent significant management changes and ultimately dissolved, emerging, in part, as Biogaz Lipp, a new component of Dominion & Grimm. This process caused significant delays and negatively impacted construction and operations. Vermont Tech has obtained service contracts through the manufacturers for some individual components such as the flare and generating engine. They have limited access to the original Bio-Methatech project personnel through Dominion & Grimm, and discussions continue regarding warranties and the longterm support they had been promised. Limited support regarding biochemistry and feedstock issues, hydrogen sulfide levels, and testing and adjustment of some mechanical systems is still impacting operations. Experience with the operation of complex plants with a wide variety of feedstock materials is limited in Vermont and in the region. Vermont Tech is looking for operational advice and expertise from the handful of co-digestion facilities in the U.S. and in the European anaerobic digester community.[42]

Vermont's Comprehensive Energy Plan also identifies a range of specific challenges for system farmers/operators. These include:

- Equipment failures in some cases, due to flawed design, sometimes accompanied by weak customer support from undercapitalized and immature equipment providers.
- Persistent issues at most projects from corrosion and/or fouling, caused by hydrogen sulfide gas.
- Additional labor demands on farmers, especially if they want to fully utilize co-products, such as running a greenhouse to use the heat, or to set up a compost operation to increase the value of the solids.
- Environmental permitting for inputs that spans several divisions of the ANR and several types of permits, depending on the material.
- Failure to fully consider various state fees, such as the air emission fees, in operational costs.[43]

Technical assistance for anaerobic digesters is limited in Vermont. The Farm to Plate Network could join state and federal agencies, GMP, Vermont Tech, and others to investigate opportunities for moving digester projects forward.

eXtension is a clearinghouse of learning resources— including videos and photos— generated by the land-grant university system, including *anaerobic digester resources*.

The National Sustainable Agriculture Information Service—ATTRA—provides many helpful *anaerobic digester reports* for free or a small fee.

The Environmental Protection Agency's *AgSTAR program* promotes on-farm anaerobic digestion opportunities.

Financing

Vermont's Comprehensive Energy Plan notes that there are fewer grant opportunities available for digesters now than when most of the digesters in the state were built. The *Database of State Incentives for Renewables and Efficiency* is the most convenient source of financing vehicles for biomass energy projects. DSIRE identifies 68 funding programs for Vermont organizations.

Education and Workforce Development

Vermont Tech developed a 12-week *Digester Operations Master Certificate* where students work directly with the VTCAD.

Marketing and Public Outreach

The Energy Cross-Cutting Team developed a series of *Farm to Plate Energy Success Stories* to showcase farms, businesses, vendors, installers, and technical assistance providers that have made a difference with energy efficiency savings and renewable energy production. One success story focused on an anerobic digester at Maxwell's Neighborhood Farm (page 53).

Digester on a Dairy Farm

Maxwell's Neighborhood Farm

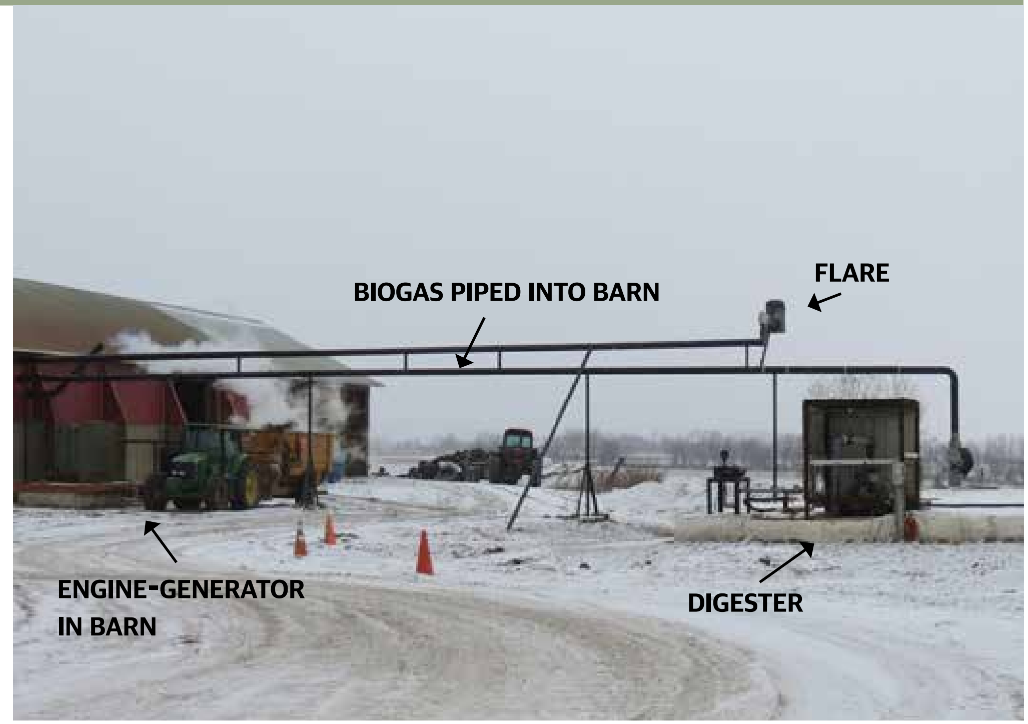
Coventry, VT

Highlights: 225 kilowatts of installed capacity ▪ 1.75 million kWh of electricity generated per year ▪ 7-year payback ▪ Cow Power farm generates electricity and uses waste heat for greenhouse

Lois and Maurice Maxwell started Maxwell's Neighborhood Farm in 1957. Four sons (Stewart, Bradley, Anthony, and Jeffrey) and a grandson, Matthew, now operate the approximately 800 cow dairy. The Maxwells pursued a methane, or anaerobic, digester as a way to diversify their operation at a time of low milk prices. Methane digesters are oxygen-free tanks or containers that use microorganisms (i.e., different types of bacteria) to transform biomass like cow manure into "biogas" (e.g., methane and carbon dioxide), while retaining the manure slurry. This biogas can then be fed to a gas engine to generate electricity, or to a boiler to generate heat. In 2008 the Maxwells partnered with the Green Mountain Power Cow Power program to build a digester system and incorporated it as *Maxwell's Neighborhood Energy*. There are currently 12 dairy farms enrolled in the Cow Power program.

Equipment Costs, Energy Payments, and System Payback

The total cost of this project was about $1.8 million. A $100,000 grant from GMP was coupled with a $357,990 grant and a $326,770 loan guarantee from the USDA Rural Energy for America Program (REAP), $250,000 from the Vermont Clean Energy Development Fund, and $75,000 from the Vermont Agency of Agriculture. Because the farm was connected to Vermont Electric Coop through single-phase electric power—and the engine-generator is three-phase electric power—over $78,000 was paid to upgrade 1.6 miles of utility lines. Maxwell Neighborhood Energy is paid for the electricity generated by the Vermont SPEED program, at the farm methane rate of $0.14 per kilowatt-hour. In addition, customers enrolled



The engine-generator is housed in the building at the left. To right is the digester, part of which can be seen protruding above the ground. A pipe emerging from the digester carries biogas to the engine, and another pipe can be seen leading to the flare, used to burn the biogas in case the engine is not able to take the biogas.

in the Cow Power program pay an additional 4 cents per kilowatt-hour for the environmental attributes of the energy produced, and this money goes to the farmer.

With the combination of electricity sales, reduced heating costs, and animal bedding savings and sales, the Maxwells believe the system will be paid off in a little over seven years. However, Vermont dairy farmers with digesters and technical assistance providers also caution that digester equipment, particularly the engine-generator, require significant attention to detail and technical issues need to be addressed promptly to avoid long-term problems.

Digester Characteristics

Maxwell's Neighborhood Energy worked with GHD (now *DVO*) for the *digester design and installation*, Martin Machinery for the 225 kW *Guascor* engine-generator package, and many subcontractors.


Guascor engines are commonly used with methane digesters in Vermont.

The digester measures 72 feet wide by 96 feet long by 16 feet deep, and is a U-shaped configuration. It holds almost 800,000 gallons and is large enough to retain incoming manure for about three weeks. The Maxwells also contract with a food processing facility in Maine for additional liquids to put in their digester (about 10% by volume) and this boosts gas production by about one-third.

After three weeks in the digester the manure odor is virtually neutralized. Liquid separated from the manure during the digestion process becomes easier to spread—and odorless. And the fertilizer value present in the manure going into the digester is still available after this "aging" process. Biogas from the digester is cooled to remove moisture, and sent to the 225-kilowatt engine-generator, which can produce enough electricity for about 200 homes. During this process, methane produced from animal waste—a greenhouse gas 20 times more powerful than carbon dioxide—is captured and destroyed. If there is too much gas, or the engine is being serviced, gas is sent to a flare to be burned off.

Additional Benefits

The engine-generator includes heat exchangers that deliver useful amounts of heat for space heating beyond the heat needed to keep the digester warm. The Maxwells decided to transfer some of the digester's excess heat through plastic piping in the ground over to a greenhouse—installed in the winter of 2013. These pipes heat both the ground and the air inside the greenhouse.

Matt Maxwell manages the greenhouses and grows greens all fall and winter. As spring approaches, he transitions from greens to tomatoes. For about six weeks, Matt is able to sell beautiful, ripe, early-season tomatoes for about four dollars a pound into the local market.


As the Maxwells worked with the system designers and equipment providers, they made sure to include heat recovery and distribution systems. The engine's heat exchangers deliver heat for milkhouse water heating, for heat in the maintenance shop (saving 4-to-5 cords of wood or $800-$1,000 each winter), for the engine room, for drying separated manure solids, and for the greenhouse (pictured above).

As Matt readily points out, selling electricity is only part of the picture. Matt also harvests peat-moss-like bedding from the digester. The bedding suits the cows very nicely, and while it saves money compared to buying sawdust, it's hard to put a price on the peace of mind that comes from knowing that they don't have to skimp on bedding and that their cows are well cared for and healthy. This bedding can also be used as a soil amendment in the greenhouse. Matt is able to compost some of the bedding and sell it to landscaping companies and other gardeners. The Maxwells also save on wood and other purchased sources of heat that used to heat the maintenance shop and the milkhouse, since the heat from the engine-generator is now displacing those fuels.


The greenhouse heated by the digester is 36 feet by 72 feet.

Photo credits: Matt Maxwell, except Guascor engine (Vermont Agency of Agriculture)

HEATING MARKET DEVELOPMENT NEEDS

Biomass fuel includes wood, crop residues, grains such as corn or switchgrass, and by-products like sawdust that can be pelletized (Table 4.6.5). Biomass can be used anywhere space heating (e.g., greenhouses) and water heating (e.g., maple syrup evaporators) is currently done with fossil fuels.[44] Vermont's Comprehensive Plan estimates that 37% of Vermont households heat at least in part with firewood or wood pellets, and many schools and institutions use wood heating.[45] **Unfortunately we do not have much information about how and where renewable heat options (e.g., wood chip/pellet furnaces or boilers, solar hot water) are being used by food system businesses.**

Research

A recent study conducted by the *University of Vermont Extension*—*Promoting Adoption of Biomass Fuels for Heating Vegetable Greenhouses in Vermont*—provides insights into the adoption of biomass fuels at vegetable greenhouses. Greenhouse production in Vermont covers 2.6 million square feet and produces $24.5 million in crops, of which about $5 million are fruits and vegetables. This translates to 60 acres of covered production with gross revenues of $408,000/acre overall and $224,000/acre for fruits and vegetables. Growing crops under cover in greenhouses and high tunnels provides a more protected and controlled environment compared to field production. This protection has become increasingly important to Vermont farmers as the incidence of extreme weather events has increased in recent years. At the same time, Vermont farmers are expanding their greenhouse and high tunnel production in order to meet the growing demand for local food, which continues even when crops are 'out of season'.

However, the production of greenhouse crops often requires the addition of heat in early spring and late fall to protect against cold temperatures. That heat is generally derived from nonrenewable fossil fuels such as propane and fuel oil. From 2008 through 2015, 25 growers received cost-share funds for greenhouse biomass heating systems. wood pellets or corn, cord wood, or solar.

Table 4.6.5: Renewable Heating Fuel Summary

Fuel	BTU Content	Cost	Delivered Heat Cost (per million BTU)	Pros	Cons
CORD WOOD	18-20 million BTU/cord	$160 – 200/cord	$11.1 @ 85% efficiency	Readily available & familiar; can generally be sourced on farm.	Manual handling; batch loading
WOOD PELLETS	8,600 BTU/lb	$294/ton	$20.1 @ 90% efficiency	Automated feeding with auger and bin; available in bags and (in some locations) bulk delivery.	Higher cost per BTU than cord wood; limited bulk delivery options currently
WOOD CHIPS	9.9 million BTU/ton	$56/green ton	$15.9 @ 65% efficiency	Inexpensive.	Generally high moisture compared to other fuels; limited small scale appliance availability.
CORN	8,500 BTU/lb	$300/ton	$23.9 @ 90% efficiency	Can be grown on farm; automated feeding with auger and bin.	Can form clinkers more easily than other biomass fuels.
GRASS PELLETS	8,600 BTU/lb	$250/ton	$16.1 @ 90% efficiency	Can be grown on farm; automated feeding with auger and bin when densified.	Relatively high ash content, needs automated removal system; clinkers possible.
BIODIESEL	118,296 BTU/gal	$4.18/gal	$39.3 @ 90% efficiency	Fuel oil replacement can be sustainably produced.	Some seals and materials may need to be changed.

Source: Chris Callahan, UVM Ag Engineering

The total installed cost of these systems was $312,766; the average cost per system was $12,511 and the average cost-share (i.e., sponsor funding) on these projects was 44% of the total cost. The growers installed a variety of system types depending on desired fuel, heating load and method of heat distribution (i.e., hot air or hot water). The systems have operated for the equivalent of 96 growing seasons in total with an average of 3.8 growing seasons per system, an average net fuel savings of $2,696 per system per year, and an average payback of 4.8 years (at full cost). From 2008 through 2015 a total of 15.3 trillion BTU of biomass energy was provided to these greenhouses, equivalent to 167,000 gallons of propane. The cumulative equivalent carbon dioxide emissions avoided by this substitution of fuel is estimated to be 2.14 million pounds. This is roughly equivalent to the annual emissions from 204 cars, or 2.3 million miles of car travel.

Researchers found that growers were more interested in biomass heat when the cost of fossil fuels were high. When fossil fuel prices stabilized or declined then growers' receptivity to change also dropped. A few growers found that if the systems were tied into other heating loads (e.g., residential heating, pack-shed heating, winter storage heating), then the systems were used for a longer period of time each year and their investment payback period was reduced.

An *analysis of grass thermal energy opportunities* (e.g., switchgrass, miscanthus) conducted for the *Vermont Bioenergy Initiative* found there are several barriers that make it unlikely that grass pellets will gain widespread acceptance in the consumer pellet fuel market without a significant price advantage over wood, which does not currently exist. These barriers are: significantly higher ash content compared to wood, clinkering (the fusion of ash into hard chunks) caused by lower ash fusion temperatures, lower heat energy content of grass compared to wood, and increased processing costs in producing a grass pellet compared to wood pellets due to increased wear on processing equipment. Ash content and composition can be controlled by managing soils, nutrient applied, and harvest practices. There are pellet stoves, furnaces and boilers available that can burn grass pellets but the high ash content compared to wood requires more robust ash handling equipment. Larger boilers and equipment is commercially available that can burn grass from bale form to briquettes, cubes and pellets however; there are very few biomass-burning appliances of this large size currently installed in Vermont or the Northeast.

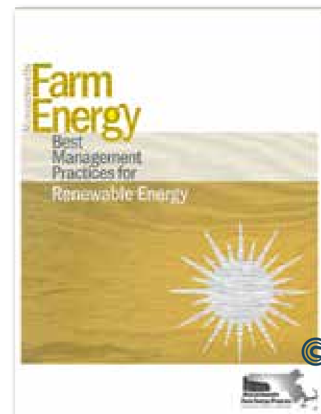
Natural Resource, Physical Infrastructure, and Technology

The Vermont Comprehensive Energy Plan estimates that net annual growth of Vermont's forests exceeds harvest by a 2:1 ratio (i.e., Vermont's forests add 166.6 million cubic feet of timber growth per year while 70.2 million cubic feet are harvested).[46] *Vermont Forest & Wood Products Directory* identifies sources of firewood and wood pellets.

Technical Assistance and Business Planning

The *Biomass Energy Resource Center* (BERC) has been the main source of technical assistance for wood heat for many years. BERC and *UVM Extension Agricultural Engineering* are Vermont's primary sources of technical assistance regarding biomass heating equipment.

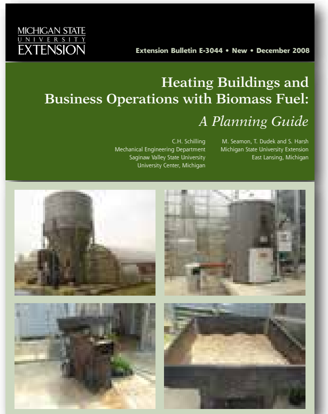
eXtension is a clearinghouse of learning resources— including videos and photos— generated by the land-grant university system, including *wood energy resources* and *solar hot water resources*.



The Berkshire-Pioneer Resource Conservation and Development Area developed a series of *Farm Energy Best Management Practices* that cover renewable energy options such as biomass heating.

Michigan State University's report, *Heating Buildings and Business Operations with Biomass Fuel: A Planning Guide*, is a detailed planning guide for biomass heating.

Penn State University created an online tool for comparing the heating values of two different fuels: *http://extension.psu.edu/natural-resources/energy/energy-use/resources/making-decisions/comparison-charts*



The Vermont Bioenergy Initiative produced a video that explains switchgrass production and use as fuel.

Financing

The *Database of State Incentives for Renewables and Efficiency* is the most convenient source of financing vehicles for biomass energy projects. DSIRE identifies 68 funding programs for Vermont organizations.

Marketing and Public Outreach

The Energy Cross-Cutting Team developed a series of *Farm to Plate Energy Success Stories* to showcase farms, businesses, vendors, installers, and technical assistance providers that have made a difference with energy efficiency savings and renewable energy production. One success story focused on an anerobic digester at River Berry Farm (page 58).

The Vermont Bioenergy Initiative made one *grass energy production video* that switchgrass production and pelletization efforts in Vermont.

NOFA Vermont and UVM Extension developed 7 videos—the "*Tunnel Tour*"—that include coverage of heating options at high tunnels used by Vermont produce farms.

NOFA Vermont and UVM Extension made a series of videos that examine heating issues with high tunnels.

Energy Success Stories

On-Farm Heating with Biomass

River Berry Farm

Fairfax, VT ▪ www.riverberryfarm.com

Highlights: 220,000 BTU/hr biomass boiler ▪ $13,000-21,000 installed cost ▪ 12-14 year payback period ▪ 5,910 pounds of CO_2 avoided ▪ Advanced pollution controls in new boilers reduce emissions

David and Jane Marchant of *River Berry Farm*—an organic vegetable and fruit producer in Fairfax—were early adopters of biomass heating when they installed a corn and pellet furnace in one of their greenhouses in 2008. The furnace required manual lighting and, whenever a strong wind blew, the fire could be snuffed out, making it a real labor burden. Although it was rated for 165,000 BTU/hr input and had a relatively low initial installation cost of $5,200, the furnace never seemed to actually produce a reasonable amount of heat. The Marchants also had a variable load in the greenhouse that peaked at night and was non-existent during the middle of a sunny day inside the greenhouse. This made for a frustrating relationship with the appliance. "I kept thinking, there has got to be a better option," recalls David, "It was a real labor burden, and you couldn't count on it."

This biomass heating demonstration was part of a *UVM Extension project* aimed at trialing several furnaces in agricultural heating applications with funding support provided by the *High Meadows Fund*. According to Chris Callahan, Ag Engineer with UVM Extension who assisted with some of the design and performance assessment, "The main lessons learned from these early installations were to buy high quality fuel, seek improved automatic ignition controls, invest in a good chimney and install it well, and know the actual heat output rating of the unit." Modern biomass heating appliances generally include a fuel storage bin, an auger for feeding fuel to the appliance, the appliance itself (boiler or furnace) with an ignition system, a combustion chamber, a heat exchanger, and a heat distribution system. They also incorporate some means of controlling combustion, fuel feed rate, and air flow and often include emissions control measures and automated ash removal.

The Central Boiler Maxim 250 boiler installed at River Berry Farm in Fairfax, VT. These boilers may look like outdoor wood boilers common around Vermont, but they are EPA Phase II qualified due to improved emissions controls.

Boilers Can Provide Advantages Since Hot Water Can be Used in Many Applications

Based on their early experiences and bolstered by a commitment to long-term sustainability and reduced fossil fuel dependence, the Marchants hosted another demonstration project on their farm. This time, they opted for a higher-rated *boiler* rather than a furnace. Boilers produce hot water, rather than hot air, which allows more options for distributing the heat. The new system also had an automated propane ignition system. The selected boiler was a *Central Boiler Maxim 250* with a 250,000 BTU/hr input rating, efficiency of 87.8%, and EPA Phase II Hydronic Heater qualification. "The boiler makes hot water which we can use in multiple greenhouses by plumbing it to them in insulated PEX piping. Once in the greenhouse, we convert to hot air with a hot water fan coil, put it in the ground for root-zone heating or on the benches in our mat-heating system for starts," says David, "I like it. I keep trying to find something wrong with it, but I can't. The payback period is a bit longer due to higher initial costs, but you have to expect that."

The basic system cost was approximately $13,000 for the boiler, bin, pad, and plumbing to a hot water fan coil. The other heat distribution systems included

in-ground PEX, heat exchange, and plumbing for a bench heat system and added approximately another $5,000. The system is more automated and reliable than the earlier furnace was, but the higher initial costs and the fact that the system is only used 3 months out of the year do prolong the payback period to about 12 years when compared with a propane furnace. If the system was used for 6 (space heating) or even 12 months (wash water, pasteurization) of the year the payback would be halved or quartered, respectively.

Paul Betz uses the Central Boiler eClassic to heat two greenhouses with cord wood.

"In addition to the financial payback, the carbon emissions avoidance is also of interest to many people," says Callahan, "In River Berry Farm's case, the Maxim is helping them avoid 5,910 pounds of net CO_2 emissions per year which is about equivalent to 5,000 miles car travel or the CO_2 sequestered by half an acre of pine forest." The *EPA Phase II qualification* of the unit refers to the emissions of criteria pollutants (e.g., sulfur oxide and nitric oxide). The same analysis that shows the net CO_2 emissions reduction also suggests the net criteria pollutant emissions are also reduced when using the biomass boiler compared to propane.

Photo credits: Chris Callahan

A less expensive underground insulated PEX tubing option (left) is wrapped in foiled bubble wrap and has space between the insulation on the pipe as well as the outer wall. Cost is approximately $7.00/ft. The solid EPS insulated PEX tube (right) is more expensive at $11.00/ft but has demonstrated reduced heat loss and pipe to pipe heat transfer. Water infiltration is a concern on the foil wrapped version on the left due to the open area that exists.

Biomass heating is being used in other greenhouses as well. Paul Betz was interested in using his woodlands to fuel his greenhouses at *High Ledge Farm* in Woodbury. With the installation of a *Central Boiler eClassic 2300* cord wood boiler he is doing just that. "Despite what the sales people will tell you, they are finicky to get lit, and require some babysitting for longer, reliable burn times," cautions Paul, "Once it is going, it does what it's supposed to do, which is burn clean and make hot water." **The system cost about $21,226 and saves about $1,500 per year resulting in a payback period of about 14 years.**

Paul also has two other pointers that will help anyone using a biomass boiler. "Don't skimp on the insulated piping. While I was shocked at the $13.00 a foot price, I should have gone for it. I got some for $6.95, and the insulation is not adequate, and since it's not a filled pipe, if the outer sleeve gets nicked, it will fill with water and defeat the insulation" Regarding heat distribution, Paul notes "When buying the exchangers, be sure to check the BTU ratings carefully. When they are listed they give the ratings for steam, not hot water. The end result is the exchangers can be a little undersized when connected to a hot water boiler."

The table to the right compares biomass fuels and other fuels generally used in Vermont. The key considerations when making a fuel choice are generally: Cost per delivered unit ($/gal, $/ton); energy content (BTU/gal, BTU/ton); boiler or furnace availability and cost; system reliability and automation; and emissions. It is important to note that fuel prices can and have experienced high volatility with rapid and significant increases at times. These changes will affect how one fuel compares to another. Using the *Penn State University fuel comparison calculator* can help clarify that impact.

LIQUID FUEL MARKET DEVELOPMENT NEEDS

Except for on-farm diesel use (about 6 million gallons of diesel fuel per year), we do not have data on food system business liquid fuel consumption, but we assume that most of it is used in vehicles. Ethanol—a biofuel usually derived from corn—is blended into gasoline by federal law and now equals about *10% of the U.S. motor gasoline supply*. The *Energy Information Administration* estimates that Vermont consumed 713,000 barrels (about 30 million gallons) of ethanol in 2013, the lowest amount of any state except Alaska. Vermont does not produce ethanol but does produce a small amount of biodiesel from oilseed crops and waste vegetable oil for on-farm use. Sunflowers are the most popular oilseed crop in Vermont, with hundreds of acres planted statewide. The crop is grown in rotation with grains and grasses and can yield high quantities of oil.

The *Vermont Bioenergy Initiative* (2008-2015) was a small-scale bioenergy development funded by the U.S. Department of Energy that invested in:

VERMONT BIOENERGY INITIATIVE

- Oilseed crop research, trials, and workshops conducted by the *University of Vermont Extension Oilseeds Program*
- Oilseed crop harvesting, cleaning, drying, and processing infrastructure
- Biodiesel processing infrastructure
- Developing two “Biomass to Biofuels” college courses that run repeatedly at University of Vermont and VT Tech to inspire and train the next generation of bioenergy experts and technicians
- Growing switchgrass and densifying it into “pucks” that are burned in a high efficiency commercial boiler
- Developing many educational materials, including videos, photos, and reports compiled on the VBI website: *http://vermontbioenergy.com*.

All of the 10 market development needs were explored in detail during the course of the VBI. **The results of the VBI indicate that the production of crops, seed processing, oil extraction, and fuel production can be economically viable at farm-scale facilities. At the end of the day, however, a critical mass of oilseed crop producers and biodiesel production facilities has not materialized. It is unlikely that biodiesel produce in Vermont will ever make a dent in diesel consumption in the state.**

Research

A large body of research was accumulated over the course of the VBI—including videos on how to grow and process oilseed crops and produce biodiesel—and are available on the *VBI website* and the *University of Vermont Extension Oilseeds* website. Research products included:

- *Oilseed Production in the Northeast*: A guide developed by UVM Extension on how to grow sunflowers and canola
- UVM Extension developed many Fact Sheets about such topics as *identifying insect pests*; *oilseed storage and cleaning*; processing regulations; and oilseed presses.
- *Oilseed Profit and Loss Calculator*: A spreadsheet-based tool that allows users to exame the feasibility of growing oilseeds to produce biodiesel
- *On-Farm Oilseed Enterprises: Break-Even Economics*: An analysis of land required for 5 Vermont biodiesel production facilities to operate at capacity

VBI grantee, Anju Dahiya (UVM), also edited a textbook called *Bioenergy: Biomass to Biofuels* for college coursework.

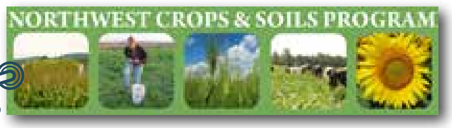
Natural Resource, Physical Infrastructure, and Technology

Oilseed Production in the Northeast and the *UVM Extension Oilseeds* website document crop planting and growth requirements (e.g., soil fertility, nutrient application, variety selection, planting dates, and so on) and crop yield data for many years. The *On-Farm Oilseed Enterprises: Break-Even Economics* report provides scenarios for a 100,000 gallon per year biodiesel facility and a 13,000 gallon per year biodiesel facility. The 100,000 gallon facilty would require 1,000 to 1,600 acres, while the 13,000 gallon facility would require 130 to 215 acres.

The VBI supported the development of State Line Biofuels (Shaftsbury) custom biodiesel production facility. Several other farms (Borderview Farm, North Hardwick Dairy) utilize Springboard Biodiesel's BioPro automated biodiesel processors. BioPro's are automated batch processors that cost about $10,000 and convert 50 gallons of vegetable oil in to 50 gallons of biodiesel.

Technical Assistance and Business Planning

The University of Vermont developed technical expertise to support oilseed crop production and the engineering of biodiesel production facilities:



UVM Extension Oilseeds Program
Dr. Heather Darby, Agronomic and Soils Specialist

UVM Extension Ag Engineering
Chris Callahan, PE, Agricultural Engineer

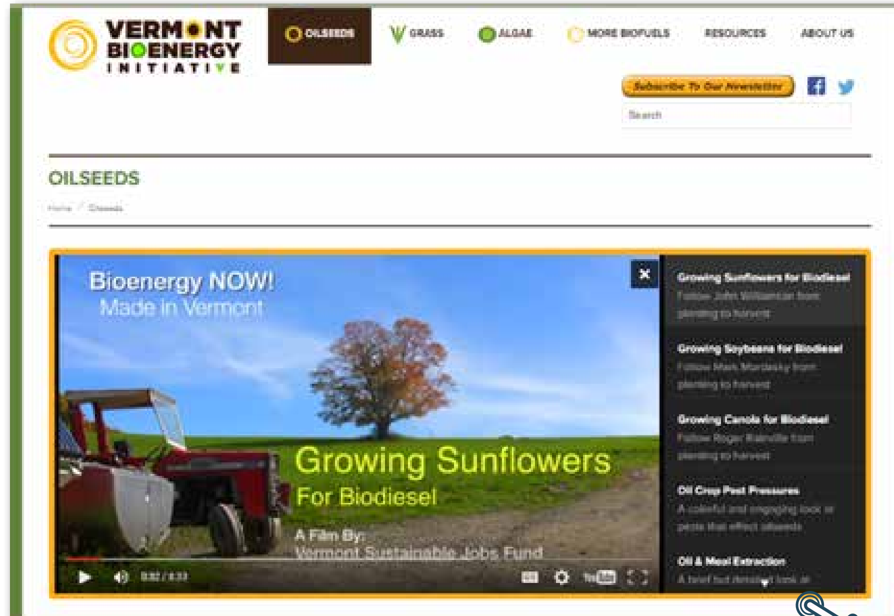
Education and Workforce Development

The VBI supported the development of two Biomass to Biofuels courses offered at UVM and Vermont Tech.

Marketing and Public Outreach

The Energy Cross-Cutting Team developed a series of Farm to Plate Energy Success Stories to showcase farms, businesses, vendors, installers, and technical assistance providers that have made a difference with energy efficiency savings and renewable energy production. One success story focused on biodiesel production at Borderview Farm (page 62).

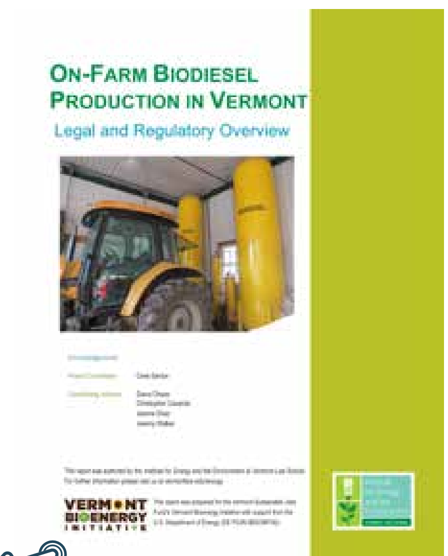
The VBI made 9 videos—available on the VBI website and a Vermont Bioenergy YouTube channel—that showcase oilseed and biodiesel producers in Vermont.



Nine videos were made to showcase oilseed and biodiesel production in Vermont.

Regulation and Public Policy

The Institute for Energy and the Environment at Vermont Law School created an On-Farm Biodiesel Production in Vermont Legal and Regulatory Overview. This overview informs farmers interested in producing biodiesel on their own farm about the potential laws and regulations that may be triggered when adding biodiesel production to their farming activities.



On-Farm Biodiesel Production

Borderview Farm

Alburgh, VT

Highlights: Cost of biodiesel production = $2.29 per gallon ▪ Seed meal used as a co-product for livestock feed or crop fertilizer ▪ Central processing facility and shared equipment use maximizes efficiency for neighboring farms

Roger Rainville's dairy-turned-energy farm in Grand Isle County is a place where area dairy farmers, organic growers, and landowners have made biodiesel from their own locally-grown sunflower seeds.

In 2008, when diesel prices rose from $4 to $5 per gallon, Rainville began experimenting with farm-scale biodiesel production. With guidance from *University of Vermont (UVM) Extension* and grant funding from *Vermont Sustainable Jobs Fund's* *Vermont Bioenergy Initiative*, Rainville began planting sunflowers on a portion of his 214 acres and installing biodiesel processing equipment. Oilseed sunflowers (as opposed to confectionary sunflowers that are grown for eating) are the most popular oilseed crop in Vermont, with hundreds of acres planted statewide. The crop is grown in rotation with grains and grasses and yields high quantities of oil.

Harvesting, Cleaning, and Pressing

Following harvest with a combine, a seed cleaner and grain dryer are used to prepare the seeds for storage in a 200-ton grain bin prior to processing. A flex auger system moves the seeds from the storage bin into hoppers on each press, and screw augers push the seed through a narrow dye at the front of the press. Extracted oil oozes from the side of the barrel and is collected in settling tanks while pelletized meal is pushed through the dye at the front and is stored in one-ton agricultural sacks. The oil can then be used as culinary oil for cooking or further refined into biodiesel. The leftover seed meal is used for livestock feed, fuel for pellet stoves, or fertilizer for crops.

Roger Rainville with BioPro 190 automated biodiesel processor at Borderview Farm.

Biodiesel Processing

The small-scale biodiesel production facility at Borderview Farm is an 800 square foot insulated and heated building (the space does not need to be heated, but the oil should be stored where it will not freeze) that houses an oil press, a BioPro 190 automated biodiesel processor, a methanol recovery system, and a set of dry-wash columns for cleaning the fuel. The clean oil at the top of each settling tank is added to the BioPro 190 processor along with lye, methanol, and sulfuric acid. The automated processor runs through several stages of processing in about 48 hours (esterification, transesterification, settling, washing, and drying), with one break after 24 hours to remove the glycerin byproduct. Safety equipment in the processing facility includes personal protective equipment like aprons, gloves, eye protection, a ventilation system, gas detectors, and spill containment materials. At Borderview Farm a set of standard operating procedures hangs on the wall and blank check-sheets are in a binder to make the process easy to repeat. The finished biodiesel is stored in 250 gallon pallet tanks making distribution to different farms easier. The installed capacity of the facility can process 100 tons of seeds from 138 acres of sunflowers per year, yielding 10,500 gallons of biodiesel and 64 tons of sunflower meal (assuming the state average yield of 1,500 pounds sunflower seeds per acre and operation of 24 hours per day for 260 days per year).

Rainville switched from purchasing diesel for five tractors and one truck to making his own biodiesel. He wanted to be independent of imported fuel, and liked creating a new way for farmers to diversify. "Using land for making biodiesel is not the most economical option compared to some other crops, but it's about creating opportunities to try something different," says Rainville.

Sharing Infrastructure Through the Farm Fresh Fuel Project

In 2012 a group of ten farmers working in cooperation with Rainville and UVM Extension—called the *Farm Fresh Fuel project*—grew 90 acres of sunflowers for development of biodiesel. Cooperating farmers were required to plant, fertilize, weed, and harvest the sunflower crop. Farmers worked to share equipment to accomplish this task. The seed was brought to Rainville for conversion into biodiesel. Rainville did the harvesting for all farms, bringing about 56,721 pounds of seed to Borderview Farm.

Seeds from the ten growers yielded about 3,000 gallons of biodiesel and about 20 tons of meal for livestock feed. The biodiesel and meal were then redistributed to the growers based on the relative volume of sunflower seeds they contributed. One participating dairy farm, Sunset Lake Farms, is using the biodiesel to heat

Photo credits: VSJF

Oilseed sunflowers at Borderview Farm, Alburgh, 2013.

office space, the milking parlor, and water for cleaning and sanitizing equipment, and fed the meal to milking cows at a rate of 3 pounds per day, saving about $3,000 on fuel and feed costs.

Rainville's annual biodiesel use has ranged from 500 to 3,000 gallons per year. At current prices (over $4 per gallon for diesel and $2.29 per produced gallon of biodiesel) biodiesel has saved him from $500 to $4,000 per year in fuel costs. He also emphasizes energy independence as an added benefit. Plus, any growers that also raise livestock can use the meal, which is leftover after the oil is extracted, as part of their feed rations. Rainville recommends talking with an animal nutritionist to blend this into feed at the right ratio, since sunflower meal has a high fat content.

When asked what advice Rainville would give others who want to make their own biodiesel, he says, "Ask questions, ask questions, ask questions. And ask them again!"

Homegrown biodiesel for tractor fuel.

GETTING TO 2020

Innovations in energy and food systems are rapidly providing new opportunities for saving energy, generating renewable energy, and strengthening local food systems. Distributed renewable energy systems and local food systems both emphasize sustainability during extraction/ harvesting, production/generation, and consumption, as well as local control, and the importance of relationships. Federal and state policies, financing options, cultural norms, and business offerings are increasing the availability of renewable energy and local food.

In 2015, the Vermont legislature passed the second strongest renewable portfolio standard in the country—*H.40 (Act 56) - RESET*, which requires utilities to purchase 55% of electricity from renewable sources (or renewable energy credits) by 2017 and 75% by 2032. *Vermont's Comprehensive Energy Plan* calls for 90% of the state's energy consumption to be derived from renewable sources by 2050 (up from 20% today—mostly renewable electricity from hydropower, biomass, and wind, followed by wood for heating and ethanol).

Vermont's food system businesses are already major contributors to renewable energy generation: from the siting of large solar and wind projects on agricultural land, to agricultural and woodland crops, animal waste, and food scraps that are used as feedstocks for electricity, heat, and liquid fuel. Vermont's food system consists of more than agricultural activities—large roofs at grocery stores and manufacturing facilities support solar installations, and several thousand buildings have made efficiency improvements. Many food system businesses have already implemented energy saving and renewable energy producing technologies.

The intersection of renewable energy systems and local food systems is fertile ground for developing sustainable solutions to pressing problems. But there is also the possibility of emerging conflicts over energy goals and food production goals. **How can we meet both Vermont's food and energy goals?** This section of the Farm to Plate Strategic Plan provided a foundation for:

1) improving understanding of food system energy issues (including food system organizations understanding energy issues better and energy organizations understanding food systems better);

2) identifying opportunities and strategies to help food system businesses reduce their reliance on nonrenewable energy sources and increase energy efficiency and the production of renewable energy; and

3) improving the delivery of energy related technical assistance to food system businesses.

As indicated in this plan section, many of the technical assistance, financing, and educational resources needed to advance energy efficiency and renewable energy at food system businesses exist within Vermont, in neighboring states, or are easily available online. But it is also clear that meeting 90% of Vermont's energy needs through efficiency and renewables by 2050 will require major creativity as we collectively tackle outstanding or emerging questions. In particular, at the intersection of food and energy systems, how can the Farm to Plate Network build relationships with energy efficiency and renewable energy networks, planning entities, educational institutions, and state government to move the solar siting question forward? How can we ensure that food system businesses are taking advantage of the full suite of services offered by Efficiency Vermont? How can we collectively advance biomass heating opportunities to food system businesses? How can reinvigorate the conversation around wind energy, anaerobic digesters, and biodiesel production?

Table 4.6.6: Objectives and Strategies for Saving Energy and Expanding Renewable Energy Production

OBJECTIVE	STRATEGY
ENERGY EFFICIENCY	
Research Objectives and Strategies	
To understand the total energy impact/usage of food system businesses	Extrapolate from current data sources and/or find new ways to collect this data. Mine energy audits from NRCS and Efficiency Vermont to gather and consolidate anonymized data for this sector.
To improve our understanding of the characteristics of energy efficient food system businesses in order to improve the delivery of services.	Collect and analyze energy savings data from a variety of categories of food system businesses and share (e.g., trainings, resource guides) among technical assistance providers.
To improve our understanding of the thermal and process energy efficiency needs of food system businesses.	Collect and analyze thermal and process energy savings data from a variety of categories of food system businesses and share among technical assistance providers.
To improve our understanding of transportation efficiency needs of food system businesses.	Collect and analyze transportation energy savings data from a variety of categories of food system businesses and share among technical assistance providers.
Technical Assistance Objectives and Strategies	
To increase consideration of energy efficiency opportunities among technical assistance providers and their clients.	Develop educational programming in concert with trade organizations (e.g., equipment suppliers) that increase the knowledge and capacity of the trades to make energy efficiency and renewable energy standard practice.
	Coordinate consideration of energy use and renewable energy practices as part of farm and food business planning processes (e.g. VHCB, VADP, VEDA, etc.)
	Complete the Farm to Plate Technical Assistance Database project and perform outreach to other technical assistance organizations that may benefit from consolidated energy efficiency and renewable energy resources.
Marketing and Public Outreach Objectives and Strategies	
To create demand for energy efficiency services.	Complete industry benchmarks for energy efficient food system operations.
	Build on current success stories, and complete others for other prominent food system business (i.e., maple, greenhouses, grocery, brewery, cheesemaker, meat processing).

OBJECTIVE	STRATEGY
ENERGY EFFICIENCY	
Education and Workforce Development Objectives and Strategies	
To improve our understanding of enrollment and job placement of students participating in engineering (e.g., electrical, mechanical), agriculture, and technical trades.	Initiate Farm to Plate Energy Cross-Cutting Team outreach to all technical and engineering program department heads. Consider developing outreach materials that demonstrate the field as a career for technically oriented students.
Regulation and Public Policy Objectives and Strategies	
To explore more opportunities for investment in thermal energy and process fuel energy efficiency projects in food system businesses.	Outline current funding situation and combine with data from energy efficiency research to create a cohesive case for additional funding support.
SOLAR ENERGY	
Research Objectives and Strategies	
To assess feasibility for solar hot water at a variety of different food system businesses.	Research feasibility of solar hot water systems for a variety of farm types and other types of food system businesses.
Natural Resource, Physical Infrastructure, and Technology Objectives and Strategies	
To enable more PV on barns and/or other food system buildings to alleviate siting issues.	Advise new barns/food systems buildings be built to structurally support PV and sited for max solar exposure. Develop a short list of qualified structural engineers who can be consulted for this matter.
	Support GMP in assessing technical feasibility of thin film in Vermont climate to get over the hurdle of barn structural problems for PV.
Network Development Objectives and Strategies	
To improve relationships between renewable energy proponents and organizations and food system organizations.	Better leverage existing Energy Cross-Cutting Team activity and communicate directly with leaders in other relevant organizations to seek overlapping activity and information sharing opportunities. Make more connections between—and communicate more clearly about—how solar is a source of revenue and/or can reduce operating expenses and improve farm viability.

OBJECTIVE	STRATEGY
SOLAR ENERGY	
Network Development Objectives and Strategies	
To improve community, producer, and developer understanding of siting to create more informed opinion, decision making, and positive community responses.	Farm to Plate Energy Cross-Cutting Team and Farmland Access and Stewardship Working Group should host community events to enable conversations about energy siting on agricultural lands.
WIND ENERGY	
Natural Resource, Physical Infrastructure, and Technology Objectives and Strategies	
To increase the number of on-farm installations of small scale wind turbines.	Focus development in the Champlain Valley region where small scale wind projects are most feasible. Propose reasonable standards for the farm sector for shadowflicker, noise, and set-back.
ANAEROBIC DIGESTERS	
Network Development Objectives and Strategies	
To provide a clear, complete cost benefit on digester technology, history, and progress, and share this information with producers.	Develop a small, focused project aimed at literature and project review to consolidate digester history, performance and project cost/benefit. Include operational strategies and lessons learned from successful operators. Assist and reduce costs associated with applying for federal funding. AD tours (virtual and field), inclusion of info in farm meetings. Support GMP and VAAFM in their current work.
BIOMASS HEATING	
Natural Resource, Physical Infrastructure, and Technology Objectives and Strategies	
To increase the number of biomass heating systems at farm and food businesses.	Support increased availability of and access to conversion appliances (boilers, furnaces, etc.) that accommodate coarse biomass fuels (chips, pucks, pellets) at output ratings relevant to Vermont's farm and food businesses (small to medium size).
	Coordinate technical assistance, education, and outreach programs to improve industry awareness and understanding of the cost / benefit structure of biomass systems; i.e. high capital, low recurring cost model.
	Continue to support research and development of both crops and conversion systems that provide for sustainable production of biomass feedstocks and delivery of fuels in forms feasible for transport, storage and use by a growing number of farm and food businesses at a reasonable replacement cost.

OBJECTIVE	STRATEGY
LIQUID BIOFUELS	
Natural Resource, Physical Infrastructure, and Technology Objectives and Strategies	
To increase the use of sustainable liquid biofuels by farm and food businesses.	Continue the work completed under the Vermont Bioenergy Initiative and other initiatives focused on reliable oilseed crop production and yields, development of algal production systems, and distributed production systems within Vermont.
Regulation and Public Policy Objectives and Strategies	
Objective: To increase the production and use of liquid biofuels by all sectors.	Explore a state level liquid fuel incentive that fosters the increased production and use of sustainable liquid biofuels (e.g., per gallon credit).

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When looking at any study offering data on energy use in food systems, it is important to remain cognizant of how system boundaries are drawn and what accounting methods are used. The differences in the studies mentioned above emerge largely because they use different methods to assess energy use in food systems, and draw different boundaries both around the food system more generally and between the sub-systems that make up the food system. For example, the University of Michigan researchers attempted to extract all of the energy used for transportation and tabulate it as a single category, while the USDA only tabulated energy used for long-distance transport separately as transport (called 'freight' in its report) and leaves the energy used in short-distance transport within other sub-systems. Although these two analyses do not match up perfectly with one another, they agree well enough to give readers a sense for the substantial energy demands of the U.S. food system, and probably offer a reasonable sense for the embodied energy in the average piece of food that Vermonters eat.

27 Op Cit., Patrick Canning.

28 Average daily food consumption is estimated at 2,500 Calories. This figure multiplied by 15 Cal of input yields 37,500 Cal, or 13,700,000 Cal per year. One gallon of gasoline contains 132 megajoules, or 31,522 Cal. The energy cost of one year's worth of food is equivalent to 434 gallons of gasoline used over that same time period. Vermont's per capita gasoline consumption hovers around 525 gallons per year, or 1.44 gallons per day.

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CROSS-CUTTING ISSUES

Food System Energy Issues

Credits

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