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Solar Energy Use in U.S. Agriculture Overview and Policy Issues

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Abstract

This report serves as an overview of solar energy use by farmers and ranchers in the U.S. that identifies trends and future potential. Agriculture was an early adopter for remote applications. These are still cost effective today, but in the last decade agriculture has seen the number of grid-connected systems and the average size of solar systems increase. System sizes range from 5 watts to 1 Megawatt (MW) and cost from a couple hundred to almost 10 million dollars. Some solar thermal installations are also used in agriculture, but are currently overshadowed by solar electric. Though solar energy can reduce energy cost volatility and greenhouse gases, its high capital cost and the lower average price of competing fuel remain impediments to growth. For this reason, development in solar has been policy driven. The report reviews the regulations and incentives that are available to farmers and ranchers and have recently boosted installations, and examines major financial influences. Solar energy development in agriculture varies considerably by State, incentives, and energy prices.

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1. Introduction

Agriculture is an important part of the U.S. economy and culture, and it can play an important role in distributed generation of energy. This report identifies the opportunities for solar energy use in U.S. agriculture. Section 2 provides an overview of energy use in agriculture. Section 3 presents the solar resource potential, and Section 4 discusses the types of solar energy available. Section 5 displays the solar energy use and potential in the U.S., and Section 6 provides selected examples. Financial considerations for solar energy adoption are examined in Section 7. U.S. policies that can support solar energy use in agriculture are compiled in Section 8. Section 9 concludes the report. A glossary with helpful definitions is available at the end of the report, as is a compilation of useful links on solar energy.

Farmers have the tradition of being stewards of the land, and their investment in renewable energy supports their role of protecting the land, air, and water. Solar energy, like other renewables, offers an opportunity to stabilize energy costs, decrease pollution and greenhouse gases (GHGs), and delay the need for electric grid infrastructure improvements (Brown and Elliott, 2005). Solar energy systems have low maintenance costs, and the fuel is free once the higher initial cost of the system is recovered through subsidies and energy savings (from reduced or avoided energy costs). According to the first USDA On-Farm Energy Production Survey, solar panels have been the most prominent way to produce on-farm renewable energy (USDA, 2011).

Agriculture hosted some of the first terrestrial photovoltaic (PV) applications of solar energy, as it found uses for solar in remote locations around ranches and farms. Early on, solar electric made economic sense for a number of low power agricultural needs when running utility lines to a specific location was either not possible or too expensive.

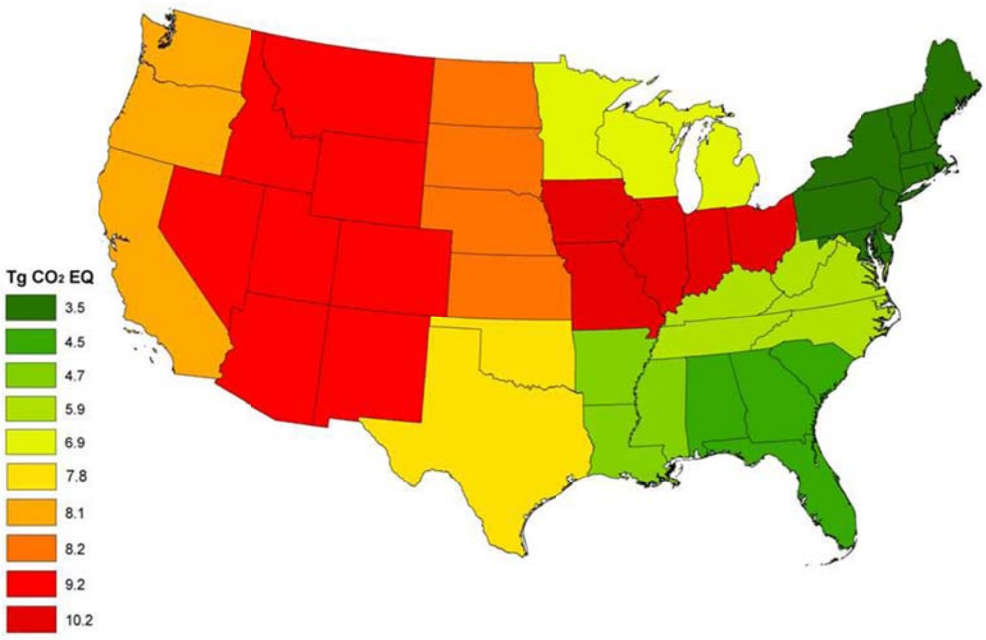
Kerosene, diesel, and propane have traditionally been used in agricultural operations to power generators when grid connection was not available. However use of these fuels has problems: cost of transporting fuel, volatility of fuel costs, fuel spillage, noisy generators, noxious fumes, and high maintenance needs. The disadvantages of using propane or bottled gas to heat water for pen cleaning or in crop processing applications, or to heat air for crop drying, are the cost of fuel and transportation, along with safety concerns. For many agricultural needs, solar energy provides a good alternative. Modern, well-designed, simple-to-maintain, and cost-effective solar systems can provide energy that is needed when and where it is needed.

Today, distributed generation, backup in the case of utility grid outage, and net metering present further opportunities for grid-connected solar energy use in agricultural settings. Larger solar installations have been developed; still, in agriculture solar energy generation has been small when compared to wind energy generation and to date has not surpassed 1Megawatt (MW). Small solar PV installations are below 10 kilowatt (kW), small commercial are 10kW-40kW, and large commercial PV installations range from 40kW-1MW. According to USDA (2011) the average size of a PV system for U.S. farms is 4.5kW.

Solar thermal (low-temperature thermal), which can be used in agricultural operations for hot water needs or for space heating, is overshadowed from PV installations. The residential sector dominates this market, but the potential in agricultural settings is large.

By using solar energy, U.S. agriculture has the potential to significantly reduce the use of gasoline, diesel, gas, electricity, wood and subsequently emitted GHGs. Almost one quadrillion British thermal units (Btu) of direct energy was used for agriculture in 2008, releasing almost 69 Tg (~76 million Tons) of carbon dioxide (CO_2) emissions (around 1% of CO_2 emissions from total US energy consumption). The fuel distribution of the CO_2 emissions came from 43% diesel fuel and 33% electricity, 13% gasoline, 7% petroleum liquefied petroleum (LP) and 4% natural gas (USDA, 2008a). The geographic distribution of CO_2 emissions from direct energy use in agriculture in Figure 1 shows a strong correlation between production and energy use/emissions: States with high agricultural production use the most energy and therefore have the highest CO_2 emissions. However, emissions are also influenced by the types of energy used for farm production in each region, hence the potential for the clean solar energy source (USDA, 2008a).

Figure 1. CO_2 Emissions from 2005 Energy Use in Agriculture by State



Source: USDA, 2008a

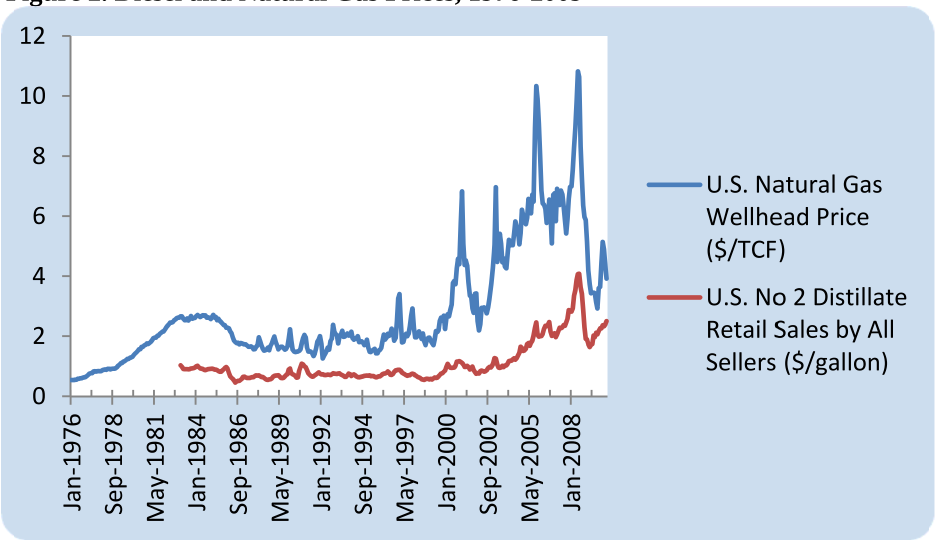
2. Energy Use in Agriculture

As energy prices and volatility have increased in the past decades, incentives for energy efficiency and on-site renewable energy use have emerged.

Figure 2 shows the upward trend and the persevering volatility in diesel and natural gas prices for the last decade. With a nationwide average of 6% of farm expenses relating directly to energy (Brown and Elliott, 2005), solar has emerged as an alternative energy source that ensures predictability, independence, and even cost effectiveness for a number of agricultural applications. Potential is even higher for crop farming where energy expenses reach 9%. Energy expenses on the farm are also above average for greenhouse nurseries, floriculture, aquaculture, sheep, goat, and beef production (Table 1).

Unfortunately 69% of direct energy use on farms is not categorized, which makes it more difficult to identify opportunities for solar energy use. Of the remaining 31% energy to run motors represents 18% of overall energy use, and energy use in machinery represents 9%. Onsite transportation is 3% and lighting 1%. Though quantitative data is lacking, Brown and Elliott (2005) also identified drying, curing, heating, ventilation, air conditioning, and water heating as end uses widely accepted as using large amounts of energy.

Figure 2. Diesel and Natural Gas Prices, 1976-2009



Source: Energy Information Administration (EIA)

Table 1. Energy Expenditures in Agriculture by Farm Type (% of farm expenses)

Farm Type	Energy Expenditures
Oilseed and Grain Farming	9%
Other Crop Farming	9%
Greenhouse Nursery and Floriculture	7%
Animal Aquaculture	7%
Sheep and Goat Farming	7%
Beef Cattle Ranching and Farming	7%
Fruit and Tree Nut Farming	6%
Dairy Cattle and Milk Production	6%
Hog and Pig Farming	4%
Poultry and Egg Production	3%
Cattle Feedlots	2%
United States Farm Average	***6%***

Source: Brown and Elliott, 2005

Gasoline, diesel, LP gas, and natural gas are used mostly in planting, tillage, harvesting, drying, irrigation, water pumping and transportation. Natural gas is also commonly used to control greenhouse temperatures, for space and water heating, and for crop drying. The main use of electricity is for irrigation and in operations in livestock and dairy facilities. Lighting, ventilation, refrigeration, water/space heating, pumping, and fanning for aeration and crop drying are common electricity uses. Today solar energy can substitute for the more traditional energy sources identified in Table 2 in all the above categories for a variety of applications.

Table 2. Energy Uses in Agriculture by Source (trillion Btus)

	Motors	Lighting	Machinery	Other	Onsite Transport
Total Energy (trillion Btus)	*167*	*5*	*80*	*653*	*30*
Gasoline	80.2%	-	1.3%	0.8%	1.3%
Diesel	4.2%	-	96.3%	38.1%	96.3%
Other	9.0%	40.0%	2.5%	25.9%	2.5%
Natural Gas	1.2%	-		14.4%	-
Electricity	5.4%	60.0%		20.8%	-

Source: Brown and Elliott, 2005

The potential for solar energy use is diverse. As can be seen in Table 3, the distribution of energy use differs largely by agricultural sector. Oilseed and grain farming uses the most energy and dominates motor use. Oilseed and grain farming, dairies, and poultry operations rate high on energy use for machinery.

Table 3. Energy Use for Select Agricultural Sectors (trillion Btus)

	Motors	Lighting	Machinery	Other	Onsite Transport	*Total*
Oilseed and Grain	49	1	13	93	8	*163*
Dairy	12	-	13	54	0	*83*
Poultry	12	1	13	49	1	*63*
Greenhouse/Nursery	8	-	4	34	0	*46*
Fruits and Trees	8	-	4	23	1	*37*
Hogs and Pigs	7	1	1	21	0	*31*

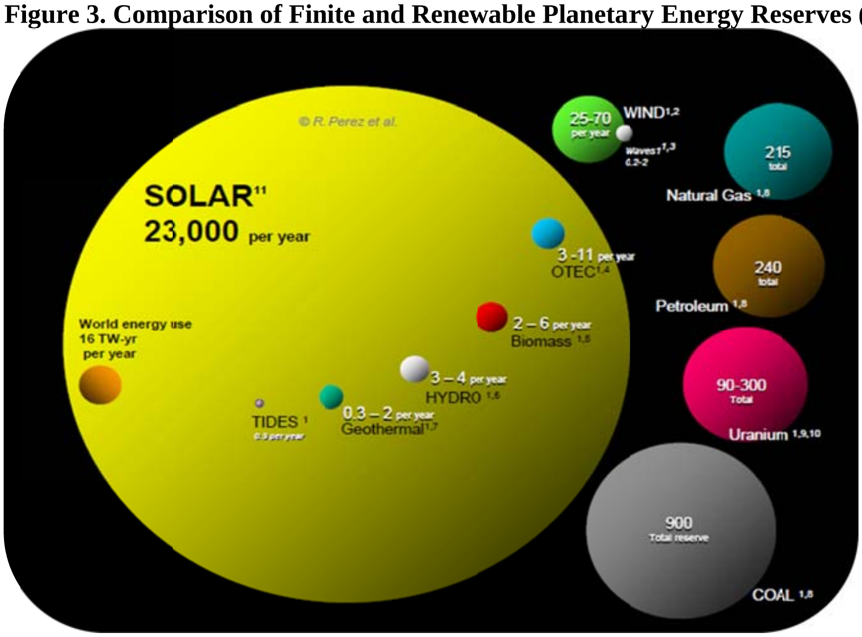
Source: Brown and Elliott, 2005

3. Solar Resource Potential

In 1931, not long before he died, the inventor Thomas Edison told his friends Henry Ford and Harvey Firestone, "I'd put my money on the sun and solar energy. What a source of power! I hope we don't have to wait until oil and coal run out before we tackle that." (Newton, 1989). The schematic developed by Richard Perez of the University of New York at Albany (Figure 3) shows the vast potential of this resource. This potential has yet to be fulfilled since the amount of solar energy used for heating and electricity in the U.S. is less than 1% of total energy generated.

Solar energy use in the U.S. has increased significantly over the years. With just 43.5 MW in 1992, installed PV capacity reached 1168.5 MW in 2008 (IEA, September 2009). The backbone of solar energy development has been the approach of distributed generation (DG) - the generation of energy close to the point of use - that typically ranges from 1 kW to 5 MW. Utility scale power plants accounted for just over 5 % of U.S. cumulative installed PV capacity (IEA, September 2009) and 7% of the grid-connected PV capacity in the U.S. However with the 2008 extension of the Investment Tax Credit to utilities, such installations should grow significantly in the future. In 2009 annual utility installations tripled to 18% of the annual grid connected PV installations (Sherwood, July 2010) and companies continue to announce plans for many large solar projects, including solar thermal electric projects, utility-owned projects, and third-party-owned projects. The biggest utility-scale project that came on line in 2009 was a 25 MW PV installation in Arcadia, FL[1] (EIA, 2009). Concentrated solar projects (CSP) add 432.5 MW of solar thermal electric capacity to utility scale solar (Sherwood, July 2010).

Figure 3. Comparison of Finite and Renewable Planetary Energy Reserves (Terawatt-years)



Total recoverable reserves are shown for the finite resources. Yearly potential is shown for the renewables. Source: Perez and Perez, 2009.

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[1] Commissioned by Florida Power and Light, it is the largest PV facility in North America (90,000 PV modules).

The cumulative, grid-connected PV capacity by State through 2009 is presented in Table 4**.** California is the leading State with six times the capacity of the subsequent State. New Jersey, Colorado, Arizona, Florida, Nevada, and New York also stand out with over 30 MW capacity each. Most of the States in the U.S. (about 70%) have less than 6 MW installed each. In terms of growth the California market slowed down in 2009 to a marked 7% increase versus 95% in the previous year (but still represented about 50% of the 2009 installations). The market more than doubled in New Jersey, Florida, Arizona, Massachusetts and Texas, while Florida's market increased over 30 times largely due to a single utility installation (Sherwood, July 2009).

Solar resource data are collected by NREL[2] for most locations in the U.S. and U.S. territories. The availability of the solar resource in the U.S. can be seen in Figure 4. While solar radiation is best in the southwestern part of the U.S., a large portion of the U.S. has good to very good access (4.5 to 6.5 kWh/m^2/day) to the sun's energy.

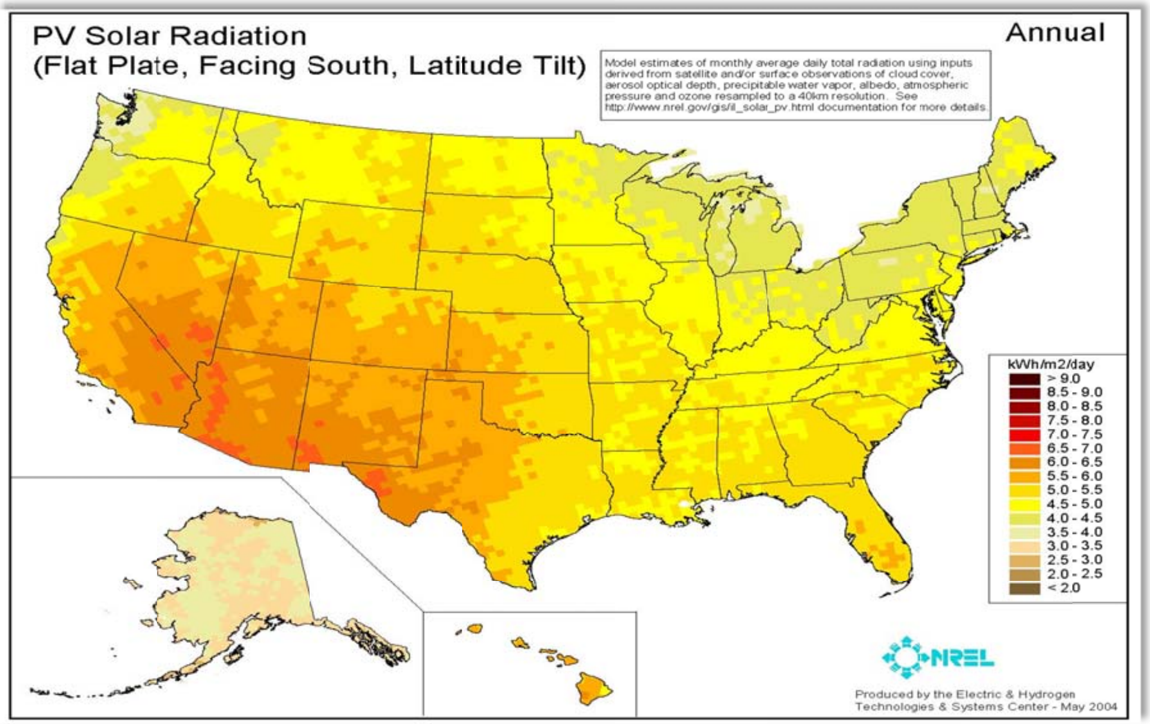
Table 4. Grid-Connected PV Capacity (MW) by State through 2009

	State	MW	Share
1	CA	768	61%
2	NJ	128	10%
3	CO	59	5%
4	AZ	46	4%
5	FL	39	3%
6	NV	36	3%
7	NY	34	3%
8	HI	26	2%
9	CT	20	2%
10	MA	18	1%
	All Other	***83***	***7%***
	Total	***792***	***100%***

Source: Sherwood, July 2010

[2] http://rredc.nrel.gov/solar/old_data/nsrdb/ (Accessed September 13, 2010)

Figure 4. PV Solar Radiation



Model estimates are of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40 km resolution. See http://www.nrel.gov/gis/il_solar_pv.html documentation for more details.
Source: National Renewable Energy Laboratory (NREL)[3]

Typically, the highest solar irradiance occurs in the summer, but the amount of solar radiation also depends on the amount of cloud cover. Thus, sometimes the maximum radiation occurs in the spring time. During winter, solar radiation is usually at its minimum.

The photovoltaic or thermal panel should be oriented for optimum exposure to the sun's radiation. There are a number of variables in calculating the best direction, but general guidelines usually cited are: (1) Solar arrays should face south in the Northern Hemisphere and north in the Southern Hemisphere; (2) With no seasonal adjustments to a solar module's angle, the angle should be set to the equivalent of the location's latitude; (3) If the solar array angle is tilted seasonally, two alternatives are followed as a rule of thumb: (a) the angle is set to the location's latitude plus 10 degrees for fall/winter, minus 10 for spring/summer or (b) the angle is set to the location's latitude in the spring/fall, plus 15 degrees during winter, minus 15 degrees in the summer. Small improvement in energy capture may be gained (3-5%) with further refinement[4,5]. Figure 5 shows the angle change when it is adjusted twice a year. Panels that track the movement of the sun throughout the day can receive 10% (in winter) to 40% (in summer) more energy than fixed panels, but tracking can be uneconomical or impractical in many cases.

[3] http://www.nrel.gov/gis/images/map_pv_us_annual_may2004.jpg; http://www.nrel.gov/gis/solar.html (Accessed October 20, 2009)
[4] http://www.macslab.com/optsolar.html (Accessed July 10, 2009)
[5] http://www.theenergygrid.com/grid/articles/paneltilt.html (Accessed July 10, 2009)

Figure 5. Change in PV Module Angle for Two Adjustments per Year

Left shows fall/winter and right shows spring/summer. Photographs courtesy of Brian Vick, ARS

4. Types of Solar Systems

Two types of solar systems are examined in this report: solar electric that converts solar energy to electric power and solar thermal which uses solar energy to heat water or air[6]. Both convert sunlight into usable energy and both have many applications in agricultural settings to aid farmers and ranchers in satisfying the energy requirements of their operations. The report focuses on active solar technologies, though crop drying and outbuilding heating are discussed under solar thermal systems. Passive solar techniques, like building orientation, space design and materials selection for favorable heat, air, or light dispensing properties are not presented in the report[7].

a. Solar Electric (PV Systems)

PV devices generate electricity directly from sunlight via an electronic process that occurs naturally in certain materials. Solar energy frees electrons and induces them to travel through an electrical circuit, powering an electrical load. PV devices can be used to power anything from small electronics such as calculators and road signs to homes and large commercial buildings.

The photoelectric effect was discovered by a French physicist, Edmund Bequerel, in 1839 and the science behind this effect was published in a paper by Albert Einstein in 1905. Einstein would later win the Noble Prize in Physics for this work in 1921.

The basic building block of photovoltaics is a round or square cell that converts sunlight into direct current (DC) electricity. Cells are wired together to form a module; multiple modules are arranged together to form a panel; and multiple panels produce a PV array. In general, the larger the area of a module or array, the more electricity will be produced. The cells and modules can be wired (in series and/or parallel electrical arrangements) to create a wide range of voltage and current combinations. The majority of applications in smaller projects (< 200 W) are for 12 to 24 volt outputs with the amperage depending on how much power is required.

PV systems produce DC power. When energy is needed to operate alternating current (AC) equipment, the DC output is converted to AC with an inverter. Most household appliances require AC electricity, but DC-powered appliances can be ordered.

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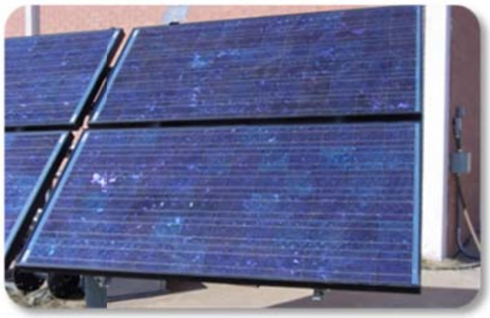
[6] Solar chemical with hydrogen technologies is also a solar option, but will not be discussed in the context of this report.

[7] Though not the focus of this report, passive solar applications can include some of the simplest, most logical and cost-effective applications in agriculture to be considered during building construction or later additions and changes.

Currently, the two most common types of PV modules sold are crystalline silicon (mono-crystalline and multi-crystalline[8]) and thin film (amorphous-silicon and cadmium-telluride), examples of which are seen in Figure 6.

Figure 6. Example of Multi-Crystalline Modules (left) and Amorphous-Silicon Thin Film Modules (right).



Photographs courtesy of Brian Vick, ARS

[8] Also called polycrystalline

The advantages of using crystalline silicon modules:

1. According to Solarbuzz[9], an international solar energy research and consulting company, 82% of PV modules manufactured in the world are crystalline silicon, making them easy to find in the market;
2. Module efficiency of crystalline silicon modules is higher than thin film (12 to 20% versus 3 to 11%), so fewer modules are required and the system uses less space, which can be of importance when used on high-valued agricultural land;
3. The multi-crystalline modules have been demonstrated to last over 30 years and warranties up to 20 years are offered (According to Vick 2003, thin film modules have only been around since 1988, and early modules demonstrated problems with performance degradation over time.);
4. Crystalline silicon modules demonstrate only a slight decline in power output over time (~1% per year) while amorphous-silicon (a-Si) thin film modules experience about a 20% initial decrease followed by a 1% annual decrease thereafter) (Osborne, 2003). Normally, solar-PV companies installing a-Si modules expose the modules to the sun prior to installation so power fluctuation will not vary significantly for customer;
5. Tempered glass makes multi-crystalline modules less likely to break (thin film modules currently require untempered glass). While thermal cracking occurred with a-Si modules prior to 2005, most manufacturers are able to either strengthen glass without tempering or using a stronger nonglass material like tedlar; and
6. Crystalline silicon modules are non-toxic and can be disposed of in landfills[10] (e.g., unlike cadmium-telluride, according to EPA, which cannot be disposed in landfills due to toxicity of cadmium).

The advantages of thin-film modules:

1. Amorphous silicon modules use less than 1% the amount of silicon that crystalline silicon uses which decreases the manufacturing cost;
2. Thin film modules can generate higher voltage than crystalline silicon modules, which is important in applications with power requirements from 200 Watts to 2 kilowatts;
3. Generally the price per Watt for thin film modules is cheaper for large PV (Megawatt and larger size) installations;
4. The power loss with increased module temperature for a-Si modules is ~0.25%/^{o}C compared to crystalline silicon modules (King et al, 2001);
5. Efficiency improvements have been demonstrated by a-Si modules over crystalline silicon modules in cloudy conditions (Wu and Lau, 2008); and
6. Flexibility of a-Si modules allows them to more easily be integrated into buildings (e.g., building integrated PV, BIPV).

In addition to modules, PV systems can include inverters and/or batteries, depending on the application. Installations may be ground-mounted (sometimes integrated with farming and grazing), mounted on a roof, or built into the walls of a building.

One way to collect more energy with a PV module is to cause the module to track the sun during the day in order that the sun's rays are closer to perpendicular to PV module surface (e.g. solar tracking). Solar tracking can result in 25 to 40% more energy capture depending on location and

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[9] http://www.solarbuzz.com/marketbuzz2010-intro.htm (Accessed July 12, 2010)
[10] It should be noted however that some thin-film manufacturers have end-of-life take-back and recycling programs.

tracker, and can be either motorized (motor turns PV modules toward the sun) or passive. Passive tracking does not use a motor, but relies on the converting of liquid into gas through heat[11] in tubes located on either side of PV modules; solar-heated gas flows back and forth between the two tubes, which shifts the center of gravity of the PV modules and results in the PV modules tracking the sun (see Figure 7). Passive (single axis tracking) or active (single or dual axis) tracking systems are not economical unless the tracking system is for a PV array size of at least 500 Watts. If more power is desired for lower wattage systems, it is recommended to add more PV modules. Since most residential PV systems are mounted on the roof, from an aesthetic, maintenance, or structural design perspective, fixed PV systems are almost always preferred. As PV arrays get larger (especially in megawatt range), motorized tracking systems are much more likely.

Figure 7. Example of Passive Tracking PV Array

Photographs courtesy of Brian Vick, ARS

The introduction of solar PV in the late 1950s came through space applications. During the energy crisis in the 1970s, PV technology gained recognition as a source of power for non-space applications and found an application in remote powering, including rural settings. For agriculture, the sales of solar-PV stand-alone systems began in the 1980s. At the time, the most common agricultural applications included running motors, pumping water, charging vehicle batteries, and powering remote security lighting.

The primary agricultural applications for solar-PV electricity have been for battery charging (fence chargers, gate openers, and building lighting), and water pumping from remote wells, streams, or lakes (to provide water for domestic uses, livestock, and small-scale irrigation). Supplementing (or substituting) electricity from the grid has gained momentum over the last decade. Depending on the size of the system and the application required, PV systems for an agricultural operation can cost as little as a few hundred dollars to as much as thousands of dollars.

[11] The liquid is usually a refrigerant used in cooling systems like air conditioners, refrigerators, etc.

On–grid and Off-grid PV Systems

PV applications are divided into two categories: on-grid and off-grid. On-grid PV systems are connected to the utility grid; they can power electrical loads at the location or when the energy produced is not used they can feed it back into the electrical grid. Off-grid PV systems are not connected to the utility grid and provide power onsite in remote areas.

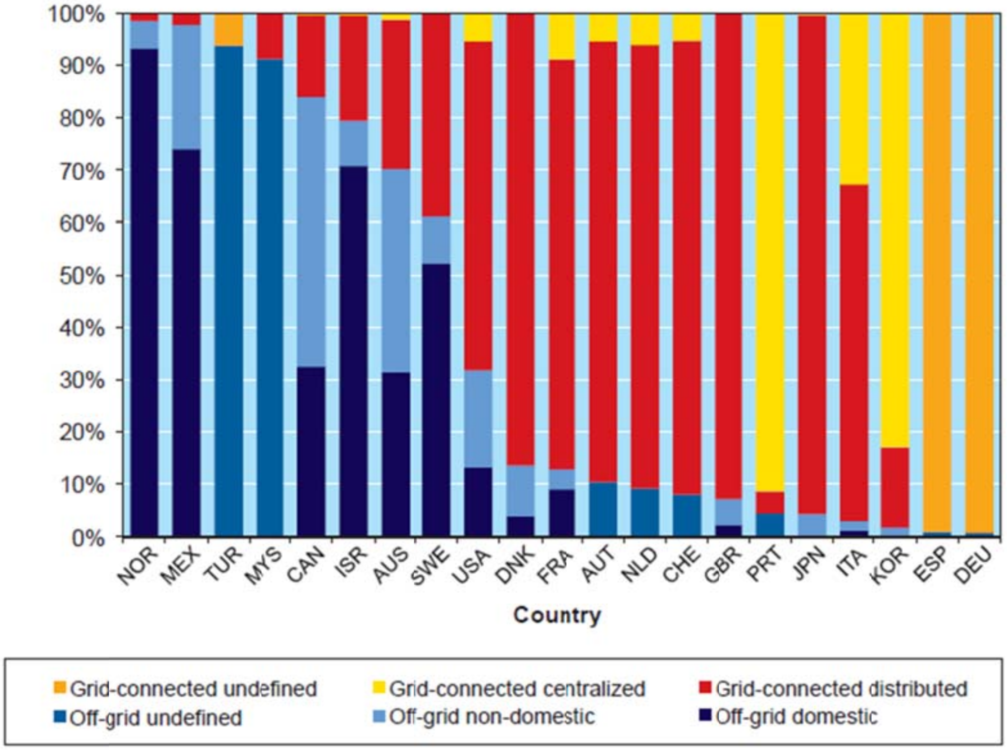
A grid-tied electrical system is a semi-autonomous electrical generation system which links to the local electrical grid. A typical system is between 1 and 100 kW in size. When excess electricity is generated, it feeds the excess electricity back into the grid. When insufficient electricity is generated by the sun, then electricity is drawn from the grid. The DC power from the PV array is converted to AC through an inverter. When a solar system is connected directly to the electrical grid, battery storage is not needed; therefore, a grid-tied system costs less than an off-grid system.

A PV off-grid electrical system is not connected to a local utility grid and basically relies solely on the solar-generated electricity for the application's needs. Such a system might use batteries to store the generated energy, in which case a charge controller (or regulator) is also needed. In the case of water pumping systems, energy storage is not required. Excess water is pumped into a storage tank on sunny days so to be used on cloudy days[12]. Nearly all batteries used for PV systems are deep discharge lead-acid type; other types such as nickel cadmium (NiCd), and nickel-metal hydride (NiMH) are considerably more expensive. The battery lifetime is typically between 5 and 10 years as long as the batteries are well maintained[13] and aren't excessively discharged or overcharged. Most off-grid systems are rated at less than 1-2 kW, have several days of battery storage, and usually serve DC loads (Sandia, 1991). An inverter is required when AC power is needed. A backup generator (wind, gas, or diesel) may also be recommended in some cases and for larger systems.

Though off-grid applications were the first natural outlet for PV, and prior to 1996 the U.S. market was comprised primarily of stand-alone, off-grid systems, it was the grid-connected electricity generation that boosted PV to its present market potential. At the end of 2008, grid-tied electrical systems accounted for approximately 95% of the 13,425 MW cumulative global PV capacity. This is a dramatic rise for on-grid capacity which was less than 30% in 1992, and means that the global off-grid share fell from over 70% to just 5% in the same period (IEA, 2009). Off-grid actually accounts for a larger percentage of PV installations in the U.S. (32% of the 1,168.5 MW installed capacity) due to substantial commercial and residential off-grid needs, including agriculture. Figure 8 shows that globally the U.S. resides in the middle of the spectrum relative to the balance of on- and off- grid installations. Nonetheless, the majority of PV modules in the U.S. are used for grid-connected power generation (68%). The U.S. on/off- grid picture completely flipped between 1995 and 2008, with about 68% off-grid and 32% on-grid PV back in 1995 (IEA, September 2009).

[12] If there are too many cloudy days (making storage tank excessively large), then additional PV modules can be added so that water can be pumped on cloudy days.
[13] Stored in well-ventilated buildings or enclosures, distilled water added when low, and not placed on concrete.

Figure 8. Percentage Share of On- and Off-grid Power Throughout the World



Source: International Energy Agency (IEA), September 2009

Traditionally, **solar energy in agriculture** has been associated with off-grid applications. Today many applications in the U.S. are off-grid systems, but in States where interconnection and net metering policies are available, on-grid systems are gaining momentum; the number of farms, ranches and especially wineries that are offsetting part of their energy needs with PV panels has been increasing over the years. A number of these efforts are linked to green and carbon neutral initiatives.

For agriculture, a "remote" location where an off-grid PV system is used can be several miles away or as little as 50 feet from a power source. It all depends on the location, the application, the economics, and the original energy fuel used. Water pumping, a major agricultural application, is among the principal off-grid, non-domestic PV power system applications[14]. Stand-alone systems around the farm or ranch are also excellent for uses that don't require a lot of power. PV is most cost competitive with other small generating sources in applications where a small amount of electricity has a high value. PV is also cost effective in places where utility-generated power is unavailable, impractical, or too costly. PV systems can be cheaper than installing or extending power lines, which also require a transformer for voltage step down, which makes them an economical alternative at distances of more than 0.5 to 1 mile from existing power lines (Zahedi, 2006). A utility study into livestock watering and other potential markets for PV presented in a Food and Agriculture Organization (FAO) report illustrates this point both in terms of life-cycle cost and installation cost for a pump 1 mile from the existing electrical distribution

[14] Examples of other principal off-grid applications for PV include remote communications and communication relays, as well as safety and protection devices that are not connected to the utility grid.

system (Table 5). In general Solarbuzz estimates solar to be on average 20-90% cheaper than the competing energy alternative for off-grid applications[15].

Table 5. Cost Comparison of Livestock Watering Pump for PV or Grid Extension

Type of Service	Installation Costs ($)	Annual Operating Costs ($)	Total Costs ($0	Lifetime (years)	Annual Life Cycle Costs ($)
Conventional Service	10701	1036	11737	30	910
PV Service	4350	355	4705	20	420

Source: Food and Agriculture Organization (FAO), 2000

According to IEA (June 2008), off-grid system turnkey prices vary $10-20/W depending on the project, battery storage use and remoteness. Such systems can be used both for small agricultural energy needs under than 1 kW (examples include lighting, fencing, water pumping for livestock and irrigation), as well as for larger energy needs in irrigation and other applications around the farm and ranch. Irrigation systems that can use a water storage tank instead of a battery can be cheaper ($7-10/W). Worldwide, a system price of about $10–12/W appears to be common (Zahedi, 2006). In the case of off-grid solar, the cost of PV modules only constitutes one-third of the total system cost.

System prices for off-grid applications tend to be two times higher than those for grid-connected applications when batteries and associated equipment are utilized. Turnkey prices for 2-5 kW grid-connected, roof-mounted systems are $7-9/W; grid-connected systems up to 10 kW (that can be used for irrigation and other agricultural operations) are priced at $7-8/W, while systems above 10 kW can be cheaper at $5.5-7.5/W (IEA, June 2008). Systems above 750 kW average $6.8/W (IEA, June 2009). Average system prices vary geographically from a low of $7.60/W in Arizona followed by California at $8.10/W and New Jersey at $8.40/W. The highest cost based on available data was $10.60/W in Maryland (IEA, June 2009). The cost of the PV modules in on-grid installations accounts for two-thirds of the total system cost. Additionally 73% of the reduction in the solar system price from $10-11 /W[16] in 1998 to $7-9/W in 2007 came in the form of non-module costs.

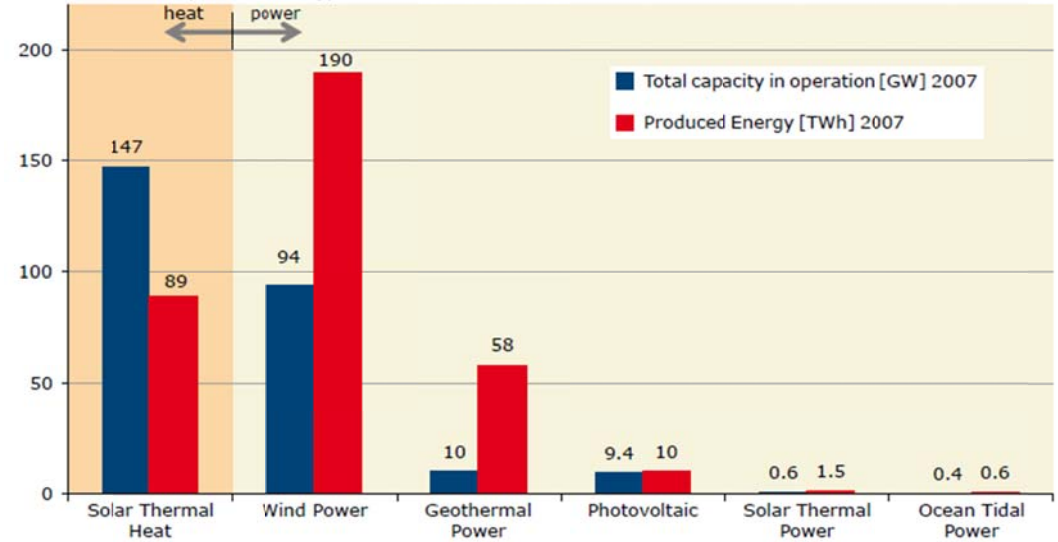
Solarbuzz[17] estimates that an average 2 kW off-grid residential system with battery backup will cost around $16,618, a 50 kW commercial system will cost around $311,199, and a 500 kW industrial system will cost around $2,256,616.

b. Solar Heating

The PV industry is still in its relative infancy compared to the solar heating industry. If the efficiencies of PV panels (20% for best crystalline modules) commercially reach the efficiency of today's heating collectors (70-90%), solar energy usage will dramatically increase. As shown in Figure 9, excluding hydroelectric capacity, thermal heat comes second only to wind power in terms of capacity and produced energy.

[15] http://www.solarbuzz.com/StatsCosts.htm (Accessed July 12, 2010)
[16] 2007 dollars
[17] http://www.solarbuzz.com/SolarIndices.htm (Accessed 6/29/2010)

Figure 9. Worldwide Renewable Energy Capacity in Operation [GW] and Annual Energy Generated [TWh] in 2007 by Technology Used



Source: International Energy Agency (IEA), May 2009

Solar heating uses the energy of the sun to heat air or water. Thermal air-heating is used for the heating or ventilation of buildings and also for crop drying. Solar hot water systems are mainly used for heating water for domestic or commercial applications; alternatively, they can be used for space heating through radiant (hydronic) heating systems (floor, wall, or radiators) or less commonly through air heating with a heat exchanger. A relatively new application, still under development, involves solar air cooling, or air-conditioning.

There are a variety of designs for solar heating. Each has strengths for specific climates and needs, and solar system professionals can help with selecting the most appropriate system. A basic difference exists between active and passive solar heating. Active solar heating uses circulating pumps and controls to move air or liquid from the solar collector directly to a load (such as the building space heating or hot water system) or to storage. Passive solar heating does not use pumps or controls; it relies on means of natural forces to circulate the hot air or liquid medium.

Another distinction lies in the solar collector used. Collectors can be mounted on roofs, walls, or on the ground. Solar hot water systems collectors can be unglazed (low temperature needs), glazed flat plate collectors (usually for temperatures of 86-158°F and for winter needs) or vacuum tube collectors (able to heat water to temperatures of 170-350°F; well-suited for commercial and industrial heating; appropriate for cooling, and, especially in cloudy regions, an effective alternative for space heating). The collectors have different characteristics and the choice of collector will depend on temperature, seasonal hot water needs, and other design requirements. For air heating, glazed and unglazed collectors are used. Glazed panel collectors are often used to reduce the use of natural gas or electric heat for houses, commercial buildings, or factories. Unglazed collectors are used for low temperature needs, such as pool heating, fish farming, or low-solar-fraction domestic water heating. The unglazed perforated plate or transpired solar plate has proven to be a very efficient collector and is most commonly used for heating ventilation air for large spaces and in crop drying.

Worldwide capacity is divided into: 46.4 GW thermal equivalent (GWth) glazed flat-plate collectors (32%); 74.1 GWth evacuated tube collectors (50%); and 25 GWth unglazed collectors

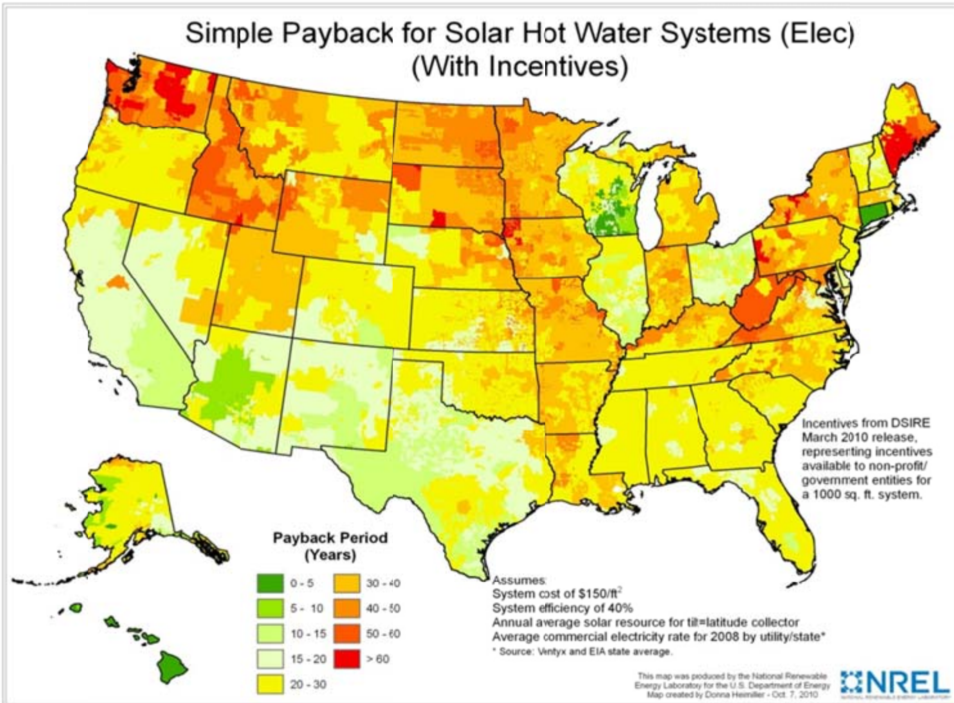
(17%) with water as the energy carrier; and 1.2 GWth glazed and unglazed air (1%). In the U.S. where swimming pool heating is the dominant application, 91% of the installed capacity is unglazed plastic collectors. Worldwide, however, flat-plate and evacuated tube collectors account for 82% of installed capacity and 92.5% of installed capacity growth in 2007. Although the installed capacity of flat-plate and evacuated tube collectors in the U.S. is very low compared to other countries, the market for new installed glazed collectors has increased significantly in the years 2005, 2006, and 2007 by 45 MWth, 87 MWth, and 91 MWth, respectively. Canada and the U.S. also have a growing unglazed solar air heating market for commercial and industrial building ventilation, air heating, and agricultural applications. (IEA, May 2009)

In the U.S., solar hot water systems are basically used for heating water in domestic or commercial applications. In agriculture, livestock, food processing, and dairy operations, for example, require substantial amounts of heated water for production, building wash-down, cleanup, sterilization of equipment, and environmental control. Solar water heating systems can be used to supply all or part of these hot water requirements. Outbuilding and barn hot water needs can also be covered with solar hot water systems. Inexpensive unglazed collectors can be used for aquaculture and other agricultural applications where higher temperatures are not needed. Solar air heating is used to heat spaces in barns and for crop drying.

Solar hot water (SHW) is the most direct, efficient, and cost-effective way to convert the sun's energy into useable energy. Still its financial costs and benefits will depend on the type of system, the climate it is installed in, constancy of load throughout the year, and the cost of competing conventional energy sources. In the U.S., solar thermal collectors can be a good investment for domestic hot water heating. In most residences, water heating is the second largest energy consumer next to space heating, costing anywhere from $180 to $480 per year[18]. Upfront prices for solar water heating systems are higher than for electricity or gas water heating, 4-6 times greater than a gas heater, and 9-10 times greater than an electric heater, according to NREL (1996), but the life-cycle cost of a solar water heating system is at least 20% lower. Active flat plate collector residential systems can be installed at a pre-rebate cost of $90 to $150 per square foot of flat plate collector[19]. Depending on location and climate, the cost of a typical active flat plate collector system of 35 to 50 square feet, producing 50 to 100 gallons of hot water per day will cost $4,000 to $8,000 (Jay Burch, NREL; Katrina Phruksukarn, California Center for Sustainable Energy[20]). However, simple systems without circulation pumps and controls that can be used in hot moderate climates are much cheaper, at a cost between $1,500 and $3,500[21]. Usually the solar systems are installed with a supplementary or backup heat supply such as gas, electric, or wood. Depending on the location solar water heaters can provide up to 80% of annual water-heating needs; as high as 100% in the summer and as low as 10% in the winter. A solar water heater can pay for itself in energy savings in 5 to 20 years against electricity (Figure 10), and 15 to 70 years against natural gas (Figure 11). The higher the alternative energy costs, the smaller the payback period.

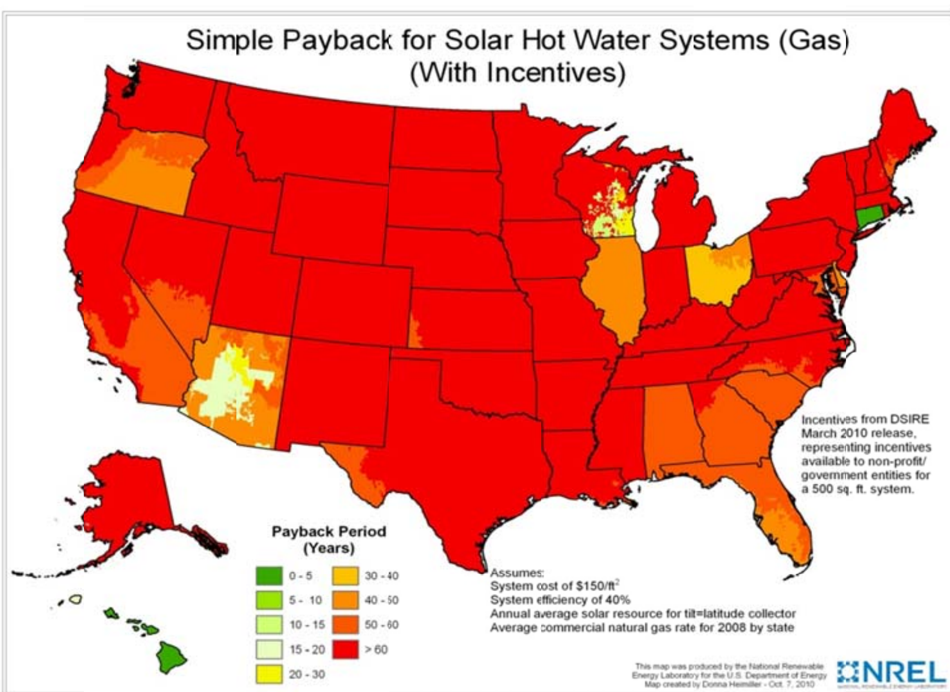
[18] IREF. http://www.farm-energy.ca/IReF/index.php?page=technologies (Accessed October 12, 2009).
[19] Installation costs for evacuated tube collectors are higher: $200 to $300 per square foot.
[20] Personal communication
[21] http://www.house-energy.com/Solar/Prices-Hot-Water.htm. (Accessed June 25 2009)

Figure 10. Solar Hot Water Payback with 2005 Electricity Prices



Source: Personal Communication with Jay Burch in NREL on work performed by Donna Heimuller in 2010

Figure 11. Solar Hot Water Payback with 2005 Natural Gas Prices



Source: Personal Communication with Jay Burch in NREL on work performed by Donna Heimuller in 2010

Agricultural applications that use large amounts of hot water, such as heating water for fish hatcheries, and cleaning/sterilizing equipment in animal operations, can benefit from a solar hot water system, especially when electricity is used to meet the load. For hot water uses in aquaculture, dairies, barns, and outbuildings, needs and economics will vary depending on the volume and temperature of hot water required. The collector array size is determined based on the size of the storage tank chosen to meet hot water needs as well as the solar exposure and climate. Whereas domestic solar hot water systems may require 2-6 solar hot water panels, commercial systems can have 40 to 400 collectors, with a collector area of 1,300 to 13,000 ft^2. A rule of thumb to size collectors is that 1 square foot of collector plate area is needed per 1 gallon of hot water storage. Commercial hot water systems are installed at a cost of $80 to $140 per square foot of flat plate collector ($200 to $280 per evacuated tube). Fish hatcheries that heat large volumes of low-temperature fresh water to enhance fish growth can use unglazed solar collectors with lower installation costs. Their payback ranges between 2-5 years[22] [23] IREF). Solar collectors can provide 25-50% of annual aquaculture heating needs and have the potential of reducing life-cycle fuel costs by tens of thousands of dollars. Costs run between $7 and $12 per square foot of the pool surface area depending on system design and collection type[24]. Ten-year warranties on the systems are available to farmers, and life expectancies of solar hot water systems are 20-30 years.

Solar air heaters are incorporated into buildings to preheat incoming fresh air. They range from very small to very large installations. Depending on the size of the heated space, a solar system could cost anywhere from $2,000 to more than $10,000. The collectors themselves require little to no maintenance while the ventilation system requires normal maintenance and operation. An analysis of solar air heating systems has demonstrated an internal rate of returns (IRR) of 10-30% is possible. Their economics depend on the application and technology employed. Flat plate glazed solar air collectors can cost from $2,000 to $6,000 for a household system and have a payback of 3-15 years, depending on fuel being offset and solar exposure during heat load times of year. Perforated-plate or transpired solar collectors have excellent economic returns and provide multiple benefits when fresh air circulation, air destratification, or heat assistance with dehumidification are desired. Projects typically have a payback of 1-5 years, and because they double as wall cladding, can be installed on new construction for little additional cost. In general the cost of solar air collectors ranges from $8-22/square foot and the cost of ventilation systems ranges from $4-8/square foot. The warranties on solar air collectors are 1-20 years, and the life expectancy can be more than 20 years. In the air heating application of crop drying, the costs are similar when perforated-plate solar collectors are used. However small-scale food dehydrators with readily available materials can be built for less than $100 (IREF).

Until 2006, about half of the solar water heaters sold each year in the U.S. were in Hawaii due to a combination of utility rebates, State tax credits, and high energy prices. By 2008, the national capacity of systems installed each year was quadruple the number in 2005, and installations outside Hawaii increased by 7 times (Sherwood, July 2010). After Hawaii, Florida and California lead the States in solar hot water installations (Figure 12). The States with the most installed capacity for solar hot water are different than the States with the most installed PV.

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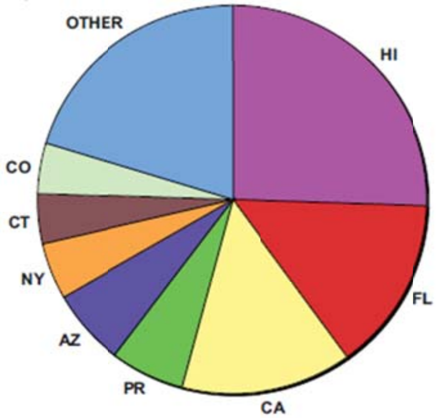
[22] http://www.house-energy.com/Solar/Prices-Hot-Water.htm. (Accessed June 25, 2009)
[23] IREF, http://www.farm-energy.ca/IReF/index.php?page=technologies. (Accessed October 12, 2009)
[24] http://www1.eere.energy.gov/solar/sh_basics_pool.html

Figure 12. Installed Solar Hot Water and Space Heating Capacity by State for 2006-2007



Does not include Solar Pool Heating Capacity.
Source: Sherwood, July 2009.

5. Solar Energy Farm Use and Potential in the U.S.

Solar energy can supply and/or supplement many farm energy requirements (Table 6). Motor energy generation is the primary use for PV on farms. Water pumping, one of the simplest and most prevalent uses of PV, includes irrigation in fields, watering livestock, pond management, and aquaculture. Portable or ground-mounted PV systems can be used to pump water from underground wells or from the surface (e.g. ponds, streams). PV water pumping systems can be the most cost-effective water pumping option in locations where there are no existing power lines. When properly sized and installed, PV water pumps are very reliable and require little maintenance. Environmental benefits can include keeping cattle and other livestock out of wetlands and waterways. The size and cost of a PV water pumping system depends on the local solar resource, pumping depth, water demand, as well as the system purchase and installation costs. Although today's prices for PV panels make most crop irrigation systems expensive, PV systems are very cost effective for remote livestock water supply, small irrigation systems, and pond aeration. While the upfront costs are generally greater than a gas-fuelled, generator-based water pumping system, extra costs are met over 5 - 10 years or sooner in maintenance and fuel cost savings (IREF).

Table 6. Farm Applications of Solar Energy

		Fields	Livestock	Other
Water Pumping	PV	wells, ponds, streams, irrigation	wells, ponds, streams	domestic uses
Buildings Needs	PV		security and task lighting, ventilation, feed or product handling equipment, refrigeration	battery charging, task lighting, ventilation fans, AC needs, refrigeration
	S H*		air cooling, air/space heating, water heating	domestic uses of solar heat
Farm and Ranch	PV	feeder/sprayer, irrigation sprinkler controls, security and task lighting,	electric fences, feeder/sprayer	electric fences, invisible fences, battery charging, compressor for fish farming, fans for crop drying, greenhouse heating
	S H*			crop drying, greenhouse heating

*Solar Heat
Source: Expanded from NREL (1997)

There are a number of other solar applications to be found around the ranch or farm, with the most notable being lighting, electric fencing, battery charging, as well as feeder, sprayer and sprinkler control. PV is an attractive alternative because most applications are considered to be remote and maintenance is easy. Table 7 shows the pricing for a number of on-farm stand-alone applications.

Powering buildings is an important application for solar energy on the farm. When grid connection and net metering are available, solar energy can help reduce grid energy needs and balance year-round electricity bills. When a building is off the grid, PV electricity generation provides a good source of energy that can cover needs, especially since running electrical wiring from the grid to an outbuilding can be expensive.

Table 7. Stand-Alone Solar Electric Applications on the Farm

Application	Description	Typical Cost
Electric Fencing	A solar fence charger replaces a utility grid connection or a battery that must be recharged by a fossil fuel-powered generator.	$100 to $400 (grounding rods and wiring supplies excluded)
Lighting	A solar-powered lighting system is comprised of the solar panel, a battery, a charge controller, and an efficient DC lighting fixture.	$50 to $200 (each)
Water Pumping	Solar electric systems can pump and store water from ponds or streams for livestock or irrigation in isolated fields.	$1,500 to $7,500, depending on size of system (well drilling excluded)
Pond Aeration	Aerators oxygenate ponds in the summer and create holes in ice of ponds and stock tanks in the winter.	$350 to $400
Gate Opener	Electric gate openers can be cost effectively connected to solar PV, systems in locations over 1,000 feet from grid power.	$750 to $1,500
Dashboard Battery Charger	A solar electric panel feeds a trickle charge to the battery in seldom-used vehicles or farm equipment.	$30 to $40
Ventilation	A rooftop fan powered by a solar panel can provide ventilation or air flow for cooling in livestock buildings, storage sheds or other outbuildings.	$200 to $500 depending on CFM* (fan and panel included)

*CFM (cubic feet per minute) are the typical units that measure the ventilation rate.
Source: Focus on Energy, 2006.

Lighting is another application. Solar can be used for remote building lighting, residential lighting, and large-scale lighting for barns such as hog confinement buildings. Outdoor and security lighting as well as greenhouse lighting are typical off-grid applications. General indoor lighting for farm shops and sheds and lighting for animal production buildings (dairy swine and poultry) may be on or off grid.

Around the farm, solar heat can be used for crop drying instead of the more traditional heating methods with LP gas, electricity, diesel or natural gas. Farmers use a significant amount of energy to dry crops, such as grain, tobacco, and peanuts. Solar heat applications can also be used for livestock and dairy operations. Hog, poultry, and greenhouse farm types have large cooling and space heating loads. Modern hog and poultry farms raise animals in enclosed buildings where it is necessary to carefully control temperature and air quality to maximize the health and growth of the animals. These facilities need to replace the indoor air regularly to remove moisture, toxic gases, odors, and dust. Heating incoming air, when necessary, requires large amounts of energy. With proper planning and design, solar air/space heaters can be incorporated into farm buildings to preheat incoming fresh air. These systems can also induce or increase natural ventilation levels during summer months. Canada's ecoENERGY for Renewable Heat Program,[25] for example, has funded almost 360 poultry barn solar air heating systems.

Livestock and dairy operations also have substantial water heating requirements. Solar hot water heating systems can provide hot water for pen cleaning and may be used to supply all or part of hot water requirements in dairy farms. Commercial dairy farms use large amounts of energy to heat water for cleaning milking equipment, as well as to warm and stimulate cow udders[26]. Heating water and cooling milk can account for up to 40% of the energy used on a dairy farm. Aquaculture and breweries are two other industries that can use solar energy for hot water needs.

In February 2011, USDA published the first On-Farm Energy Production Survey, which provides a picture for solar energy production in agriculture for 2009. According to the survey results, solar panels are the most prominent way to produce on-farm renewable energy and agricultural production of solar energy occurs in every state. Solar systems are present in 93% of farms with on-farm renewable energy production[27]. Up to 2009, almost 8,000 farms have installed a solar energy system on their farms; 7,236 farms use solar electric and 1,835 use solar thermal. Fourteen percent of these farms have both a PV and a thermal system (USDA, 2011).

Based on the survey, the pattern for PV and solar thermal in agricultural operations shows some similarities. The share for the top ten users is comparable for PV and solar thermal (Table 8). Additionally top states for PV such as California, Hawaii, Texas, Colorado and Oregon are also prominent for solar thermal installations. However states like North Carolina and Florida with fewer PV systems are high ranking solar thermal users (Table 8).

[25] Provides 25% of the cost for solar air and water systems.
[26] Many modern dairies also pasteurize the milk before refrigeration and solar heat could help in this application too.
[27] Wind rights lease agreements are not included in the survey.

Table 8. Farms with Solar Energy Systems by State

Rank	Solar Energy Systems			Solar PV Systems			Solar Thermal Systems		
	State	Farms	%	%	Farms	%	State	Farms	%
1	California	1,906	24	California	1,825	25	California	385	21
2	Texas	573	7	Texas	541	7	Hawaii	213	12
3	Hawaii	520	7	Hawaii	469	6	Colorado	117	6
4	Colorado	504	6	Colorado	445	6	Oregon	97	5
5	Oregon	332	4	Oregon	294	4	Wisconsin	78	4
6	New Mexico	258	3	Arizona	242	3	Texas	67	4
7	Arizona	255	3	New Mexico	241	3	North Carolina	55	3
8	Montana	238	3	Montana	226	3	Arizona	41	2
9	Washington	205	3	Washington	188	3	Washington	39	2
10	Oklahoma	187	2	Wyoming	168	2	Florida	39	2
All Other States		***2,990***	***38***		***2,597***	***36***		***704***	***38***
United States		***7,968***	***100***		***7,236***	***100***		***1,835***	***100***
Top ten States		***4,978***	***62***		***4,639***	***64***		***1,131***	***62***
Western States		***4007***	***50***		***3739***	***52***		***913***	***50***

Source: USDA, 2011

On the state level, California leads the nation with 24% and half of the operations generating on-farm solar energy are concentrated in the western parts of the U.S. (Table 8). Based on the survey, the number of farms using solar energy ranges widely from just four farms in Delaware to 1,906 operations in California, with an average of 159 and a median of 86 farms per state. In Texas, Hawaii and Colorado over 500 farms produce solar energy; Oregon, New Mexico, Arizona, Montana, and Washington have over 200 operations with a solar energy system.

Agriculture represents a small portion of the cumulative PV capacity in the U.S.: just 4%; however this is higher than the 1% of direct energy used in agriculture relative to total U.S energy consumption. Table 9 shows the states with the largest PV capacity installed in the agricultural sector. Most of these states also rank high in total PV capacity with the exception of Wisconsin and New Mexico. In terms of capacity the concentration of solar energy production is more pronounced. California represents almost 64 % of agricultural PV capacity, the western states 74 %, and the top ten states 83 %.

The difference in PV capacity from the number of farm operations using solar is due to the average capacity per farm which ranges substantially by state as can be seen in Tables 9 and 10. New Jersey for example has the second largest capacity of PV installed in agriculture with just 138 farms. The smallest average capacity found in the three lowest ranked states is around 0.4 kW and the largest average capacity found in Delaware, New Jersey and California is over 10 kW. The average capacity in the rest of the U.S. states ranges from about 0.5 kW to 4.5 kW, with a median of 1.35kW.

Table 9. Agricultural PV Capacity by State

State	Cumulative Capacity (watts)	%	Average capacity (watts)	Farms
California	20,492,925	63.7	11229	1825
New Jersey	1,943,178	6.0	14081	138
Oregon	882,588	2.7	3002	294
Hawaii	839,510	2.6	1790	469
Colorado	736,030	2.3	1654	445
Arizona	484,484	1.5	2002	242
Texas	423,603	1.3	783	541
New York	350,140	1.1	2501	140
Wisconsin	332,856	1.0	2484	134
New Mexico	303,901	0.9	1261	241
All Other States	***5,403,749***	***16.8***	***1817***	***2,767***
United States	***32,192,964***	***100.0***	***4449***	***7236***
Top Ten States	***26,789,215***	***83.2***	***4,079***	***4469***
Western States	***23,757,159***	***73.8***	***2392***	***3739***

Source: USDA, 2011

Table 10. Smallest and Largest Agricultural PV Capacity by State

	Three Smallest			Three Largest		
State	Kansas	Oklahoma	North Dakota	Delaware	New Jersey	California
Average Capacity (watts)	408	428	429	15500	14081	11229

Source: USDA, 2011

Based on the reported data for average installation cost and capacity by State[28] the installation cost per watt for an average U.S. farm is $7.18 (based on a 4.5kW system) but the cost ranges widely by state from $5.65/W in Florida and $16/W in Mississippi. This estimate includes a range of applications and system sizes, as well as on- and off- grid systems (where the prices of off-grid systems are almost double the prices of on-grid systems). The average system cost is between $7-9/W in forty three percent of states; in 23% of the states the price is $9-10/W and in 27% it is above $10/W.

For solar PV, based on the survey, systems smaller than 1kW the cost to farmers averaged $8,000, for 1-5kW systems $18,000, and for 10-16kW systems $98,000. Farmers spend on average less than $10,000 for installing solar energy systems in 17 states. The average expense was $10,000-$20,000 in 20 states, and $20,000-$40,000 in 10 states; only in 3 states the average expense for solar energy was higher than $40,000.

Farmers received financial support for installing solar energy from a number of sources such as federal, state, and local government as well as utilities. The average financial support received for solar PV was 44% of the project cost, slightly lower than the support for small wind (49%) and methane digesters (48%). Figure 13 shows the average financial support farmers reported in different States. Additionally, farmers that use solar energy or other renewables, like wind turbines and methane digesters reported savings on their utility bills in 2009[29] [30](USDA, 2011). The savings were especially noticeable in

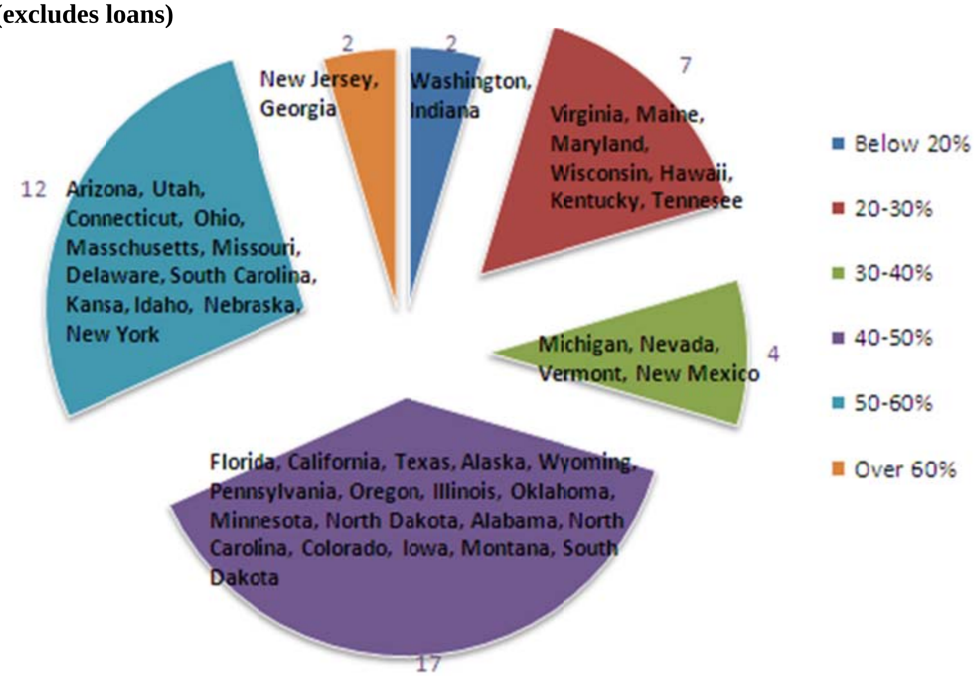
[28] Only includes positive data, operations that reported zero or failed to report are not included.
[29] Energy Savings are estimated based on all renewable energy produced on farm, which also includes wind turbines and methane digesters.

New York, with over $5,000, Rhodes Island and California with over $4,000, as well as South Carolina, Vermont, New Jersey, and Arizona with savings above the national average of $2400. The median utility savings was $1250; 13 states saved less than $1000 in utility bills, 21 between $1,000-2,000, and 15 over 2000$.

According to the survey, on-farm solar energy production has increased significantly in the last 10 years. Sixty three percent of solar panels in agriculture were installed from 2005-2009 while 26 % were installed from 2000-2004 (Figure 14). The growth rate was almost fivefold from 2000-2009 and 1.5 from 2005-2009. The highest growth rates are found in New Jersey (43) and Georgia (16) which are the States with the highest reported financial support for on-farm solar system installations (Figure 13). The financial support however for other high growth States like Pennsylvania, California, Rhode Island and Iowa (8-16) was close to the U.S. average.

In a number of States, solar energy adoption in agriculture was accelerated since 2005. While nine States had growth rates higher than the US average for 2000-2009, 19 States had growth rates above the U.S. average from 2005-2009. These high growth States typically did not rank high in installed PV capacity (Table 9) and might change the geographic picture of solar use in agriculture in the future if their growth rates are sustained. For example, 21 States had growth rates higher than California and five States had growth rates over 5 from 2005-2009.

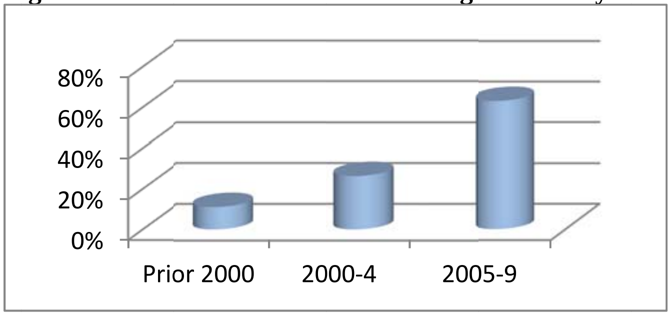
Figure 13. Average Financial Support Farmers Reported to Receive for Installing Solar by State (excludes loans)



Source: USDA, 2011

[30] In addition to avoided energy purchases, savings also included revenues from electricity sold back onto the grid when this option was available under a net metering or a different purchase agreement

Figure 14. Solar Panel Installations in Agriculture by Year



Source: USDA, 2011
Data on farm energy use in the U.S. is limited[31].

According to a Food and Agriculture Organization (FAO) survey [32]on international uses of solar electric in agriculture, 30% of respondents reported using PV for pumping irrigation water, 9% for livestock watering, 16% for electric fences, and 14% for building lighting for poultry and livestock. PV pumping for livestock and irrigation dominate (FAO, 2000). Solar water pumping has earned widespread acceptance with more than 50,000 PV pumps worldwide[33]. In the U.S., PV has mainly been used for off-grid livestock watering and powering electric fences, but net metering is changing the landscape as more and more on-grid solar systems are installed in agricultural operations. Additionally a number of farms in California are now using PV for irrigation[34].
On-grid systems have increased substantially over the last decade, leading the growth in PV installations, and are expected to increase further relative to off-grid uses. This trend might spill over into the agricultural sector as farmers install solar systems both for residential and commercial needs. A number of operations are adopting solar energy for environmental benefits and marketing purposes rather than strictly cost considerations. Another development in solar that could influence the agricultural sector is that the average size of a grid-connected PV has increased substantially from 1999 to 2008 (Sherwood, July 2009). It has doubled from 2.5kW in 1999 for residential style installations and has increased eleven fold to 110 kW in 2008 for non-residential installations. Additionally systems larger than 500 kW accounted for 30% of the total PV capacity installed in 2008. The average size of solar systems in agriculture has increased since the 1990's, and this report showcases a number of larger systems. Still, in agriculture, solar energy generation, with few exceptions (found in Europe[35]), has been relatively small (compared to wind energy generation, for example). To date it has not surpassed 1MW per installation contrary to wind energy where the interaction between agriculture and energy generation has developed through multi-megawatt wind farms.

In addition to overall farm needs that can be covered with grid connected systems, there is potential for more PV-powered irrigation in the future. Brown and Elliott (2005) note that the largest percentage of identified on-farm energy use involves motors. Irrigation is the largest on-

[31] Data on fuel and electricity expenses for on-farm use is collected in USDA by NASS. The USDA Census of Agriculture also provides 5-year snapshots, but since 2002 electricity expenses in the census are integrated into utility expenses.
[32] The majority of responses came from Latin America and Asia. The percentages do not add up to 100% because responses on PV applications were not mutually exclusive.
[33] A large number are installed in India through the Solar Water Pumping Program.
[34] Sporadic cases are also found in States like New Mexico, Utah, and Georgia.
[35] Examples include Sepra in Portugal, Pocking in Germany, and Monte Alto in Spain.
http://en.wikipedia.org/wiki/List_of_photovoltaic_power_stations

farm motor application, and water pumping for irrigation represents approximately 15% of total energy use in agriculture. This is a high number considering that only 18% of harvested cropland in the U.S. is irrigated. While many irrigation systems in the U.S. are gravity flow systems that require little or no energy, irrigation systems that use pumps are energy intensive, because of the amount of energy it takes to pump water to and through the system. Nevertheless, PV pumping systems are also well-suited for water- and energy-saving methods of irrigation such as drip irrigation (FAO, 2000).

Based on the 2008 USDA Farm and Ranch Irrigation Survey, about 49 million acres of U.S. farmland were pump irrigated[36] with an energy expense of $2.68 billion (USDA, 2008b). Seventeen percent of the irrigated acres were in Nebraska, 15% in California, and 10% in Texas. Over 60% were powered with electricity (about 30 million acres); the diesel fuel share was nearly 27%, while just slight of 10% of irrigated acres were powered with natural gas pumps.

Based on the 2008 USDA Farm and Ranch Irrigation Survey, 1405 farms used solar and other renewable energy for irrigation (USDA, 2008b). If this number is compared to the 2009 On-Farm Renewable Energy Production Survey and under the assumption of sample overlap in the two surveys, its seems a high number of farms (17%) use solar and other renewable energy production to power irrigation. Specifically 1,482 water pumps (Table 11) irrigated a small area of 25,854 acres. This compares to 411 pumps and 16,430 acres reported in the 2003 USDA Farm and Ranch Irrigation Survey (Table 8). In the 2008 Farm and Ranch Irrigation Survey, the bulk of the solar-powered pumps in 2008 (90%) were located in California and the Pacific Northwest (Oregon and Washington). The Lower Mississippi and Hawaii also stood out[37] (USDA, 2008b). In the 2003 USDA Farm and Ranch Irrigation Survey, Washington, Nebraska, New York, and Pennsylvania were identified as States with the most solar/other renewable energy water pumps [38](USDA, 2003).

[36] Total irrigated land including gravity flow irrigation was 55 million acres.

[37]The data were not published at the State level because of low data reliability at the State level. There are few operations with solar pumps in the population (USDA, 2008).

[38]The 2003 and 2008 data are not commensurate. Generally the data reliability at the State level is low due to the small sample of irrigated acres using solar pumps to the total irrigation sample. The U.S. number has the most reliability. Additionally, the 2008 data do not include horticultural operations while the 2003 data include them.

Table 11. Irrigation With Solar and Other Renewable Energy

2008†	Pumps	Farms	Acres	2003	Pumps	Farms	Acres
California	819	810	10,294	Washington	134	134	10,050
Pacific Northwest	517	517	1,609	Nebraska	82	82	4100
Lower Mississippi	55	5	3,335	New York	54	54	162
Hawaii	36	25	(w)	Pennsylvania	64	32	64
Mid-Atlantic	14	14	70	Tennessee	(w)	19	19
New England	10	10	170	Wisconsin	32	16	32
South Atlantic-Gulf	6	6	900	Hawaii	8	8	8
Souris-Red-Rainy	5	5	600	New Hampshire	9	6	9
Upper Colorado	3	3	4,770	Vermont	5	5	10
USA	***1482***	***1405***	***25,854***	***USA***	***411****	***360****	***16,430****

†The 2008 Farm and Ranch Irrigation Survey published data by the U.S. Geological Survey (USGS) Water Resources Region (WRR) boundaries
* Of these, only 379 pumps irrigating 16,430 acres in 328 farms related to the population used in the 2008 survey. In 2008, small horticulture operations with less than $10,000 in sales were excluded.
(w) Withheld to avoid disclosing data for individual farms.
Source: USDA Farm and Ranch Irrigation Survey, 2008, 2003[39].

[39] http://www.agcensus.usda.gov/Publications/2002/FRIS/index.asp (Accessed, October 10, 2009).

6. Selected Case Studies

The case studies that follow serve as an overview of examples of solar energy use in agriculture. Mention of trade names or commercial products in this report is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

Spottswoode Estate Winery and Vineyard St. Helena, California; Grid-Connected PV Systems

Photograph courtesy of Premier Power Renewable Energy, Inc.

Spottswoode Estate Winery and Vineyard is a small, family-owned, organically farmed estate that is striving to apply the precepts of sustainability in different aspects of its operations. Organically farmed since 1985, Spottswoode was certified by the California Certified Organic Farmers (CCOF) in 1992. Continuing to go green, it installed two grid-tied PV systems in April 2007. A 32.76 kW system produces electricity for the vineyard well pumps and lighting at the vineyard shop. The 40.39kW system produces electricity for the winery, barrel rooms, and offices. The two systems cover approximately 65% of the estate's energy needs. They are rooftop mounted, taking up no valuable St. Helena, CA, farmland and according to Aron Weinkauf, assistant winemaker of Spottswoode Estate,"will be a consistent energy producer for decades to come, and reduce the estate's reliance on other energy sources."

Spottswoode Estate Winery System Specifications	
System Size	40.39kW
Installation Year	2007
Storage	Electric Grid
Total Cost of System	$367,249
Incentives	- California Solar Initiative (CSI) Rebate: $89,585 -30% Federal Investment Tax Credit (ITC) -5 year MACRS.
Spottswoode Estate Vineyard System Specifications	
System Size	32.76 kW
Installation Year	2007
Storage	Electric Grid
Total Cost of System	$286,274
Incentives	- CSI Rebate: $70,388 -30% Federal (ITC) -5 year MACRS
Maintenance: $900 per year. PV cleaning schedule three times per year. The panels can get covered during the dry months by dust, pollen, etc.	
Contact about Case Study Danielle Heim Premier Power Renewable Energy, Inc. Phone: 916.939.0400 ext. 120 http://www.premierpower.com	

Oakhurst Dairy, Portland, Maine; Solar Hot Water System

Photograph courtesy of Oakhurst Dairy.

In the spring of 2008, Oakhurst Dairy, a family-owned dairy in Portland, ME, installed one of the largest commercial solar thermal systems in the northeastern U.S. on the roof of its headquarters. Seventy-two panels preheat water for milk case washing, as well as floor and equipment cleaning. In the first year of operation, the solar system reduced the company's heating oil consumption by more than 5,000 gallons. The savings increased by 2,500 gallons because of the waste heat recovery extension that was integrated with the system. Total annual savings average 7,000 to 10,000 gallons, reducing the company's expenses by $14,000-20,000 per year. The company boasts that the benefits of the project reach far beyond energy cost savings. A decrease of 88 metric tons of CO_2 emissions per year helped the company towards meeting its "Governor's Carbon Challenge" goal of reducing its CO_2 emissions 20% by 2010. Additionally the solar system enhances the company's public image and the employees' pride in their work.

Oakhurst Dairy has also started to install solar PV panels to reduce electricity costs and dependence on the grid.

Oakhurst Dairy System Specifications	
System Size	2,880 ft^2
Installation Year	2008
Storage	Two 1,500-gallon water tanks
Total Cost of Systems	$215,000
Incentives	-$10,500 State of Maine Energy Program. -30% Federal ITC -5 year MACRS.
Maintenance: $200/year	
Contact about Case Study William P. Bennett Oakhurst Dairy Phone: (207) 772- 7468 wbennett@oakhurstdairy.com http://www.oakhurstdairy.com	

Also featured at:
The Innovation Center for U.S. Dairy
http://www.usdairy.com/sustainability/BestPractices/Documents/Solar%20Thermal%20Systems%20-%20Oakhurst%20Case%20Study.pdf
Clean Air Cool Planet:
http://www.oakhurstdairy.com/docs/OAK14109_ECS_9r.pdf

Limoneira Company, Ventura County, California; Grid-Connected, Leased PV Systems

Photos courtesy of Limoneira Company

Limoneira Company, founded in 1893, grows many crops on about 7,300 acres. It is one of the largest lemon producers in North America and the largest avocado grower in the U.S. Two solar systems installed in 2008 are the latest addition to the company's sustainable energy and resource management business practices. The 5.5 acre fixed mounted solar energy system at the company headquarters in Santa Paula, CA, generates 1 MW of electricity and powers more than 50% of Limoneira's lemon packing house and cold storage facilities. The second system, on 10 acres in Ducor, CA, consists of four 250kW arrays on tracking systems that pump deep well water into reservoirs for the irrigation of 1,000 agricultural acres. These two systems - 12,800 PV panels and 2 MW in total - produce the equivalent needed to power about 400 single-family homes for one year, and save the company over $500,000 per year in energy costs. They also help the company maintain a green image in the local community and globally. Up until April 2010, the use of the solar systems has avoided the emission of about 6,600 pounds of CO_2, 1970 pounds of NO_x, and 160 pounds of SO_2. And the miniature sheep that control the native grasses planted under the panels are very popular with the local schools.

The systems required no capital from Limoneira; they were developed through a lease agreement with Farm Credit Systems that actually owns the systems for the first 10 years. Through the lease, Limoneria is purchasing electricity at an estimated fixed rate of 9 ¢/kWh for the next 25 years, compared to the 13 ¢/kWh charged by the utility. According to the terms of the lease, Limoneira could buy the system in the 11th year for $1 million. Sustainability Manager Tomas Gonzalez called the solar systems "one of the company's greatest investments in the last century."

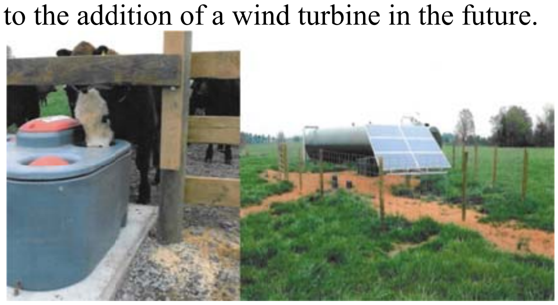
1. Santa Paula, CA, System Specifications	
System Size	1MW
Installation Year	2008
Storage	Electricity Grid
Total System Cost	$7.5M
Incentives	-30% Federal ITC -5 year MACRS -26c/kWh CSI performance based incentive for 5 years
2. Ducor, CA, System Specifications	
System Size	1MW
Installation Year	2008
Storage	Electricity Grid
Total System Cost	$8.5M
Incentives	-30% Federal ITC -5 year MACRS -22¢/kWh CSI performance based incentive for 5 years
Maintenance: Monitoring output, washing dust and grime off the panels 3 times a year. At Santa Paula, native vegetation was planted close to the panels to reduce dust.	
Contact about Case Study Mark Palamountain Perpetual Power Phone: 415-305-3223 mark@perpetualpowerllc.com http://www.p2solarsolutions.com	

Limoneira CEO Harold Edwards believes this investment will continue to pay off for decades to come and notes the importance of the fixed electricity rate given the volatility of energy prices and the continuous electricity rate increases. According to Edwards, "solar is coming, and coming rapidly and we really are proud to be at the front end." He suggests that farms are a natural outlet for solar generation because they have the land and often have high-use electric needs.

Also featured at:
http://www.limoneira.com/energy-and-resources/solar-energy.html.

Circle B Farms, Cherryville, North Carolina; Off-Grid PV System

Circle B Farms, owned and operated by Larry Baxter, installed a solar-powered gravity watering system in 2006 to supply water from a well for a 70 cow/calf pair herd. The solar installation, in conjunction with fencing cattle out of a stream that flows into Buffalo Creek (the city drinking water source), also helps to reduce bank erosion and improve water quality for the stream. Larry Baxter originally was contemplating wind power, but was advised that his operation was more suitable for solar. And although solar system distributors were not plentiful in the Charlotte area, Larry Baxter is now happy about the free fuel from the sun to operate the solar pump and believes that the upfront cost of these systems will diminish over time. He also finds the potential of combining solar with other renewable sources very beneficial, and indicates that his system is adaptable to the addition of a wind turbine in the future.



Photographs courtesy of Larry Baxter.

CIRCLE B FARMS SOLAR PUMP SYSTEM SPECIFICATIONS	
System Size	1kW
Installation Year	2006
Storage	16,000-gallon tank connected to five gravity fed waterers
Total Cost of System	$24,669 (includes pump and water storage tank cost, approximately $7,000)
Incentives	- USDA REAP: $6,117 -NC Agricultural Cost Share Program[40]: $6,928 -30% Federal ITC - NC 35%Renewable Energy Tax Credit -5 year MACRS.
Line Extension Alternative	-0.5 miles from existing power line; $14,000 per mile -$78/month electricity
Maintenance: practically cost free	
Contact about Case Study Mike Floyd McCall Bros. Inc Phone: 704-399-1506 information@mccallbro.com http://www.mccallbro.com/	

[40] The NC Agricultural Cost Share Grant applied to the cost of the whole project to restrict the cattle from degrading the water stream. This included additionally the cost for the well, storage pump, plumbing, waterers and fencing.

__Pinehold Gardens, Milwaukee, Wisconsin, Grid-Connected PV Systems__

PINEHOLD GARDENS SYSTEM 1 SPECIFICATIONS	
System Size	2.528kW
Installation Year	2005
Storage	Electric Grid
Total Cost of Systems	$19,689
Incentives	Focus on Energy ($6,891) USDA REAP ($4,922.5) -10% Federal ITC -5 year MACRS
PINEHOLD GARDENS SYSTEM 2 SPECIFICATIONS	
System Size	2.772kW
Installation Year	2008
Storage	Electric Grid
Total Cost of Systems	$22,710
Incentives	Focus on Energy ($5,413) USDA REAP ($5,677.5) -30% Federal ITC -5 year MACRS
Maintenance: Practically labor free	
Contact about Case Study Pinehold Gardens, LLC Phone: 414-762-1301 info@pineholdgardens.com http://www.pineholdgardens.com/index.html	

Pinehold Gardens is a 21-acre sustainable vegetable and fruit farm in the metropolitan area of Milwaukee, WI, that operates a Community Supported Agriculture (CSA) program and sells produce at farmers' markets and to local restaurants. Sandra Raduenz and David Kozlowski who own the farm have installed two grid-connected systems; a 2.5kW dual axis mounted system in May 2005, and an additional 2.78 kW fixed mounted system in October 2008. Together the two systems produce almost 100% of the farm's energy needs - irrigation and refrigeration - saving them thousands on their energy bills. The excess energy generated is sold onto the grid for 22.5 ¢/kWh. This arrangement is part of the "Energy for Tomorrow Program," a voluntary green purchasing program provided by We Energies, to which the farm serves as a Power Partner. The couple is proud that the sun not only helps grow their crops, but also produces the electricity needs for their farm, reducing their impact on the environment and increasing public interest in their farm.

Photograph courtesy of Pinehold Gardens.

Also featured at Midwest Renewable Energy Association (MREA): http://www.the-mrea.org/solartour.php?id=1186925104.

Verendrye Electric Cooperative, Minot, North Dakota; Solar Livestock Watering Off-Grid PV Leasing

Verendrye Electric Cooperative, looking for alternatives to building and maintaining power lines to remote parts in its large distribution area of 4,000 square miles in six counties surrounding Minot, ND, started installing solar-powered pasture well systems for its members in 1990. Its innovative program leased small solar PV systems to farmers for powering stock-watering pumps. Since farmers pay the majority of the costs for the alternative of extending the electric lines (as much as $20,000 per mile) and the stock wells are only used in the summer months, the option became popular and over 200 systems have since been installed. The lease price depends on how much water is needed for the cattle herd, but the most common system used by ranchers costs $15 per month to lease. The benefits are shared by the utility and the farmers. The co-op reduces its maintenance costs by no longer having to maintain remote, underutilized lines. Farmers save money by having a dependable source of electricity at a lower cost than traditional electric service.

Also featured at FarmEnergy.org: http://farmenergy.org/success-stories/rural-electric-cooperative/verendrye-electric-cooperative

VERENDRYE ELECTRIC CO-OP PROGRAM	
Program Start-up	1990
Pump Number in Program	Over 200
Average System Size	130 W
Average Cattle Size per System	20-90 pair
Average System Cost	$ 3,000 (paid by utility) $ 500 (pump cost paid by customer)
Average Lease Price	$15/month
Storage per System	Holding tank for a 3-day water supply
Line Extension Alternative (paid by customer)	-$18,000-$20,000 per mile -$30/month +8.5¢/kWh
Incentives: Between 2007-2008, REAP awarded $100,800 to support the program by covering the cost of pumps that were compatible with the solar panels for the farmers who enrolled.	
Maintenance of solar systems: Once each system is installed, only periodic checks or repairs are needed. The systems are not used in the winter (they are simply turned off till spring) and are durable enough to survive North Dakota winters without a cover.	
Contact about Case Study Tom Jespersen Phone: 800-472-2141 tomtj@verendrye.com http://www.verendrye.com/	

3-Corner Field Farm, Shushan, New York, Solar Hot Water System

Photograph courtesy of 3-Corner Farm and Peter Skinner of E2G

The 3-Corner Field Farm is a family run sheep dairy on a 100-acre farm in Washington County, NY. Since 2001, owners Karen Weinberg and Paul Borghard, along with daughters Emily and Zoe, raise more than 150 sheep and 300 lambs on their sustainable farm using a pasture-based system, where the animals feed on natural forage, and produce milk and meat for local and national sale. The farm takes advantage of the sun's power by operating two 10kW PV systems for electricity needs and a 160-gallon solar hot water system. The solar hot water system, installed in 2006, covers on average 60% of the dairy's solar hot water needs, mostly for milking and cleaning. According to Paul Borghard, the farm was using a significant amount of energy for hot water, so he paid attention to the rising costs of energy and turned to solar to contain these costs.

Although the cost of the project was high for the farm, tax and grant incentives made the project economically feasible and now the system is estimated to save the dairy $1,452 annually in electricity costs. Happy with their hot water system, Karen Weinberg and Paul Borghard encourage other farmers to turn to solar for their hot water needs, while cautioning them that solar thermal is more complicated than solar electric and a good installer makes all the difference.

3-Corner Field Farm Dairy System Specifications	
System Size	240 ft^2
Installation Year	2006
Storage	160 gallon water tank; supplemental hot water needs are covered with an electric water heater.
Total Cost of Systems	$22,333
Incentives	-$5,583 USDA REAP Grant -30% Federal ITC -5 year MARCS.
Maintenance: minimal	
Contact about Case Study Peter Skinner E2G Phone: (518) 369-3208 E2g@verizon.net	

Crop Drying Demonstrations in California

The California Air Resources Board funded a cost share project for demonstrating the use of solar energy crop drying in California with transpired collectors[41]. The five demonstrations that resulted were installed between 2001 and 2005 and constitute the first applications of the transpired collector or SolarWall™ technology in the U.S. for the drying of crops. Most traditional commercial dryers on the market run on oil, natural gas, propane, or steam and often produce higher temperatures than necessary. Solar panels are well suited for heating large volumes of air with low grade heat. The panels are placed on the roof or walls of the building housing existing dryers and either heat or preheat the air entering the fan and dryer. According to the project the best candidates for solar crop drying proved to be those that dry all year long as they allow longer utilization of the equipment and thus have a quicker payback time to recover capital investment. Short drying periods for a number of crops can prolong the payback. High-value crops also made for good SolarWall™ drying candidates. Participants in the California Air Resources Board project are shown in the table below.

Company	**Sunsweet**	**Carriere**	**Keyawa**	**Korina**	**Sonoma**
Location	Yuba City, CA	Glenn, CA	Chico, CA	Corning, CA	Sebastopol, CA
Crop	Prunes	Walnuts	Walnuts	Pecans	Herbs
Installation Year	2002	2003	2003	2003	2004
System Size	1,225 ft^2	3,200 ft^2	9,300 ft^2	5,200 ft^2	105 ft^2
Air Volume Preheated	10,000 of 50,000 cfm	17,500 of 70,000 cfm	65,000 cfm	37,000 cfm	350 cfm
Projected Savings/month	100 MMBTU	172 MMBTU	572 MMBTU	163 MMBTU	3 MMBTU
Energy Savings/Year	$1,000	$3,500	$13,800	$3,200	$350
Months of Use per Year	1	2.5	2	2	12
Total Cost of System	12,400	33,634	80,000	50,000	4,000
Incentives: Up to 50% CA ITAC Grant and 10% Federal ITC. Korina farms also received USDA REAP grant for $25,250					
Contact about Case Study Conserval Systems Inc Phone: 716 835-4903 info@solarwall.com www.solarwall.com					

[41] The project provided a financial contribution of up to 50% for each drying site.

Carriere Family Farms, the featured case study for solar drying systems, is a family company that produces walnuts, almonds, olive oil, and rice. It has embraced solar energy in its production and processing. The farm has 378 kW of photovoltaic panels in four separate systems and also uses solar crop drying for its walnut drying.

Photograph courtesy of Carriere Family Farms

Carriere Family Farms President, Bill Carriere, was fast to relay "our experience with the solar crop drying has been outstanding. It integrated into our existing drying system without modifications. Once in place it works on its own and repairs are basically non-existent." With the commercial price for natural gas having increased from $.63/therm in 2002 to $1.22/therm in 2008, and now at around $.95/therm, Carriere has been able to keep its operating costs stable and realize large energy savings. Since 2003 the energy savings for the 2.5 months of operation of the solar drying system (from September 1 to November 15) were 5,140 therms of natural gas (150548kWh) and 1,050 kWh of electricity per year on average. The company estimated its natural gas savings at about $6,000/year, and its electricity savings at almost $170/year for the past 3 years.

"When the conditions are right, on a warm sunny day, we can completely turn off the natural gas and still achieve the temperatures needed to dry efficiently," says Bill Carriere, and adds "because we are warming outside air, the time needed to dry the walnuts has also been reduced saving us about a half an hour of run time per day on the 50 hp fan forcing the air."

Also featured at Solarwall.com
http://solarwall.com/media/download_gallery/cases/Carriere&SonsWalnutDrying_Y02_SolarWallCaseCropDryingV2.pdf

CARRIERE FAMILY FARMS SYSTEM SPECIFICATIONS	
System Size	3,200 ft^2 roof mounted
Air Volume Preheated	25,000 cfm of 70,000 cfm
Temperature Required	110 F
Months of Use	2.5 (9/1-11/15)
Installation Year	2003
Storage	None; integrated into existing natural gas forced air drying system
Total Cost of System	$33,634
Incentives	-$18,500 CA ITAC Grant -10% Federal ITC
Maintenance: Minor repairs and cleaning amount to a maximum of $200/year	
Contact about Case Study Bill Carriere Carriere Family Farms Phone: 530- 934-8200 wcarriere@carrierefarms.com http://www.carrierefarms.com/	

Among the other participants, Sunsweet, a national brand, utilizes the SolarWall™ to preheat 20% of the hot air requirement for drying prunes at its Yuba City, AZ, dryer. It has shown an interest in adjusting the system to also dry produce such as apricots, peaches, pears, and cherries. The largest solar drying project in California, Keyawa Orchards, dries over 12 million pounds/year of walnuts, and the SolarWall™ saves the company $14,000/year in energy costs. Korina Farms dries pecans from a 62-acre farm and nuts from neighboring producers. Seeking to reduce high propane costs, Korina Farms built a new drying facility and incorporated a 5,000-square-foot SolarWall™ system into its roof. By adapting it to a variety of nut crops grown on neighboring farms, Korina Farms maximizes the system's use during the year. Last, the Sonoma County Herb Exchange represents the smallest system. It is a clearinghouse for medicinal herb growers in Sonoma County and adjoining regions of northern California that offers dried herbs prepared in a batch dryer that runs off the sun instead of propane. According to Conserval Engineering that participated in the California Air Resources Board cost share project as the supplier of the systems, another potential application for transpired collectors is space heating for animal confinement buildings. SolarWall™ systems have been used in many animal buildings for poultry and hog ventilation, reducing heating costs by up to 30%. Almost 25% of the solar air and water system projects supported by Canada's ecoENERGY for Renewable Heat Program was for poultry barns solar air heating systems.

Also featured at California Air Resources Board: http://www.arb.ca.gov/research/abstracts/01-5.htm

Vick Farm, Wheeler Co., Texas, Off-Grid Solar Fence Charger

Photographs courtesy of Brian Vick

Vick Farm, owned by Brian Vick, has been leased out for cattle grazing for the last 20 years. Additionally Brian Vick operates a small orchard on the farm that produces mostly peaches and apricots and installed a solar-powered electric fence in 2002 to keep the cattle out of the orchard. Due to the remoteness of the location, no utility electricity was available, and Brian Vick used solar energy to charge his fence because of the cost effectiveness and convenience it offered. The installation keeps the neighboring cattle and other small animals from damaging the trees and eating the fruit. Most of the expense incurred annually to maintain the fence is for travel to the farm.

For the solar component, the deep cycle battery needs to be replaced every 2 to 3 years ($60) and the angle of the PV module needs to be increased for the winter months to keep the battery charged.

VICK FARM SOLAR FENCE CHARGER SPECIFICATIONS	
System Size	10 Watts
Installation Year	2002
Storage	12 Volt 85 amp-hour deep cycle battery
Total Cost of System	$240 (excluding the fence)
Incentives	None
Line Extension Alternative	-0.75 miles from existing power line; 25,000$/mile; -$16/month
Maintenance: $50-80 annually	
Contact about Case Study Brian Vick Vick Farm Phone: (806)358-7428 brian.vick@ars.usda.gov	

7. Financial Considerations for Solar System Installations

The installation of solar energy will depend on the farmer's needs, resources, and alternative options. Financial variables include: the system cost, current and projected cost of fuel, available financing, tax credits and incentives (utility, State, Federal or local), additional income like Renewable Energy Certificates (RECs), net metering, carbon banking or cap/trade values (which will be discussed later in the section), even LEED[42] points.

a. Financing

Solar energy requires a large upfront investment that is recovered through revenues or savings over time. The upfront costs of this equipment can be daunting to farmers and a barrier to new purchases. Consequently, financing availability is important in the adoption of solar energy. Financing options for installing a system include cash, commercial bank loans, a mortgage or home equity loan, a limited partnership, vendor financing, a lease, an energy savings performance contract, utility programs, chauffage, subsidies, and grants (Walker, 2001).

Commercial bank loans are characterized by fixed payments of the principal plus interest over the loan. The Small Business Administration (SBA) can aid small businesses purchasing a PV or solar thermal system through the 7(a) Standard Small Business Loan if the resulting energy savings will positively affect the company's cash flow. The SBA guarantees loans for $100,000 or less up to 80% and a maximum of 75% for loans of more than $100,000, with a limit of $750,000.The payback period is required to be less than 10 years. (Eckhart, 1999)

The home mortgage and home equity loan options have the advantage that their interest rates are tax deductible, resulting in a lower effective project cost. Additionally, the 15- to 30-year terms that mortgages offer are much longer than those available through other types of loans (usually less than 10 years) and are comparable to the payback needs for solar energy. Fannie Mae, Freddie Mac, Federal Housing Administration (FHA), and the Veteran's Administration (VA) provide specific criteria for energy mortgages (Energy Improvement Mortgage, EIM, or Energy Efficient Mortgage, EEM) that credit a home's energy efficiency in the loan[43]. These loans are up to $15,000 and offer below market interest rates[44].

For farmers, Farmer Mac, through USDA's Rural Housing Service, guarantees and insures loans in rural areas, and provides a secondary market for agricultural real estate and rural housing mortgage loans. Additionally, USDA's Rural Business-Cooperative Service offers business and industry guaranteed and direct loans. USDA also has a leveraged loan program for rural borrowers and there are programs for conventional mortgages at market rates (Eiffert, 1999).

Vendor financing offers an easy, low-cost solution and is an effective way for the supplier to stimulate markets. A third party, such as a bank, is often the actual source of financing (Walker, 2001).

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[42] The LEED green building certification program encourages and accelerates global adoption of sustainable green building and development practices through a suite of rating systems that recognize projects that implement strategies for better environmental and health performance.
[43] www.energystar.gov/index.cfm?c=bldrs_lenders_raters.energy_efficient_mortgage (Accessed October 10, 2009)
[44] www.eere.energy.gov/de/project_financing.html (Accessed October 10, 2009)

Chauffage is an agreement where the customer purchases the electricity, heating, or cooling of the solar project instead of the system. This allows the customer to not be burdened with development and ongoing operation of the distributed generation (DG) project, and the risk of non-performance falls on the owner/operator of the equipment (Walker, 2001). This system has been very successful for the development of solar and has taken the form of Power Purchase Agreements (PPA) for larger projects. According to the AltaTerra Research Network, about 72 % of non-residential PV installations in 2008 were driven by third-party financing and PPAs. The PPA has relied on third-party financing, consisting of financing partners like banks with a tax appetite that can benefit from the Federal tax credit offered for solar. The same instrument for smaller systems has developed since 2007 in the residential market. In California, two examples are the SunRun PPA and the Solar City's SolarLease (Johnston, 1-20-2009). The reduction in the homeowner's upfront costs for a PV system can be substantial. For example a lease customer will pay $2,000 in setup fees for a typical 2.5 kW system that would have cost up to $25,000 to own (IEA, June 2009). Whether it's called a lease or a PPA, the end result is the same: the company owns, maintains, and profits from the system and the customer pays a monthly charge for a long-term contract (usually 20 years) that is offset by electrical cost savings.

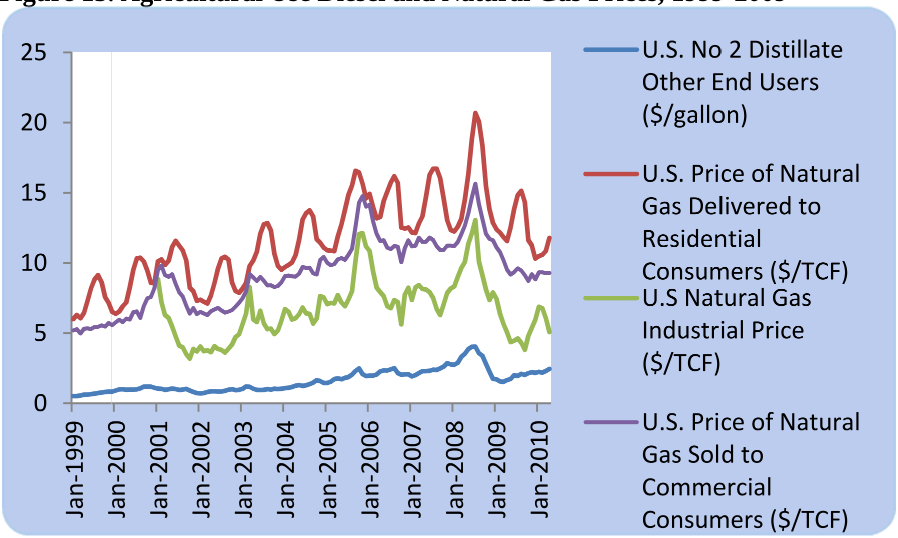
Group purchases can also negotiate discounted prices for their members. Community group purchases by the company 1 Block Off the Grid (1BOG) negotiated up to 48 % off the market price of 2 kW PV systems for its participants in San Francisco during 2008. Other programs such as Go Solar Michigan of the Great Lakes Renewable Energy Association and Go Solar Marin have offered group purchases for several years. Partnerships between PV suppliers and large employers have also emerged, offering as the option to buy discounted residential solar systems as an employee benefit (IEA, June 2009). In the same vein, Organic Valley, a farmer-owned cooperative consisting of more than 1,600 organic family farmers in 33 States and 4 Canadian provinces has agreed with Bubbling Springs Solaron discounted bulk purchase rates for solar thermal collectors for its members and employees (The Dunn County News, 1/18/2010).

Grants, rebates, tax incentives and subsidies are also very important in that they reduce the high up-front cost of the solar energy system that constitutes a deterrent to installation. For example, the Federal investment tax credit (ITC) and, when applicable, the Modified Accelerated Cost Recovery System (MACRS) can account for 40-60 % of the installed cost of a PV system (Cory et al, 2008). Section 9 of this booklet details Federal and State incentives that are available to farmers and ranchers.

b. Fuel Costs

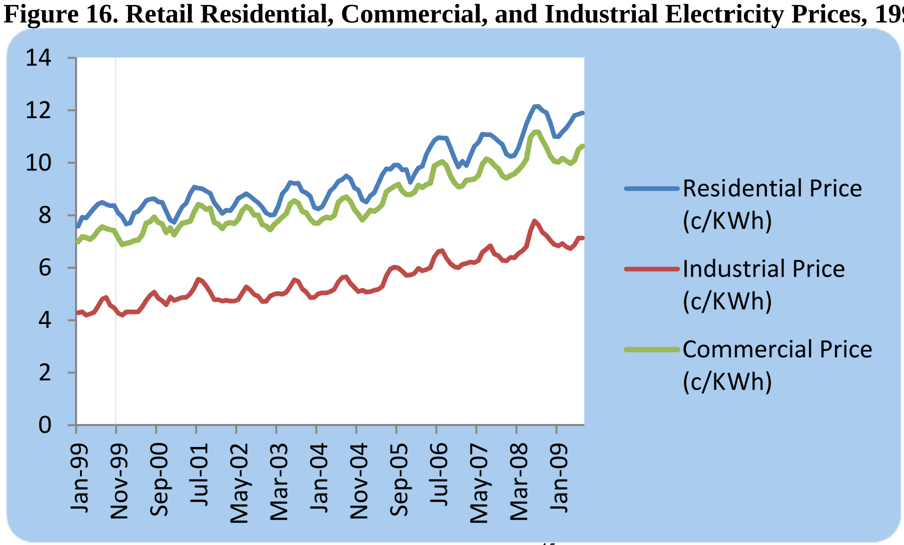
As energy prices and volatility have increased in the past decades, solar energy offers a reliable, fixed and predictable energy source. Solar heating systems can replace or reduce natural gas use and electricity. Grid-connected PV systems reduce electricity needs; off-grid systems can replace the need for grid extension, batteries, natural gas, propane, gas or diesel, depending on the application. Figure 15 shows the upward trend and the persevering volatility in diesel and natural gas prices that farmers faced for the last decade. Electricity prices for farmers have also trended upwards (Figure 16) increasing the attractiveness of on-grid solar energy. Of course, incentives for investing in solar energy are higher in States with higher electricity rates (Figures 19, 20).

Figure 15. Agricultural Use Diesel and Natural Gas Prices, 1999-2009



Source: Energy Information Administration (EIA)

Figure 16. Retail Residential, Commercial, and Industrial Electricity Prices, 1999-2009



Source: Energy Information Administration (EIA)[45]

The fuel of solar energy is free and its life-cycle cost is predictable. Still, high installation costs often make solar energy a more expensive alternative compared to, for example, electricity. Solarbuzz calculates off-grid solar to be on average 20-90% cheaper than the competing energy alternative, but on-grid solar to cost on average two to five times more than the competing source.[46] According to Solarbuzz, the cost of solar in June 2010 was 34.74 ¢/kWh for a small 2kW off-grid residential system, 24.71 ¢/kWh for a 50kW commercial system and 19.27 ¢/kWh for a 500 kW industrial system. Though cheaper than the 2000 prices (39.85 ¢/kWh, 29.62 ¢/kWh and 21.50 ¢/kWh)[47], these compare to an average price of about 11.5 ¢/kWh for residential, 10¢/kWh for commercial and 6.5¢/kWh for industrial electricity rate in 2010.

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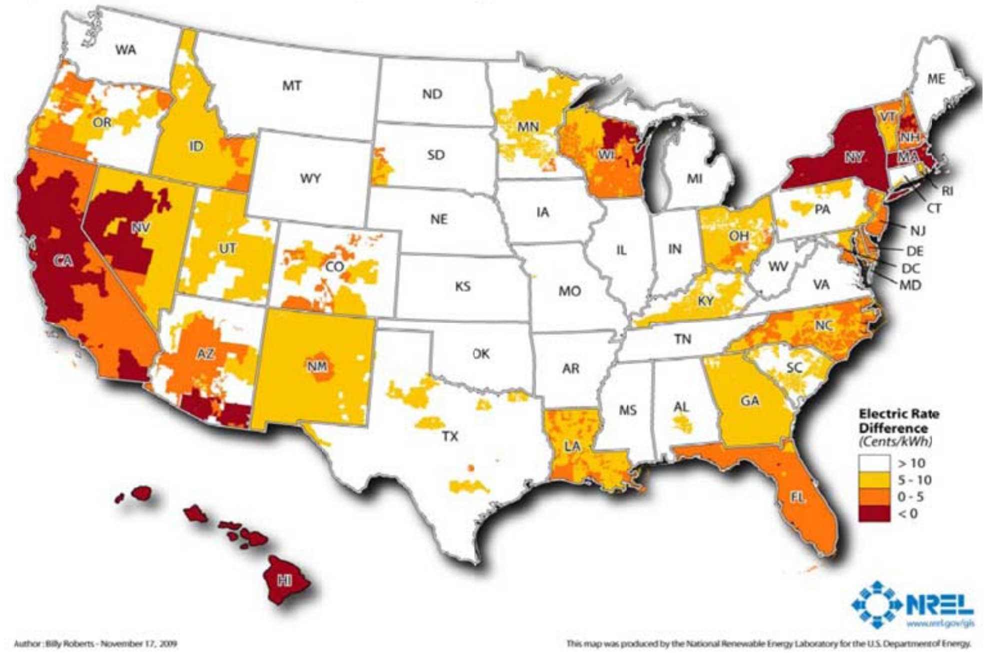
[45] Report No. DOE/EIA-0384, Annual Energy Review, http://www.eia.doe.gov/emeu/aer/elect.html (Accessed July 12, 2010).
[46] Solarbuzz, http://www.solarbuzz.com/StatsCosts.htm (Accessed July 12, 2010)
[47] Solarbuzz, http://www.solarbuzz.com/SolarPrices.htm (Accessed June 28, 2010)

Denholm et al. (December 2009) provide some insight by comparing PV to electricity cost for residential customers in the largest 1,000 utilities (Figure 17)[48]. They show that the areas where PV is close to breakeven are areas where there is a combination of high electricity prices and good solar resources (such as California), or a combination of high electricity prices and incentives (such as New York and Massachusetts).

Figure 17. Increase in Electricity Price Required for Residential PV Breakeven at $8/W

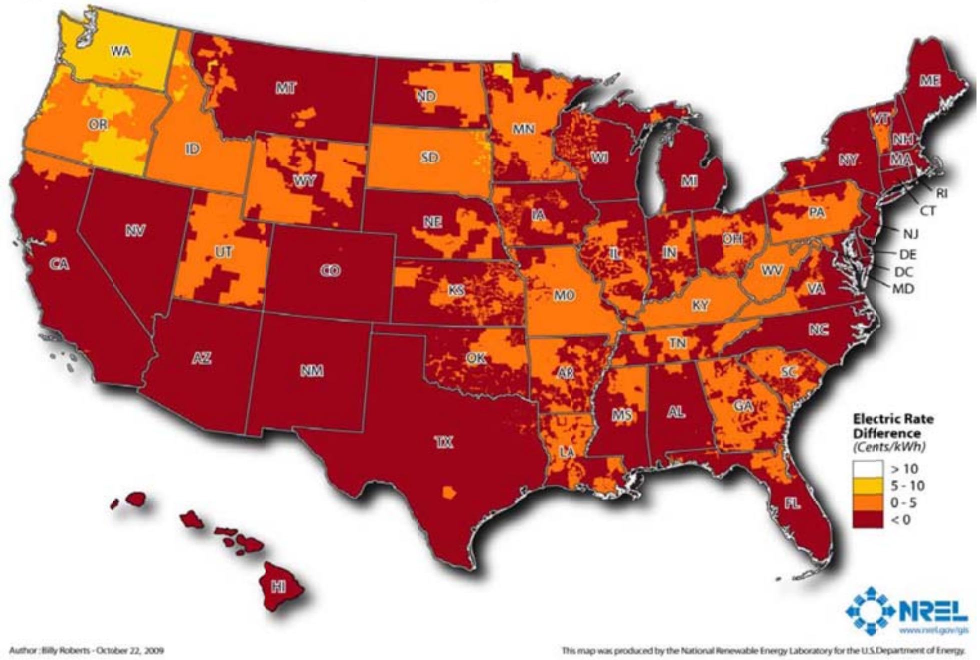


Source: Denholm et al., December 2009

There are two primary factors to consider when comparing solar to conventional fuel sources. First, the cost of conventional fuel is often calculated on a marginal basis while alternative fuel costs are calculated on a fixed cost basis. That is to say that for solar, hydrogen fuel cells, and wind energy systems, while the marginal cost of producing electricity is virtually free, the cost to construct the system is factored into the total cost. That is why solar proves economical in many off-grid applications when the extension line cost for utility supplied electricity needs to be accounted for. Second, the cost of financing to the owner of the installation can have an important impact on the price of solar due to its high up-front cost. Another potential longer term consideration is the environmental value of solar energy. A future carbon tax or cap and trade policy would tip the scales more towards solar and other renewable energy, as the cost of carbon would be added to the price of hydrocarbon fuels. According to Denholm et al. (December 2009), a carbon policy pricing carbon at 25$/ CO_2, along with a 0.5% increase in real electricity prices per year, a reduction of PV cost to 3.5$/W, and elimination of all incentives except the ITC would lead to breakeven values in the majority of the country by 2015 (Figure 18).

[48] Known incentive programs are included in the analysis.

Figure 18. Increase in Electricity Price Required for Residential PV Breakeven at $3.5/W in 2015



Source: Denholm et al., December 2009

c. Net Metering

Net metering is a regulatory policy that has important financial implications for solar energy installations, as it allows farmers to get credit for the excess electricity they generate on their farm by sending it back onto the grid. Under a net metering arrangement, a single, bi-directional meter is used to record both electricity drawn from the grid (the meter spins forward) and the excess electricity fed back into the grid (the meter spins backwards). Thus, farmers can use their energy generation to offset their electricity consumption, usually over a set period or continuously if rollover is allowed[49]. During this period customers receive retail prices for the excess electricity they generate. The higher the retail electricity price, the greater the benefit of net metering to the farmer. Figures 19 and 20 show the average State electricity rates. At the end of the period, the remaining credit is transferred to the utility, paid at the retail rate or paid at the avoided cost[50].

This carryover of electricity credits provides flexibility and helps farmers maximize their electricity generation, especially since the solar resource is seasonal. If a farmer is able to combine net metering with time of use (TOU) rates, the value of solar on average should increase, since the output from the solar systems occurs disproportionately during the times that rates are high under the TOU plan. For example, from noon to 6 p.m. between May 1 and November 1, PG&E will buy or sell electricity at 35 ¢/kWh. During all other times, PG&E will buy or sell electricity at 5 ¢/kWh. If a small farmer moves his electricity usage load (to irrigate his crops for example) after 6 p.m., he can take advantage of this differential.

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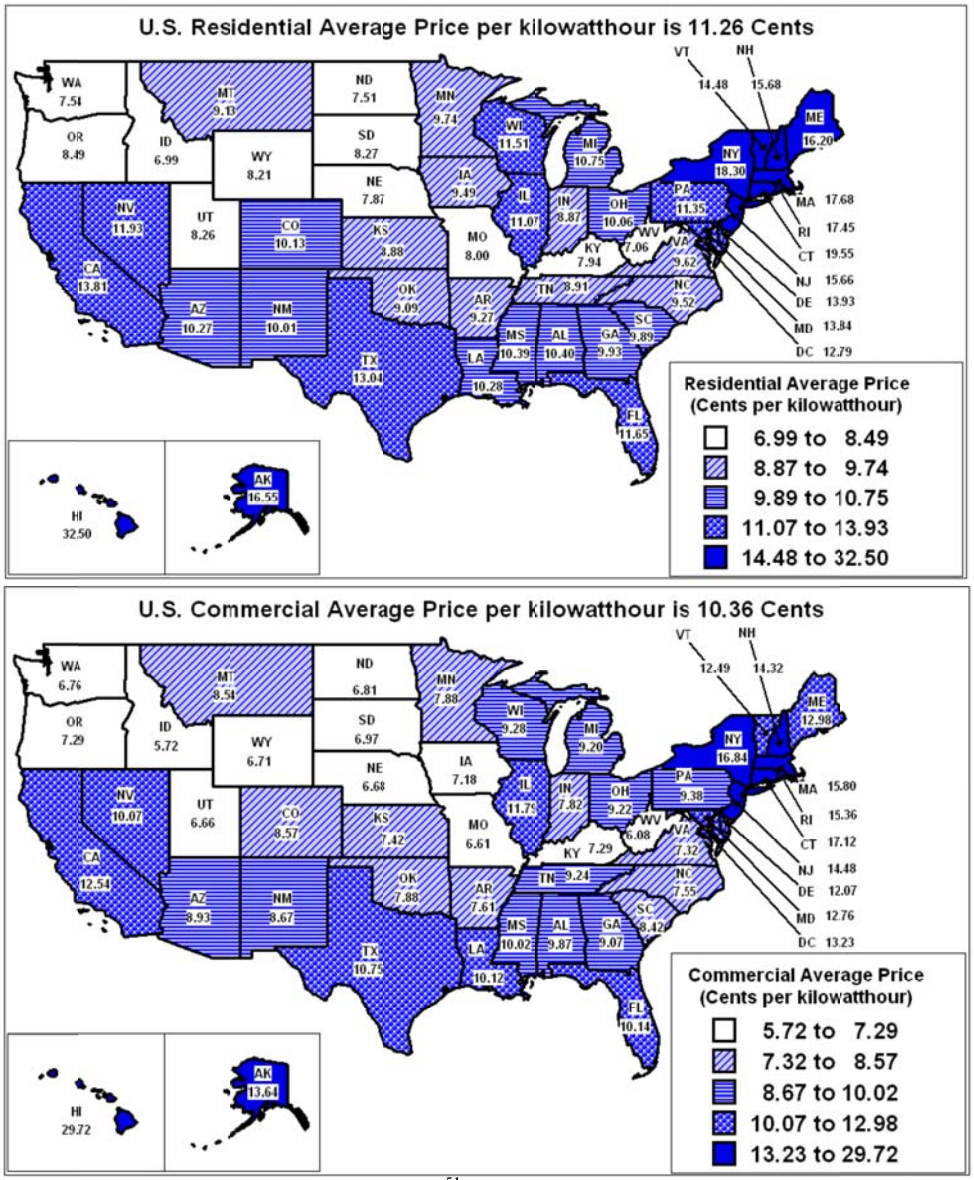
[49] Twelve states allow indefinite rollover.
[50] The price the utility pays for electricity produced from fossil fuels.

Figure 19. Average Residential and Commercial Price of Electricity by State, 2008



Source: Energy Information Administration (EIA)[51]

The number of renewable energy customers in net metering programs has been steadily increasing: from 4,472 customers in 2002 to 48,886 customers in 2007, up to 70,009 customers in 2008. The majority of these customers (over 90%) were residential[52]. In 2007, customers in net metering programs were dispersed across 47 States and the District of Columbia; California alone accounted for 71.4 %[53].

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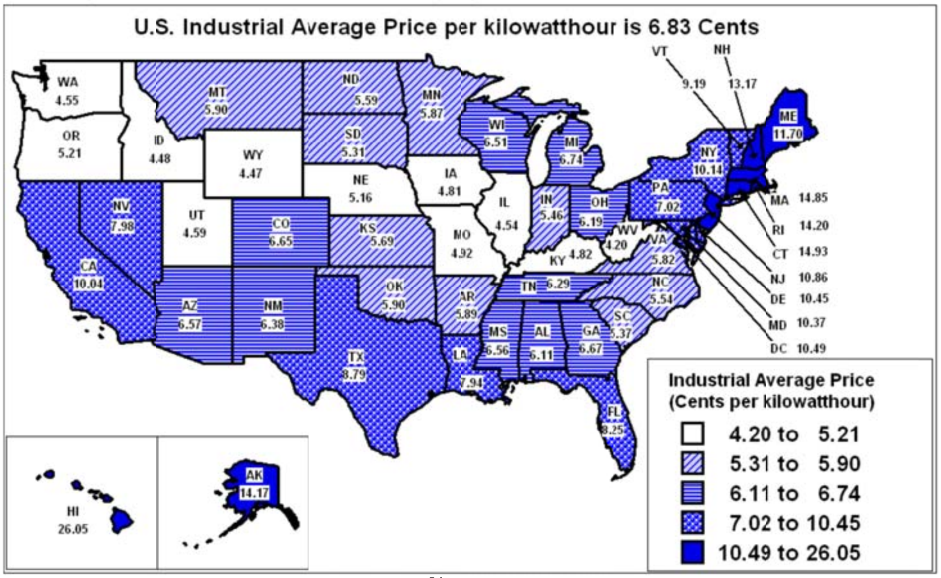
[51] Form EIA-861, "Annual Electric Power Industry Report", http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html (Accessed July10, 2010).
[52] Farmers can be residential or commercial customers depending on the utility schedule they qualify for.
[53] Form EIA-861, "Annual Electric Power Industry Report".
2007: http://tonto.eia.doe.gov/FTPROOT/electricity/034807.pdf (Accessed July10, 2010);
2008: http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html (Accessed July10, 2010).

Figure 20. Average Industrial Price of Electricity by State, 2008



Source: Energy Information Administration (EIA)[54]

Though the norm is a single bi-directional meter, it is possible that the electricity provider requires two meters: one measures the flow of electricity from the grid and the other into the grid. For this arrangement of net purchase and sale, the customer receives only the utility's avoided cost for the excess electricity, a much lower price than the retail rate (Table 12). In this case, sizing the system can limit the excess electricity generated.

Table 12. Comparison of Net Metering and Avoided Cost Buy Back Rates (October 2007)

State	Average Retail Price	Estimated Generation Cost*
California	0.126	$0.08
Idaho	0.052	$0.02
Michigan	0.083	$0.05
Minnesota	0.070	$0.04
New Mexico	0.076	$0.04
New York	0.155	$0.10
Pennsylvania	0.091	$0.06
Texas	0.103	$0.07
Washington	0.066	$0.03
Wisconsin	0.083	$0.05
U.S.	***0.092***	***$0.05***

*Generation costs from conventional fossil fuels and nuclear and hydroelectric sources.
Source: Lazarus et al, 2009

The utility might alternatively offer a purchase agreement that pays the renewable electricity producer a premium above the utility's avoided cost. Smaller utilities (especially smaller rural electric cooperatives) that do not have net metering billing policies in place usually handle each request on an individual basis.

[54] Form EIA-861, "Annual Electric Power Industry Report", http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html (Accessed July10, 2010).

d. Renewable Energy Certificates (RECs) and Potential Carbon Credits

RECs might also be a revenue source from the solar installation in some States. A REC (alternatively called a green certificate, green tag, or a tradable renewable certificate) is created when one (net) megawatt hour of electricity is generated from an eligible renewable energy resource; the REC represents the environmental attributes of the power produced and can be sold unbundled from the generated electricity. RECs are used for renewable portfolio standard (RPS) compliance in a number of States. In voluntary markets, RECs are sold to consumers directly or through green pricing programs; additionally, they are used to supply some carbon offset programs. States with RPS requirements typically have higher REC prices.

In smaller projects, as would usually be found in agriculture, RECs are typically sold through an aggregator. However, the ownership of RECs does not necessarily belong to the solar system owner. In about half the States, the ownership is not defined in net metering rules and past contracts with the Federal Public Utility Regulatory Policy Act of 1978 (PURPA) qualifying facilities. In the States where it is defined, ownership is often, but not always, offered to the renewable energy system owner. Different States have taken different approaches relative to the ownership of RECs (Holt and Bird, 2005; Holt et al., 2006). Customers in New Jersey own the RECs. In Nevada, the customers get the RECs for the energy that is consumed on-site and the utility gets the RECs from the net excess generation. In Maryland, the customer retains the RECs in excess of the required RPS percentage. Additionally, some State Renewable Energy Funds or utilities have required transfer of all or a portion of the RECs in return for providing financial incentives. In Washington and Connecticut, the RECs belong to the customer; however, in Nevada and in Austin, Texas, the utility gets all the RECs from the PV program. In Oregon, the Energy Trust gets RECs proportionate to the level of funding or gains ownership after the fifth year.

The value of RECs varies considerably by region and market. In a number of cases, it can be small. In others RECs can add incremental revenue streams for project developers and owners. As an indication of the potential value of RECs as revenue source, the net income from REC sales for wind generator accounts for roughly 1–10 % of total project revenue (Gillenwater, 2008). For solar development projects, depending on the market price, income from RECs could even double revenues (Cory et al, 2008). Still REC sales on average are not the driving factor in the deployment of solar electricity.

The variation in REC prices depends on location, resource type, and differs between compliance and voluntary markets. In RPS compliance markets RECs vary by State and classification. They are dependent on the stringency of the quota mandated by the State RPS (Gillenwater, 2008). When an Alternative Compliance Payment (ACP) is imposed to penalize non-compliance, it forms the price ceiling for the REC market. According to Holt and Bird (2005), the prices range from as low as 70 ¢ per MWh for existing renewables in Maine[55] and Connecticut[56], $4-$8/MWh in New Jersey, $10-$15/MWh in Texas, and as high as $35-$49/MWh for new renewable energy sources in New England. The variation of prices from 2002 to 2007 in the markets for the District of Columbia, Connecticut, Massachusetts, Texas, Maryland, and New Jersey extended from below $1/MWh to above $55/MWh. During the economic downturn in 2009, the prices only reached slightly above $30/MWh; in Massachusetts they traded in the range of $15-$32/MWh, in

[55] Derived from facilities in service on or after September 1, 2005 (including large hydropower)

[56] Derived from eligible trash-to-energy biomass facilities that began operation before July 1, 1998, or eligible hydropower facilities in operation prior to July 1, 2003

Connecticut $18-$31/MWh, in New Jersey $2.5-$9/MWh, in Pennsylvania $2-$8/MWh (Evolution Markets).

Solar RECs (SRECs) can trade higher (Holt and Bird, 2005) when there is a specific solar carve-out, and because customers exhibit a higher willingness to pay for solar (Borchers et al., 2007). In Colorado the price is over $100/MWh [57] and in New Jersey it reaches above $650/MWh [58]. SREC Trade[59], an auction platform for SRECs, reported that for September 2010 prices in the States that have SREC markets were $229/MWh for Delaware, $290/MWh for the District of Columbia, $327/MWh for Maryland, $601/MWh for New Jersey, $302/MWh for Ohio, and $300/MWh for Pennsylvania.

The prices of RECs in voluntary markets vary by resource type (e.g., biomass, wind, and solar) (Holt and Bird, 2005) and region (Gillenwater, 2008). In 2006, wholesale REC prices in the U.S. voluntary market ranged from $0.5 to $10/MWh with a typical price around $2/MWh (Bird and Swezey, 2006; Gillenwater, 2008, Evolution Markets). Solar RECs may sell for significantly more, around $21/MWh (Evolution Markets). The wholesale price of RECs represents the gross income from certificate sales. Added certification and brokerage costs typically range from 3 to 5 % (e.g., $0.05–$0.15/MWh) (Gillenwater, 2008).

In the future, it is likely that REC values will be closely correlated with carbon credits since both are motivated by the same pressure to reduce carbon emissions. CO_2 prices on the Chicago Climate Exchange ranged from $1 to $5 per metric ton (mt) since 2005 (except for a brief rise to $7.50 in mid-2008), dropped below $1 in June, 2009, and were trading at 0.15 in November 2009 and 0.10 in June 2010[60]. Prices on the European Climate Exchange might be more indicative of future U.S. prices under a cap-and-trade system because Europe already operates under such a system. Prices on that exchange in June 2009 were around 14 euros/mt, which is $19.41/mt in U.S. dollars at an exchange rate of $1.3866/euro. Still the relationship between REC and a potential carbon market is not yet determined and will be influenced by the developments in the U.S. carbon policy.

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[57] http://www.xcelenergy.com/Residential/RenewableEnergy/Solar_Rewards/Pages/home.aspx (Accessed October 10, 2009).
[58] http://www.njcleanenergy.com/renewable-energy/project-activity-reports/srec-pricing/srec-pricing (Accessed November 10, 2009).
[59] http://www.srectrade.com/index.php (Accessed September 2010)
[60] Historical Closing Prices. http://www.chicagoclimatex.com/data/cfi_closing_prices_historical.xls (Accessed November 10, 2009).

8. U.S. Policies Promoting Solar Energy on Farms

A number of policies and programs that promote solar energy adoption are available to farmers and ranchers. According to USDA's first On-Farm Energy Production Survey the average financial support received for solar PV was 44% of the project cost [61] (USDA, 2011). Federal programs are available to all farmers and ranchers, state policies and utility programs differ by locality.

a. Federal Agricultural Support

The USDA ***Renewable Energy Systems and Energy Efficiency Improvement Program*** has provided support for many solar energy installations that are in operation today. This Federal program was established in section 9006 of the Energy Title of the 2002 Farm Bill and renamed ***Rural Energy for America Program* (*REAP)*** in the 2008 Farm Bill. It is administered by the Business Program of the Rural Business-Cooperative Service (RBS), Rural Development, USDA. It provides grants and loan guarantees for energy efficiency and renewable energy systems to qualified farms, ranches, and rural businesses. Both solar electric and solar thermal projects are eligible.

The grants provided can cover up to 25% of the solar energy system cost. The remainder of the funding would have to be acquired through private funds, loans, investors, or available State or local grants. The minimum grant amount per project is $2,500 and the maximum is $500,000[62].

The loan guarantee, which reduces the project risk by protecting the lender against a portion[63] of the value of a loan in the event of a default, can cover up to 50% of eligible project costs with a minimum amount of $5,000 and a maximum of $10 million. Combined grant/guaranteed loan applications are also limited to 75% of eligible project cost[64].

In 2008, REAP awarded 769 projects with a total of $34 million in grants and $15.5 million in loan guarantees. Seventy-four percent of awards were given to energy efficiency projects. Of the remaining 200 projects for renewable energy, 59 projects were for solar energy, putting it in first place with 29.5% of renewable energy projects[65]. In 2009, of the 1,485 REAP projects, again only 26 % were for renewable energy projects. With most renewable projects going to solar, the solar energy share increased to about 50%[66]. Wind followed with almost 35% (Figure 21).

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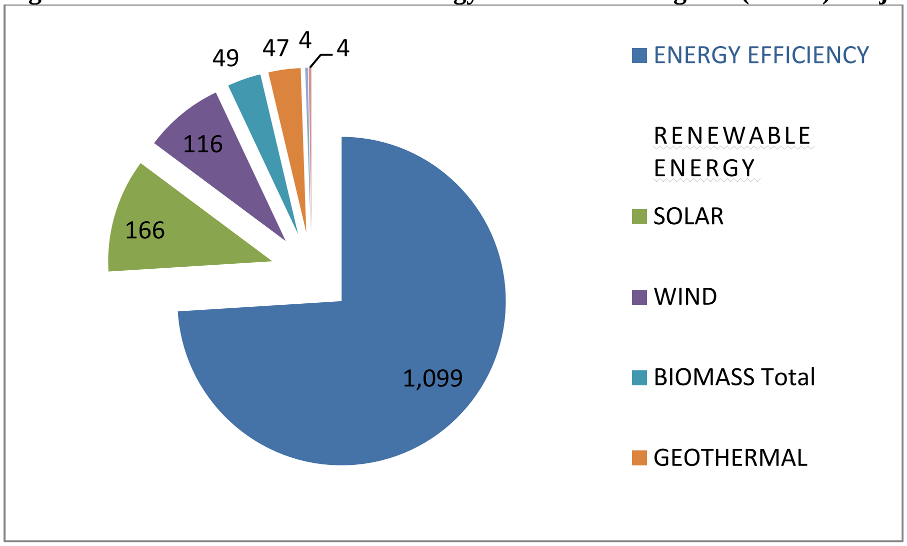
[61] Excludes loans.
[62] The amount available from multiple projects per applicant cannot exceed $750,000.
[63] Up to 85% of the loan amount for loans under $600,000, declining to 80% for loans between $600,000-5 million and 70% for loans of $5-10 million.
[64] Increased from 50% in the 2002 Farm Bill.
[65] The five awarded hybrid projects included a solar component.
[66] The four awarded hybrid projects also included a solar component.

Figure 21. Number of 2008 Rural Energy for America Program (REAP) Projects

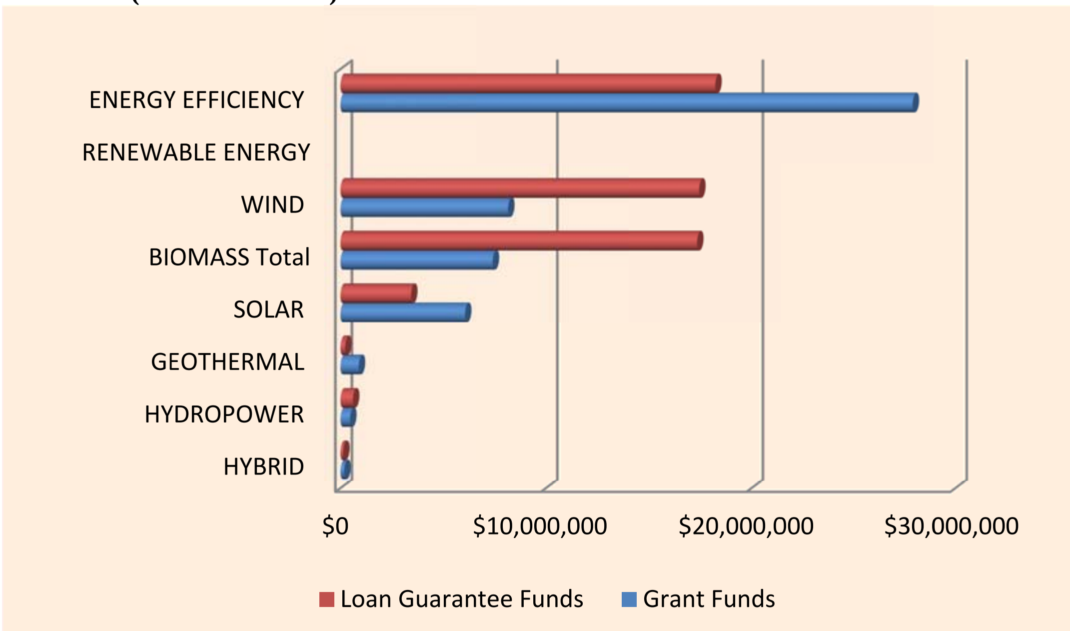


Source: Business Program of Rural Business-Cooperative Service (RBS), Rural Development, USDA

In 2008, these solar energy projects (including the hybrids) were scattered across 24 States. Most projects were in Oregon (13) and New York (9). Colorado and New Jersey each had four solar projects supported by REAP. Four projects were funded in Wyoming and three in Hawaii. All these states rank high in stalled PV capacity in agriculture (USDA, 2011). California, the State with the largest installed solar capacity in agriculture, only had two solar projects supported by REAP while Florida did not have any. The geographic distribution of solar awards should be re-shaped due to a less concentrated fund allocation in the REAP program from 2009 and on. In the first 5 years of the REAP, grant awards tended to be concentrated in a few States, but as of 2009, each individual State Rural Development office has been allocated funds for its State (FarmEnergy.org). The dispersion of the 2009 solar awards increased to 39 States, Puerto Rico and the West Pacific. Thirty-two projects were located in Oregon, 16 in Georgia, 14 in Wyoming, Massachusetts followed with 9, New York and Arizona with 8, and Tennessee with 7. California, New Jersey, and Colorado, which ranked highest in PV grid-connected energy capacity for 2009, had six, three, and four projects, respectively. Florida again had no installations, while Hawaii had six installations supported by REAP.

In 2009, energy efficiency projects received the most grant and loan guarantee money, followed by wind and biomass. A smaller amount of funding was given to solar projects – about $6 million in grants and 3.4 in loan guarantees (Figure 22). This was almost a threefold increase in grants and a sevenfold increase in loan guarantees from 2008 ($2.3 million and $457,000, respectfully). Up to 2007, there were no loan guarantees for solar projects. This increase in loan guarantee awards shows that farmers are moving towards credit financing for solar projects, an assistance which is used much more for other renewable energy options.

Figure 22. Funds for 2009 Rural Energy for America Program (REAP) Grants and Loan Guarantee (thousand dollars)



Source: Business Program of Rural Business-Cooperative Service (RBS), Rural Development, USDA

Solar system awards grew substantially in 2008. They had the largest growth in terms of grant money and second-largest in terms of awards. This nearly doubled the solar energy participation in the REAP program in 2008. By the end of 2008, a total of 117 solar energy projects were awarded almost $5 million in grants and $457,000 in loan guarantees. Solar projects are projected to increase further in the future due to a change in the 2008 Farm Bill that reserves 20% of the funds for applications requesting less than $20,000 in funding. The smaller scale of solar energy applications in agriculture combined with solar's modular nature favors it. The expansion of eligible projects in the 2008 Farm Bill to include the sale of renewable energy and the State allocation of part of the REAP funds since 2009 might also have a positive influence on the number of solar energy awards in the future. In 2009 solar projects more than doubled relative to 2008, reaching 283 projects awarded, with slight of $11 million in grants and $3.9 million in loan guarantees.

Another source of funding for farmers and ranchers that can be used for solar energy systems is the USDA's ***Value-Added Producer Grants***. In general, these grants are used for planning activities and working capital in marketing value-added agricultural products and farm-based renewable energy. Up to $100,000 can be provided for business planning or feasibility studies and up to $300,000 for working capital. Eligible applicants are independent producers, farmer and rancher cooperatives, agricultural producer groups, and majority-controlled producer-based business ventures. Though only a couple of solar projects have been funded through this program, many biomass, biofuel, biobased products, and wind energy projects have received funding.

More solar projects have been funded through ***Sustainable Agriculture Research and Education (SARE)***, which is supported by USDA's National Institute of Food and Agriculture (NIFA). Though SARE has provided competitive grants for sustainable agriculture research and education since 1988 (and farmer involvement has been instrumental in the process), it was not until 1992 that SARE's North Central Region began directly funding farmers and ranchers. By 1995 each

SARE region had followed suit. Today, farmers and ranchers can apply for grants that typically run between $500 and $15,000. Over 20 active solar systems, and more than 10 passive solar projects, have been funded through SARE grants between 1994 and 2009. Funding amounts ranged from $2,000 to $18,000, though not all of the funding was applied to the solar component of the project. Since 2005, funding for solar projects was provided to aquaculture, hybrid geo-solar heating systems, livestock watering, sustainable energy, irrigation, and greenhouse heating.

b. Federal Investment Tax Credit

The Federal ***Investment Tax Credit (ITC)*** has been instrumental in propelling many solar installations in residential and commercial settings. Farmers, ranchers, and rural businesses, depending on their status, are able to use the corporate (26 USC 48) or residential (26 USC 25D) ITC in addition to agricultural support described in the previous section to help fund renewable energy installations.

The ITC works as a reduction in the overall tax liability for individuals or businesses that make investments in solar energy generation. Extended and expanded in October 2008 and February 2009[67], both the corporate and residential ITC are equal to 30 % of the expenditures to install a solar system after the exclusion of any subsidized portion of the project, with no upper limit on the total amount. Set at 30% in 2005, the ITC has had a marked influence on the solar market. By 2008, the capacity of solar and PV systems installed each year was triple the annual amount installed in 2005. The ITC will be effective until December 2016 and can be used by individual and corporate taxpayers, as well as alternative minimum tax (AMT) taxpayers and public utilities (excluded in previous law). The American Recovery and Reinvestment Act of 2009 also allowed that the corporate ITC may instead be received as a grant from the U.S. Treasury Department by eligible taxpayers. For further information, on the ITC visit www.energytaxincentives.org or www.dsireusa.org.

c. Federal Modified Accelerated Cost-Recovery System (MACRS)

The Internal Revenue Service (IRS) allows commercial owners of solar systems to use a 5-year ***MACRS*** schedule. The 5-year schedule for most types of solar, geothermal, and wind property has been in place since 1986. Under the MACRS, businesses may recover investments in certain property through depreciation deductions with schedules ranging from 3 to 50 years, over which time the property may be depreciated. Depreciation reduces an entity's taxable income, and subsequently, its tax burden. The shorter the depreciation schedule, the greater the percentage of the asset that can be depreciated each year. For solar energy, a 5-year MACRS is more advantageous than longer depreciation schedules since shorter schedules allow businesses to accelerate the accrual of tax benefits of depreciating a particular asset, improving the return of the project.

The Economic Stimulus Act of 2008 contains bonus depreciation for qualifying assets placed in service in 2008. Extended (retroactively to the entire 2009 tax year) by the American Recovery

[67] The 30% ITC for residential installations was set by the Energy Policy Act of 2005 (EPAct 05) and extended for an additional year by the Tax Relief and Health Care Act of 2006 until the Energy Improvement and Extension Act of 2008 (H.R. 1424, Division B) and the American Recovery and Reinvestment Act of 2009 (H.R. 1: Div. B, Sec. 1122, p. 46) extended the TRI to its current provisions. A 15 percent tax credit for solar energy was originally established by the Energy Tax Act of 1978. This credit expired for residential use in 1982; for commercial use it was phased out by the Tax Reform Act of 1986 to 10 percent in 1988 where it remained until 2005.

and Reinvestment Act of 2009, the bonus depreciation can apply to solar systems if certain criteria are met. Instead of the standard 5-year MACRS schedule, 50% of the installed cost of the solar system can be depreciated in the first year, with the remaining 50% to be depreciated over the original schedule. For further information on the MACRS and the 2008-2009 bonus depreciation, visit www.dsireusa.org.

d. Financial State Incentives

In addition to the Federal tax credits, States such as New Jersey, Colorado, and California also have provided sizable financial incentives to promote solar PV. State incentives have led to New Jersey ranking second in distributed PV capacity with limited solar radiation. In March 2009, the Office of Energy Policy and New Uses (OEPNU) in USDA concluded a survey of State level financial incentives that farmers and ranchers could use for installing solar energy systems. Up-to-date State-level incentives for solar energy are available on DSIRE, www.dsireusa.org.

Farmers and ranchers can have access to a number of State-level financial incentives that support solar energy (Table 13). Depending on the program requirements, they might be eligible as commercial entities or residents. For example, some programs might exclude residential systems while others apply only to these systems. The specific programs are provided in the Appendix of this report. Interested farmers would have to check for eligibility on a case-by-case basis. Eligibility may depend on being connected to the grid, paying the State's public benefits fund (PBF) surcharge, or being a customer of a certain investor-owned utility. Farmers are encouraged to check with their State, locality, and electricity providers.

Table 13. Summary of Financial Incentives Available to Farmers

Incentive Type	Programs*	State Programs
Rebate Programs	Numerous	20 Programs in 15 States
Grant Programs	11 Programs in 9 States	8 Programs in 8 States
Production Incentives	28 Programs in 21 States	3 Programs
Tax Incentives	29 in 16 States	29 Programs in 16 States
Sales Tax Incentives	21 Policies in 19 States + PR	19 Policies in 18 States + PR
Property Tax Incentives	39 in 27 States + PR	27 Policies in 22 States + PR
Loan Programs	59 Programs in 29 States	23 Programs in 20 States

* Includes State, local, utility and other private programs
Source: OEPNU. Compiled from information collected as of March 2009 through DSIRE, program review, and direct communication with program operators. The specific programs are presented in the Appendix.

As of March 2009, USDA identified 15 States that sponsor rebate programs (Table 14). Numerous local, utility, and other private programs are also available. Rebates are discounts for solar energy system installations and vary widely based on technology and program administrator. Rebates provide funding for solar water heating and/or photovoltaic (PV) systems. USDA also identified 12 grant programs, 9 of which are State operated (Table 14). Most programs offer support for a broad range of technologies, while a few programs focus specifically on solar systems. In general, they are designed to pay down the cost of eligible systems or equipment and are typically available on a competitive basis.

As of March 2009, 28 production incentives programs were confirmed in 21 States (Table 14). Only three programs were administered by the State in California, New Jersey, and Washington, although after March 4, more State incentive programs were enacted in Hawaii, Maine, Oregon and Vermont. Production incentives (also known as performance-based incentives) are often attractive, as they provide cash payments based on the number of kilowatt-hours that a renewable energy system generates. Most are limited to a geographic region; however, the Green Tag Purchase Program from Northwest Solar Cooperative operates in Idaho, Montana, Oregon, and Washington, and the Tennessee Valley Authority's (TVA's) Green Power Switch Generation Partners Program operates in Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia.

States also use a number of tax incentives to promote solar energy. As of March 2009, USDA discovered 30 corporate and personal tax incentives that were available to farmers in 16 States, 21 sales tax incentives available in 19 States and Puerto Rico, and 38 property tax incentives available in 27 States and Puerto Rico (Table 14).

Corporate tax incentives include corporate tax credits, deductions, and exemptions for the installation of renewable energy systems. In a few cases, the incentive is based on the amount of energy produced by an eligible facility. Some States might require a minimum amount in an eligible project and, typically, there is a maximum limit on the dollar amount of the credit or deduction. Personal tax incentives include personal income tax credits and deductions. The percentage of the credit or deduction varies by State, and in most cases, there is a maximum limit on the dollar amount of the credit or deduction.

Sales tax incentives typically provide an exemption from the State sales tax (or sales and use tax) for the purchase of a renewable energy system. Puerto Rico has a sales tax exemption that applies specifically to farmers. Though most sales taxes apply Statewide, Colorado only has local options. Property tax incentives include exemptions, exclusions, and credits. The majority of the property tax incentives provide that the added value of a renewable energy system is excluded from the valuation of the property for taxation.

There were 59 loan programs also found to be available to farmers and ranchers in 29 States (Table 14). Loan programs provide financing for the purchase of renewable energy equipment. Low or zero interest loans for energy efficiency projects are a common demand-side management (DSM) strategy for electric utilities. Some State governments also offer low-interest loans. Loan terms are generally 10 years or less. California, Hawaii, and Montana have loan programs that apply specifically to agriculture.

Table 14. States Offering Financial Incentives to Farmers

	State Programs		Production Incentives	State Tax Incentives			Loans
	Rebate	Grant		Income	Sales	Property	
Alabama			√				
Alaska			√				
Arizona				√	√	√	√
California	√		√			√	√
Colorado					√	√	√
Connecticut	√	√			√	√	√
Delaware	√						
Florida	√		√		√	√	√
Georgia			√	√			√
Hawaii				√			√
Idaho			√		√		√
Illinois	√	√				√	
Indiana		√				√	
Iowa					√	√	√
Kansas						√	√
Kentucky			√	√	√		√
Louisiana				√			√
Maine	√						√
Maryland	√				√	√	
Massachusetts	√		√	√	√	√	√
Minnesota	√		√		√	√	√
Mississippi			√				√
Missouri							√
Montana		√	√	√		√	√
Nebraska							√
Nevada	√					√	
New Hampshire						√	√
New Jersey			√		√	√	√
New Mexico			√	√	√		
New York	√			√	√	√	√
North Carolina			√	√		√	√
North Dakota				√		√	
Ohio		√			√	√	
Oklahoma							
Oregon	√		√	√		√	√
Pennsylvania		√					√
Rhode Island			√	√	√	√	
South Carolina		√		√			√
South Dakota						√	
Tennessee		√	√				√
Texas						√	
Utah				√	√		
Vermont	√		√	√	√	√	√
Virginia			√			√	
Washington			√		√		√
Wisconsin	√	√	√			√	
Wyoming	√				√		
Commonwealth of Puerto Rico					√	√	

Source: OEPNU. Compiled from information collected through DSIRE, program review, and direct communication with program operators. The specific programs are presented in the Appendix.

Due to the controversy that has arisen, only a quick mention is warranted for Property Tax Financing programs that fall under the umbrella of "Property Assessed Clean Energy" (PACE) financing. First implemented in California and legislatively adopted by 24 States in 2009, this tool allows property owners to borrow money for renewable energy and repay it through increased property tax assessments. Their expansion and implementation came to an acute halt after Fannie Mae and Freddie Mac suggested PACE violated standard mortgage provisions and the Federal Housing Finance Agency (FHFA) raised concerns of increased risk that they pose to the "safety and soundness" of the housing finance industry; at present, future developments are uncertain (Zimring et al., 2010).

Only one lease program was identified in operation in North Dakota specifically for farmers and ranchers. Still, it can be cost effective for utilities to offer leasing programs when the cost of extending and maintaining the electric distribution lines is too high, often the case in low-density agricultural lands. In some past cases, solar leasing served as a demonstration for solar water pumping and was replaced with direct investment by ranchers as adoption expanded according to Nebraska's Northwest Rural Public Power District experience.

e. Supporting State Incentives

States have an important role for the deployment of solar and other renewable energy. Since electricity generation is a State's right issue, utility policy and regulation comes under State rule. In addition to financial and tax incentives, States implement a number of policies that can also be instrumental in encouraging the use of solar energy in rural America. In October 2009, the Office of Energy Policy and New Uses in USDA concluded a review of such policies. Up-to-date information is available on DSIRE, www.dsireusa.org.

Renewable Portfolio Standard (RPS)

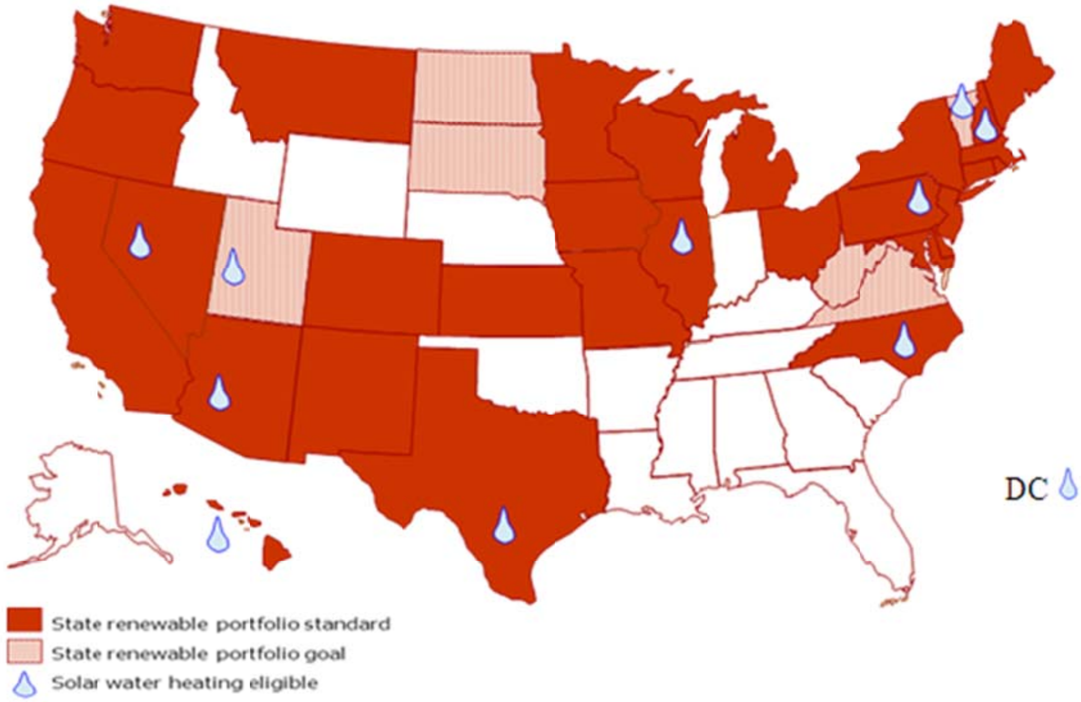
The RPS policy is widely considered to be among the most important drivers for promoting renewable energy (Wiser and Barbose 2008). It imposes a minimum amount of renewable energy generation or capacity that electricity providers must meet, propelling them to support the installation of renewable energy systems. As of October 2009, 29 States and the District of Columbia have established an RPS (Figure 23). Six additional States and Guam have set a renewable energy goal that is not legally binding. Some States meet the RPS through REC procurement. Sixteen States have specifically included in their RPS solar or DG provisions (mostly set-asides)[68] providing additional incentives specifically for solar energy infrastructure (Figure 24).

Public Benefit Fund Policies

States that have public benefit funds (PBF) finance renewable energy and/or energy efficiency projects and support renewable energy markets, usually with a small surcharge on utility customers' bills. This policy offers stable long-run funding to provide security for renewable energy investments by private, commercial, and industrial entities. As of October 2009, 16 States and the District of Columbia have a PBF program (Figure 25). Maine also has a fund, but it is paid for by voluntary contributions.

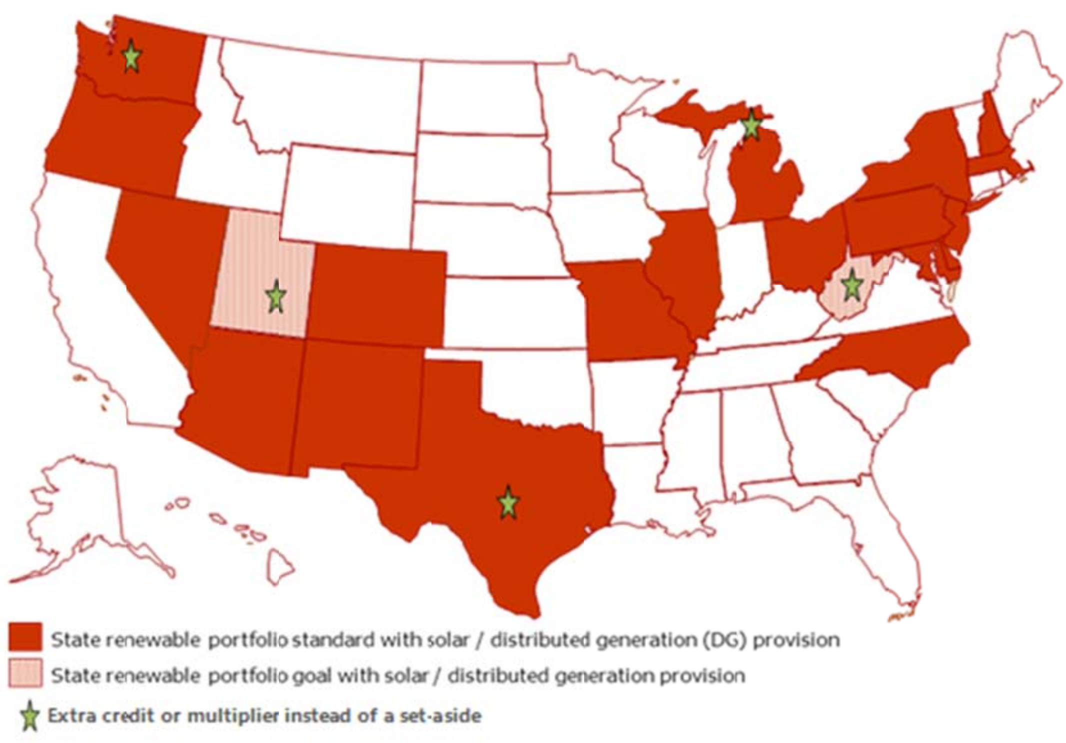
[68] A "set-aside," also called a "carve-out," is a provision within an RPS that requires utilities to use a specific renewable resource (usually solar energy) to accomplish a certain percentage of their RPS.

Figure 23. States With RPS Policies



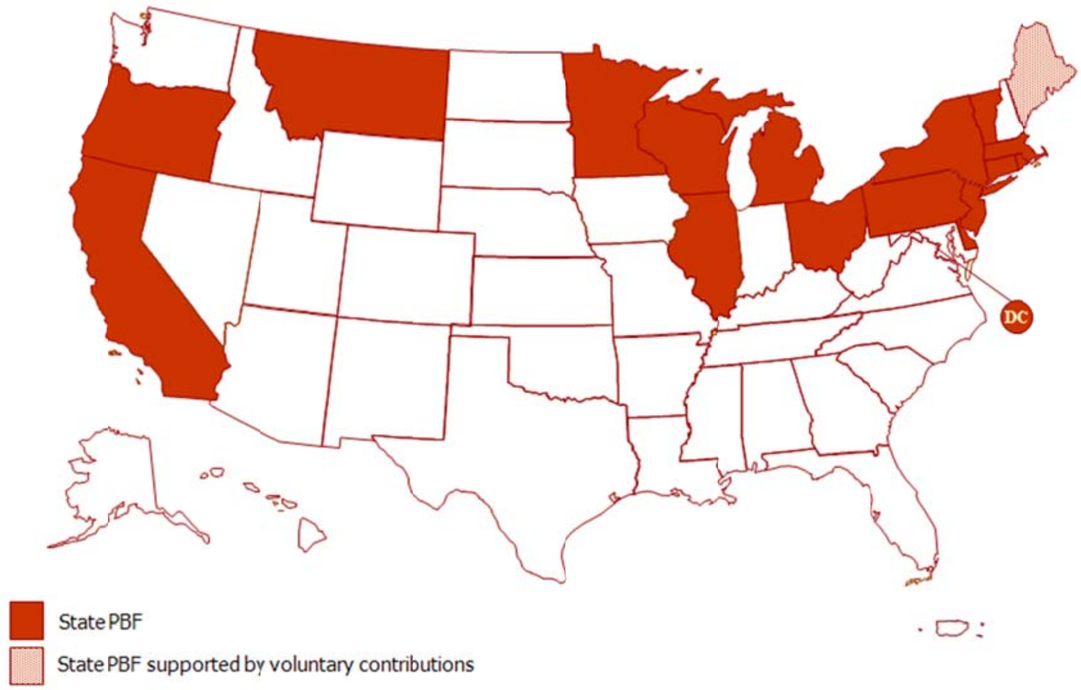
Source: DSIRE

Figure 24. RPS With Solar or DG Provision



Source: DSIRE

Figure 25. States with PBF



Source: DSIRE

Green Power Purchasing Policies

Green Power Purchasing policies create demand for renewable energy through a mandate, or by requiring utilities to offer a green power option. In other cases green power purchasing is provided voluntarily. Only eight of the 41 States with green power policies[69] have a mandatory policy. Though green policies have not been a significant driver of customer sited solar, some have been linked to the adoption of production incentives that support needed renewable energy infrastructure. Overall, there are 52 production incentive programs as of October 2009. North Carolina Green Power, TVA, GreenTag Purchase and We Energies represent some examples of programs that have supported customer sited solar energy.

Equipment Certification and Contractor Licensing

Though less relevant than other policies, equipment certification and contractor licensing policies reduce performance risks farmers and ranchers might face. As of October 2009, Arizona, California, Florida, Minnesota, and Puerto Rico require that renewable energy equipment meet set standards ensuring the quality of the equipment in the market, while nine States have implemented specific contractor-licensing requirements (Table 15)[70] that guarantee that contractors have the experience and knowledge for proper installation and maintenance of renewable energy systems[71] (DSIRE).

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[69] http://apps3.eere.energy.gov/greenpower/markets/pricing.shtml?page=4 (Accessed November 10, 2009)
[70] According to DSIRE it is difficult to obtain and verify information about these two policy types and more states might require equipment certification and contractor licensing.
[71] Contractor licensing requirements tend to focus on solar thermal and electric systems.

Table 15. States With Contractor Licensing Requirements

Arizona	Florida	Nevada	Utah
California	Hawaii	Oregon	Wisconsin
Connecticut	Michigan	Puerto Rico	

Source: DSIRE

Line Extension Analysis Policy

Four States (Arizona, Colorado, New Mexico, Texas), concentrated in the Southwestern United States, have implemented line extension analysis policies (DSIRE; Brown and Busche, 2008)[72]. These policies require utilities to provide off-grid customers who request access to electricity with the cost estimate for the line extension to the grid power, as well as information on the costs of alternative renewable energy options. This policy helps farmers and ranchers determine when it might be less expensive to build an on-site renewable energy system instead of connecting to the grid to meet their electricity needs for a certain application. The importance of this enforcement is delineated in a case in Texas where customers who were interested in a line extension often claimed to be uninformed by the utilities about the renewable energy option.

Interconnection Policies

Farmers interested in generating their own electricity with a grid-tied photovoltaic (PV) system must first apply to interconnect to the system. Under the PURPA, utilities must allow small-scale, renewable energy systems to be interconnected with the utility grid. The States, however, generally regulate the process by which the system is connected to the electric distribution grid. Standards for grid interconnection for small-scale distributed generation are essential to ensuring the safety and stability of the system. Interconnection standards can also greatly impact the attractiveness and development of customer-sited renewable energy depending on the design and implementation. Simplification, standardization, and low transaction costs for interconnection can support the development of customer-sited DG. However, an interconnection process could pose a barrier to the development of customer-sited renewable energy if it is too lengthy, arduous, or expensive.

As of October 2009, 40 States and the District of Columbia have implemented interconnection standards. However, according to the scoring methodology used by Freeing the Grid 2008, only 15 States and the District of Columbia were considered to have satisfactorily removed market barriers for renewable energy development (Table 16). Additionally, the electric cooperatives[73] that most often service farmers and ranchers are not subject to the State standards in 18 States (Table 17).

[72] According to DSIRE it is difficult to obtain and verify information about this policy type and more states might have line extension analysis policies.

[73] Electric cooperatives are owned by the customers they serve. Profits are either reinvested for infrastructure or distributed to members in the form of "capital credits." They are usually found in rural areas and were created by the New Deal to bring electric power and telephone service to rural areas. They are known as Electric Membership Corporations (EMCs) or Rural Electric Cooperatives (RECs).

Table 16. States With Interconnection Policies†

Arizona*	Indiana	Nebraska†	South Dakota†
Arkansas	Iowa	Nevada*	Texas
California*	Kansas†	New Hampshire	Utah
Colorado*	Kentucky†	New Jersey*	Vermont*
Connecticut	Louisiana	New Mexico	Virginia
District of Columbia*	Maryland*	New York*	Washington*
Delaware	Massachusetts*	North Carolina*	Wisconsin
Florida*	Michigan	Ohio	Wyoming
Georgia	Minnesota	Oregon*	
Hawaii	Missouri	Pennsylvania*	
Illinois*	Montana	South Carolina	

† Kansas, Kentucky, Nebraska, Nevada, and South Dakota adopted Interconnection Policies in 2009 and were not evaluated by *Freeing the Grid 2008*. Puerto Rico also has an interconnection Policy.
*Interconnection policies that satisfactorily remove market barriers for renewable energy development, based on scoring methodology in *Freeing the Grid 2008.*
Sources: Freeing the Grid 2008, DSIRE

Table 17. States Where Interconnection Standards Do Not Apply to Electric Cooperatives†

Florida	Montana***	Ohio	Texas
Illinois	Nevada	Oregon	Utah****
Indiana*	New Jersey	Pennsylvania	Wisconsin*****
Iowa**	New York	South Carolina	
Kansas	North Carolina	South Dakota	

† Kentucky's law requires that most electric cooperatives develop Interconnection Standards except for the five Tennessee Valley Authority (TVA) electric cooperatives.
*Interconnection Standards are required by regulated electric cooperatives only.
**Interconnection Standards are required by utilities that comply with PURPA only.
***The Montana Electric Cooperatives' Association (MECA) developed and adopted a model Interconnection of Small Customer Generation Facilities policy in 2001 (that includes guidelines for net metering), which has been adopted in whole or part by most of the 26 electric cooperatives in Montana.
****Utah law requires that most electric cooperatives offer net metering. Beginning in March 2008, electric cooperatives serving fewer than 1,000 customers in Utah may discontinue making net metering available to customers that are not already net metering. In addition, electric cooperatives not headquartered in Utah that serve fewer than 5,000 customers in Utah are authorized to offer net metering to their Utah customers in accordance with a tariff, schedule, or other requirement of the appropriate authority in the State in which the co-op's headquarters are located.
*****Electric cooperatives are not subject to the State standards but are encouraged to adopt them.
Sources: Freeing the Grid 2008, DSIRE

Net Metering

Net metering allows farmers with personal electricity-generating systems to direct excess electricity into the grid and use the electrical grid as a backup. Net metering is identified with bi-directional metering[74]; the farmer pays for the net electricity used from the grid over a set time period[75] and gets a kilowatt-hour credit for the excess electricity generated.

[74] Dual metering has historically been an alternative, but the preferred method of accounting for the electricity under net metering is with a single, reversible meter. In dual metering, customers or their utility purchase and install two non-reversing meters that measure electrical flow in each direction.
[75] Customers are generally not paid for electricity generated in excess of what they use themselves over a set time period, usually a year.

Forty-two States and the District of Columbia have net metering policies, and a few utilities in other States offer net metering voluntarily (DSIRE). Net metering policies vary in design, economic return to customers, and effectiveness. According to the scoring methodology used by *Freeing the Grid 2008,* only 26 States were considered to have effective net metering policies on renewable energy development (Table 18).

Additionally, the net metering policies in some States only apply to investor-owned utilities and not to municipal utilities or electric cooperatives (DSIRE). Sixteen States do not require electric cooperatives that most often service farmers and ranchers to net meter (Table 19). However, a few electric cooperatives have adopted net metering policies voluntarily, so interested farmers are prompted to contact the cooperative directly for information.

Farmers and ranchers who have solar energy systems tied to the grid but are not offered net metering are eligible for net purchase and sale[76], which offers a much lower return. Under this system two separate meters measure electricity in and out of the system; electricity consumed is bought from the utility at the retail rate, and excess electricity generated is sold to the utility at the lower "avoided cost" rate (the wholesale rate) or a negotiated rate offered.

Table 18. States With Net Metering†

Arizona*	Indiana	Montana*	Oregon*
Arkansas*	Iowa*	Nebraska†	Pennsylvania*
California*	Kansas†	Nevada*	Rhode Island
Colorado*	Kentucky*	New Hampshire*	Utah
Connecticut*	Louisiana*	New Jersey*	Vermont*
D.C.	Maine*	New Mexico*	Virginia*
Delaware*	Maryland*	New York*	Washington
Florida*	Massachusetts*	North Carolina	West Virginia
Georgia	Michigan	North Dakota	Wisconsin
Hawaii	Minnesota	Ohio*	Wyoming*
Illinois	Missouri*	Oklahoma	

† Kansas and Nebraska adopted net metering policies in 2009 and were not evaluated by *Freeing the Grid 2008.* Guam, Puerto Rico, Virgin Islands, and American Samoa also have net metering policies. Texas no longer has a statewide net metering policy.
*States with effective net metering policies (scores above C) based on the evaluation by *Freeing the Grid 2008.*
Sources: Freeing the Grid 2008, DSIRE

[76] PURPA requires power providers to purchase excess power from grid-connected small renewable energy systems at a rate equal to what it costs the power provider to produce the power itself.

Table 19. States Where Net Metering Does Not Apply to Electric Cooperatives†

Florida	Kansas	New Jersey	Pennsylvania
Illinois	Michigan*	New York	Rhode Island
Indiana	Montana**	North Carolina	Utah***
Iowa	Nevada	North Dakota	Wisconsin

† Up until July 2009, net metering in Delaware applied to electric cooperatives only if they opted to compete outside their service territories. Since July 2009, net metering applies to all utilities in Delaware.
*The new net metering legislation addresses all rate-regulated utilities (investor-owned utilities and rural electric distribution cooperatives) and alternative electric suppliers; however, it is uncertain if the new law will apply to electric cooperatives that opt for member regulation under recent Public Act 167 (2008). As of May 2009, none of Michigan's electric cooperatives had pursued this option.
** The Montana Electric Cooperatives' Association (MECA) developed and adopted a model Interconnection of Small Customer Generation Facilities policy in 2001 (that includes guidelines for net metering), which has been adopted in whole or part by most of the 26 electric cooperatives in Montana.
***Utah law requires that most electric cooperatives offer net metering. Beginning in March 2008, electric cooperatives serving fewer than 1,000 customers in Utah may discontinue making net metering available to customers that are not already net metered. In addition, electric cooperatives not headquartered in Utah that serve fewer than 5,000 customers in Utah are authorized to offer net metering to their Utah customers in accordance with a tariff, schedule, or other requirement of the appropriate authority in the State in which the co-op's headquarters are located.
Sources: Freeing the Grid 2008, DSIRE

9. Concluding Remarks

Agriculture was an early adopter of solar energy as a remote energy source, and many of those initial applications are still cost effective today due to low maintenance costs and the high cost of extending electricity to remote locations. As solar energy has entered the on-grid market in the last decade, agriculture is no longer limited to small off-grid applications. Many agricultural businesses are taking advantage of policy incentives for substituting part of their energy needs with fixed cost solar energy. Solar energy appeals to farmers and agricultural businesses because it helps them hedge the risk of future volatility of energy costs; it has low maintenance costs, and the fuel is free once the higher initial cost of the system is recovered. Furthermore, more and more farmers are valuing the appeal solar has on their customers as an alternative that reduces their greenhouse gases and environmental footprint.

Solar in agriculture varies by application, size, and energy type. In this report, we find solar present in agriculture from a $350 solar fence charger all the way up to a $7.5 million on-grid agribusiness installation. Additionally, applications such as irrigation that made sense only on a small scale in the past are now adopted in large scale as well. Solar PV has become the centerpiece of solar energy development in the last decade; nonetheless solar heat finds many applications in agriculture. For example, solar hot water can be the most direct, efficient, and cost-effective way to actively convert the sun's energy into useable energy. Still the financial costs and benefits of solar hot water will depend on the climate it is installed in, the cost of competing energy sources, and financial incentives available to the farmer. The emphasis on PV is evidenced as one-third of the States offering State rebates for solar energy do not include solar hot water.

When access to the grid is available, net metering has substantially improved the return on investment of solar electric by increasing the utilization ability for energy generation and maximizing the value of the system. Other incentives, like time of use and other production incentives, can also improve the economics of solar energy for interconnected farmers. Still, cooperatives, which most often serve farmers in rural areas, are not subject to State interconnection standards in 18 States, while 16 States do not require electric cooperatives to net meter.

Urban areas are in the spotlight of solar energy expansion as net metering and other incentives have promoted customer-distributed generation. This evolution makes economic sense due to the network density in urban areas, the proximity to energy demand, and the large roof space that is available. Nonetheless, rural settings and agriculture have benefits that might be overlooked. Open space is much more plentiful, and restrictions of solar access pose fewer issues. Additionally, solar can often be placed on marginal land or rooftops, limiting competition with valuable productive land. For example, Far Niente Winery in Oakland, CA, placed almost 50% of its 400kW system panels on a floating structure on a 1-acre gray water retention pond (EnerG). Solar energy is land intensive, but in the U.S. solar has seen smaller scale development in agriculture (relative to wind, for example). Larger utility scale development in the form of solar farms might interact differently with agriculture in the future, bringing forward land competition issues.

The adoption of solar in the agricultural setting will be linked to the evolution of solar energy in general. Important factors will be supporting policies and cost reductions in the industry. The

Federal tax incentives, State policies, and increased energy costs have led to a substantial boost since 2005 with a quadrupling of the annual capacity installed each year to 2009. In agriculture, the growth rate from 2005 to 2009 was 1.5 and there was a fivefold increase of solar energy projects funded under USDA's REAP between 2007 and 2009. Of course, solar is only one of the many renewable energy options available to farmers and ranchers. As the importance of GHG and renewable energy increases, USDA should continue to develop data sets for energy use on farm and renewable energy installations which will shed more light on the direction and opportunities for agriculture. Overall solar energy fits well with agriculture; farmers have land and often high energy needs, and solar represents the spirit of independence and self-reliance that characterizes agriculture and agriculture's connection to the environment.

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Appendix. Financial Incentives Available to Farmers (Program Tables)

In March 2009 the Office of Energy Policy and New Uses (OEPNU) in USDA concluded a survey of State level financial incentives that farmers and ranchers could use for installing solar energy systems. The following tables, which are the product of this survey, were compiled from information collected through DSIRE, program review, and direct communication with program administrators. Interested farmers will need to check for eligibility on a case-by-case basis. Eligibility may depend on connection to the grid, paying the State Renewable Portfolio Standard (RPS) surcharge, being a customer, or being a customer of an investor-owned utility. Other programs that have not been identified may also be available to farmers. Farmers are encouraged to check with their State, locality, and electricity providers.

Table A1. State Rebates

Program	Comments
California	
California Solar Initiative	PV
California Solar Initiative - Pilot Solar Water Heating Program	Hot Water
CEC - New Solar Homes Partnership	PV, Residential only
Connecticut	
CCEF - Solar PV Rebate Program	PV, Non Commercial only
Delaware	
Green Energy Program Incentives	PV, Hot Water
Florida	
Solar Energy System Incentives Program	PV, Hot Water
Illinois	
Solar Energy Rebate Program	PV, Hot Water
Maine	
Solar and Wind Energy Rebate Program	PV, Hot Water
Maryland	
Solar Energy Grant Program	PV, Hot Water
Massachusetts	
MTC - Commonwealth Solar Rebates	PV
Minnesota	
Solar Hot Water Rebate Program	Hot Water
Solar-Electric (PV) Rebate Program	PV
Nevada	
NV Energy - RenewableGenerations Rebate Program	PV
New York	
NYSERDA - PV Incentive Program	PV
Oregon	
Energy Trust - Solar Electric Buy-Down Program	PV
Energy Trust - Solar Water Heating Buy-Down Program	Hot Water
Vermont	

Solar & Small Wind Incentive Program	PV, Hot Water
Wisconsin	
Focus on Energy - Efficient Heating and Cooling Cash-Back Rewards	PV, Hot Water, Residential only
Focus on Energy - Renewable Energy Cash-Back Rewards	PV, Hot Water
Wyoming	
Photovoltaic Incentive Program	PV, Residential only

Table A2. Grant Programs

Program	**Comments**
Connecticut	
DPUC - Capital Grants for Customer-Side Distributed Resources	State Program
Illinois	
Solar Energy Incentive Program	State Program
Indiana	
Alternative Power & Energy Grant Program	State Program
Montana	
NorthWestern Energy - USB Renewable Energy Fund	Utility Program
Ohio	
ODOD - Advanced Energy Program Grants - Distributed Energy and Renewable Energy	State Program
Pennsylvania	
Metropolitan Edison Company SEF Grants (FirstEnergy Territory)	Local Grant Program
Penelec SEF of the Community Foundation for the Alleghenies Grant Program (FirstEnergy Territory)	Local Grant Program
Pennsylvania Energy Development Authority (PEDA) - Grants	State Program
Tennessee	
Tennessee Clean Energy Technology Grant*	State Program
South Carolina	
Renewable Energy Grant Program	State Program
Wisconsin	
Focus on Energy - Renewable Energy Grant Programs	State Program

Table A3. Production Incentives

State Programs
California
California Feed-In Tariff
Hawai*
Hawaii Feed-in Tariff*
Maine*
Community Based Renewable Energy Production Incentive (Pilot Program)*
New Jersey
NJ Board of Public Utilities - Solar Renewable Energy Certificates (SRECs)
Oregon*
Oregon Pilot Solar Feed-in-Tariff*
Vermont*

Vermont Standard Offer for Qualifying SPEED Resources*
Washington
Washington Renewable Energy Production Incentives
Local, Utility and Other Private Programs
Alabama
TVA - Green Power Switch Generation Partners Program
Alaska
Golden Valley Electric Association - Sustainable Natural Alternative Power (SNAP) Program
Florida
Orlando Utilities Commission - Pilot Solar Programs
Georgia
TVA - Green Power Switch Generation Partners Program
Idaho
Northwest Solar Cooperative - Green Tag Purchase
Kentucky
TVA - Green Power Switch Generation Partners Program
Massachusetts
Mass Energy - Renewable Energy Certificate Incentive
Minnesota
Austin Public Utilities - Solar Choice Program
Mississippi
TVA - Green Power Switch Generation Partners Program
Montana
Northwest Solar Cooperative - Green Tag Purchase
New Mexico
PNM - Customer Solar PV Program
North Carolina
NC GreenPower Production Incentive
TVA - Green Power Switch Generation Partners Program
Oregon
EWEB - Solar Electric Program (Production Incentive)
Northwest Solar Cooperative - Green Tag Purchase
Rhode Island
People's Power & Light - Renewable Energy Certificate Incentive
Tennessee
TVA - Green Power Switch Generation Partners Program
Vermont
Green Mountain Power - Solar GMP
Virginia
TVA - Green Power Switch Generation Partners Program
Washington
Chelan County PUD - Sustainable Natural Alternative Power Producers Program
Northwest Solar Cooperative - Green Tag Purchase
Okanogan County PUD - Sustainable Natural Alternative Power Program
Wisconsin
Madison Gas & Electric - Clean Power Partner Solar Buyback Program

We Energies - Solar Buy-Back Rate
Xcel Energy - Renewable Energy Buy-Back Rates

*Enacted after March 2009

Table A4. Income Tax Incentives

Program	Comments
Arizona	
Non-Residential Solar & Wind Tax Credit (Corporate)	
Non-Residential Solar & Wind Tax Credit (Personal)	
Residential Solar and Wind Energy Systems Tax Credit	
Georgia	
Clean Energy Tax Credit (Corporate)	
Clean Energy Tax Credit (Personal)	Residential only
Hawaii	
Solar and Wind Energy Credit (Corporate)	
Solar and Wind Energy Credit (Personal)	
Kentucky	
Renewable Energy Tax Credit (Corporate)	
Renewable Energy Tax Credit (Personal)	Residential only
Louisiana	
Tax Credit for Solar and Wind Energy Systems on Residential Property (Corporate)	Residential only
Tax Credit for Solar and Wind Energy Systems on Residential Property (Personal)	Residential only
Massachusetts	
Residential Renewable Energy Income Tax Credit	
Montana	
Alternative Energy Investment Tax Credit (Personal)	Doesn't apply to hot water
Residential Alternative Energy System Tax Credit	
New Mexico	
Solar Market Development Tax Credit	
New York	
Solar and Fuel Cell Tax Credit	Residential only
North Carolina	
Renewable Energy Tax Credit (Corporate)	
Renewable Energy Tax Credit (Personal)	
North Dakota	
Renewable Energy Tax Credit (Corporate)	
Renewable Energy Tax Credit (Personal)	Residential only
Oregon	
Business Energy Tax Credit	
Residential Energy Tax Credit	
Rhode Island	
Residential Renewable Energy Tax Credit (Corporate)	Residential only
Residential Renewable Energy Tax Credit (Personal)	
South Carolina	
Solar Energy Tax Credit (Corporate)	
Solar Energy Tax Credit (Personal)	
Utah	

Renewable Energy Systems Tax Credit (Corporate)	
Renewable Energy Systems Tax Credit (Personal)	
Vermont	
Corporate Tax Credit for Solar	

Table A5. Sales Tax Incentives

Program	**Comments**
Arizona	
Solar and Wind Equipment Sales Tax Exemption	
Colorado	
Boulder - Solar Sales and Use Tax Rebate	Local
Local Option - Sales Tax Exemption for Renewable Energy Systems	Local
Connecticut	
Sales and Use Tax Exemption for Solar and Geothermal Systems-	
Florida	
Renewable Energy Equipment Sales Tax Exemption	
Idaho	
Renewable Energy Equipment Sales Tax Refund	
Iowa	
Wind and Solar Energy Equipment Exemption	
Kentucky	
Sales Tax Exemption for Large-Scale Renewable Energy Projects	Large systems only: over 50 kW
Maryland	
Sales and Use Tax Exemption for Solar and Geothermal Equipment	
Massachusetts	
Renewable Energy Equipment Sales Tax Exemption	Residential only
Minnesota	
Solar Sales Tax Exemption	
New Jersey	
Solar and Wind Energy Systems Exemption	
New Mexico	
Solar Energy Gross Receipts Tax Deduction	
New York	
Solar Sales Tax Exemption	Residential only
Ohio	
Energy Conversion Facilities Sales Tax Exemption	Excludes Residential
Puerto Rico	
Excise Tax Exemption for Farmers	Agricultural only
Rhode Island	
Renewable Energy Sales Tax Exemption	
Utah	
Renewable Energy Sales Tax Exemption	Excludes residential
Vermont	
Sales Tax Exemption	
Washington	
Sales and Use Tax Exemption	

Wyoming	
Renewable Energy Sales Tax Exemption	Excludes residential

Table A6. Property Tax Incentives

Program	**Comments**
Arizona	
Energy Equipment Property Tax Exemption	
California	
Property Tax Exclusion for Solar Energy Systems	
Colorado	
Local Option - Property Tax Exemption for Renewable Energy Systems	Local
Connecticut	
Property Tax Exemption for Renewable Energy Systems-	
Florida	
Renewable Energy Property Tax Exemption	
Illinois	
Special Assessment for Solar Energy Systems	
Indiana	
Renewable Energy Property Tax Exemption	Solar restricted to active solar systems used for heating or cooling
Iowa	
Property Tax Exemption for Renewable Energy Systems	
Kansas	
Renewable Energy Property Tax Exemption	
Maryland	
Anne Arundel County - Solar Energy Equipment Property Tax Credit	Residential only, local
Harford County - Property Tax Credit for Solar and Geothermal Devices	Residential only, local
Howard County - Residential Solar and Geothermal Property Tax Credit	Residential only, local
Local Option - Renewable Energy Property Tax Credit	Local
Montgomery County - Residential Energy Conservation Property Tax Credits	Residential only, local
Prince George's County - Solar and Geothermal Residential Property Tax Credit	Residential only, local
Property Tax Exemption for Solar Energy Systems	
Special Property Assessment for Solar Heating & Cooling Systems	
Massachusetts	
Renewable Energy Property Tax Exemption	
Minnesota	
Wind and Solar-Electric (PV) Systems Exemption	
Montana	
Corporate Property Tax Reduction for New/Expanded Generating Facilities Generation Facility Corporate Tax Exemption	Generating facilities: over 1 MW under 1 MW
Renewable Energy Systems Exemption	
Nevada	
Renewable Energy Systems Property Tax Exemption	

New Hampshire	
Local Option Property Tax Exemption for Renewable Energy	Residential only, local
New Jersey	
Property Tax Exemption for Renewable Energy Systems	
New York	
Local Option - Solar, Wind & Biomass Energy Systems Exemption	Local
North Carolina	
Active Solar Heating and Cooling Systems Exemption	
Property Tax Abatement for Solar Electric Systems	
North Dakota	
Geothermal, Solar and Wind Property Exemption	
Ohio	
Energy Conversion Facilities Property Tax Exemption	Excludes residential
Oregon	
Renewable Energy Systems Exemption	
Puerto Rico	
Property Tax Exemption for Solar Equipment	
Rhode Island	
Local Option - Property Tax Exemption for Renewable Energy Systems	Local
Residential Solar Property Tax Exemption	Residential only
South Dakota	
Renewable Energy Systems Exemption	
Texas	
Renewable Energy Systems Property Tax Exemption	
Vermont	
Local Option for Property Tax Exemption	Local
Virginia	
Local Option Property Tax Exemption for Solar	Local
Wisconsin	
Solar and Wind Energy Equipment Exemption	

Table A7. Loan Programs

Program	Comments
Arizona	
Sulphur Springs Valley EC - SunWatts Loan Program	
California	
Agriculture and Food Processing Energy Loans-Agricultural, Food Processing	Agriculture, State program
Palm Desert - Energy Independence Program	Local program
SMUD - Residential Solar Loan Program	Residential, utility program
Colorado	
Aspen - Solar Power Pioneer Loan Program	Residential, local program
Fort Collins Utilities - ZILCH (Zero Interest Loans for Conservation Help) Program	Residential, utility program
Gunnison County Electric - Renewable Energy Resource Loan	Utility program
Connecticut	
CHIF - Energy Conservation Loan	Residential, State program

DPUC - Low-Interest Loans for Customer-Side Distributed Resources	State program
Florida	
Clay Electric Cooperative, Inc - Solar Thermal Loans	Residential, utility program
Orlando Utilities Commission - Residential Solar Loan Program	Residential, utility program
Georgia	
Satilla REMC - Home Improvement Loan Program	Residential, utility program
Hawaii	
Farm and Aquaculture Sustainable Projects Loan	Agriculture, State program
Honolulu - Solar Roofs Initiative Loan Program	Residential, local program
KIUC - Solar Water Heating Loan Program	Residential, utility program
Maui County - Solar Roofs Initiative Loan Program	Residential, local program
Idaho	
Low-Interest Energy Loan Programs	State program
Iowa	
Alternate Energy Revolving Loan Program	State program
Kansas	
Kansas Energy Efficiency Program (KEEP)	Residential, State program
Kentucky	
Solar Water Heater Loan Program	Local program
MACED Loans for Commercial Renewable Energy Investments and Business Development	Local program
Louisiana	
Home Energy Loan Program	Residential, state program
Maine	
Home Energy Loan Program (HELP)	Residential, state program
Massachusetts	
MassSAVE - Statewide HEAT Loan Program	Residential, utility program
Minnesota	
NEC Minnesota Energy Loan Program	Residential, State program
Mississippi	
Energy Investment Loan Program	Residential excluded, State program
Missouri	
Columbia Water & Light - Super Saver Loans	Residential, utility program
Montana	
Alternative Energy Revolving Loan Program	State program
Montana Beginning Farm/Ranch Loan Program	Agriculture, State program
Nebraska	
Dollar and Energy Savings Loans	State program
New Hampshire	
Renewable Energy and Energy Efficiency Business Loan	Excludes residential, State program

New Jersey	
PSE&G - Solar Loan Program	Utility program
New York	
NYSERDA - Energy $mart Loan Fund	State program
NYSERDA - Home Performance with Energy Star Loan Program	Residential, State program
North Carolina	
Energy Improvement Loan Program (EILP)	Excludes Residential, State program
Oregon	
Ashland Electric Utility - Bright Way to Heat Water Loan	Residential, utility program
Central Electric Cooperative - Solar Water Heater Loan	Residential, utility program
EPUD - Solar Water Heater Loan	Residential, utility program
EWEB - Bright Way to Heat Water Loan	Residential, utility program
EWEB - Energy Management Services Loan	Excludes residential, utility program
Salem Electric - Solar Water Heater Loan	Residential, utility program
Small-Scale Energy Loan Program	State program
Pennsylvania	
Keystone Home Energy Loan Program	Residential, State program
Metropolitan Edison Company SEF Loans (FirstEnergy Territory)	Excludes residential, local program
Penelec SEF of the Community Foundation for the Alleghenies Loan Program (FirstEnergy Territory)	Excludes residential, local program
SEF of Central Eastern Pennsylvania Loan Program (PPL Territory)	Excludes residential, local program
South Carolina	
Renewable Energy Revolving Loan Program	State program
Santee Cooper - Renewable Energy Resource Loans	Residential, utility program
Tennessee	
Small Business Energy Loan Program	Excludes residential, State program
Vermont	
Clean Energy Development Fund (CEDF) Loan Program	State program
New Generation Energy - Community Solar Lending Program	Local program
Washington	
Clallam County PUD - Residential Solar & Efficiency Loan Program	Utility program
Clark Public Utilities - Solar Energy Equipment Loan	Utility program
Ferry County PUD #1 - Off-Grid Solar PV Financial Assistance	Off-grid residential, utility program
Franklin County PUD - Solar Energy System Loan	Residential, utility program
Grays Harbor PUD - Solar Water Heater Loan	Residential, utility

	program
Klickitat PUD - Loan Program	Residential, utility program
Pacific County PUD - Solar Water Heater Loan	Utility program
Richland Energy Services - Residential Energy Conservation Loan Program	Residential, utility program

Glossary

AC: Alternating current. AC is electricity that changes direction (e.g., polarity) again and again at regular intervals. The rate of change of this polarity is the frequency (e.g., in U.S., the frequency is 60 Hz). The magnitude of electricity also usually changes because of this constant reversal of polarity. This type of electricity is used by most household appliances.

Active Solar Technologies: Using solar energy to generate electricity, heat water, heat/cool air in buildings, pump water, or any application using significant amounts of pumps and motors.

Avoided Cost of Electricity Production: The price the utility would have to pay for electricity produced from fossil fuels.

Bi-Directional Meter: Used in net metering to record both electricity drawn from the grid (the meter spins forward) and the excess electricity fed back into the grid (the meter spins backwards).

Capacity: Rated power of renewable energy system.

Carbon Credits: The price associated with the reduction of one ton of carbon dioxide (CO_2) under an emissions trading approach. Greenhouse gas emissions are capped and then markets are used to allocate the emissions among the group of regulated sources.

Chauffage: An agreement where the customer purchases the electricity, heating, or cooling of the solar project instead of the solar energy system. Chauffage has been very successful for the development of solar in the form of Power Purchase Agreements (PPA) for larger projects.

DC: Direct current. DC electricity can be described by two parameters magnitude (i.e., Volts and Amps) and direction (i.e., polarity), and is much simpler than AC. The polarity is usually the same for long periods of time. This type of electricity is output from a photovoltaic module and requires an inverter to convert it to AC, which is used by most household appliances. For battery applications, the DC electricity from the PV module can be used to charge the battery.

DG or Distributed Generation: The generation of energy close to the point of use. It typically ranges from 1 kilowatt (kW) to 5 Megawatts (MW).

Energy Use in Agriculture: Includes direct and indirect energy use for agricultural operations. Direct use represents the use of gas, oil, petrol, and electric energy on farm. Indirect use includes the energy spent for the production of mineral fertilizers and pesticides that are used in agriculture.

Dual Metering: In dual metering, customers or their utility purchase and install two non-reversing meters that measure electrical flow in each direction. Dual metering has been an alternative historically, but generally the preferred method of accounting for the electricity under net metering is with a single, reversible meter.

Efficiencies: Percentage of energy available after converting from one form to another.

GHGs: Greenhouse Gases. Gases that trap heat in the atmosphere. The principal greenhouse gases that enter the atmosphere because of human activities are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases.

Grants: Financial incentives designed to pay down the cost of eligible systems or equipment, typically available on a competitive basis.

Interconnection: The process by which a solar PV system is connected to the electric distribution grid.

ITC or Investment Tax Credit: A financial incentive that works as a reduction in the overall tax liability for individuals or businesses that make investments in solar and other renewable energy generation.

Inverter: Device that converts DC electricity to single or 3-phase AC electricity.

Line Extension: Transmission line extension from utility grid to rural residence or business. Usually, it is free below a certain distance (e.g., 0.25 miles), but above this distance the cost can range from $5,000 to $65,000 per mile. Many times, if significant transmission line extension is required, it will be cheaper to install a stand-alone renewable energy system with battery storage.

Net Metering: Allows personal electricity-generating systems to direct excess electricity into the grid and use the electrical grid as a backup. Net-metering is identified with bi-directional metering; the farmer pays for the net electricity used from the grid over a set time period and earns retail prices for the excess electricity he or she generates. Thus, the customer receives retail prices for the excess electricity generated.

Off-Grid PV System: A PV system that is not connected to a local utility grid and relies solely on the solar-generated electricity for the application's needs.

On-Grid PV System: A PV system connected to the utility grid. It powers electrical loads at the location but also connects to the grid as needed. When excess electricity is generated, it feeds the excess electricity back into the grid; when insufficient electricity is generated by the sun, electricity is drawn from the grid.

Passive Solar Applications: Heating and cooling of air through building design, water heating using thermosyphon, solar cooking, and solar energy used without a significant amount of energy used to power pumps and fans.

PPA or Power Purchasing Agreement: A type of chauffage where the customer buys the electricity from the developer who operates the solar energy system, and the developer relies on a third party, like a bank, to finance the project.

Produced Energy: Energy available for use after conversion.

Production Incentives: Cash payments based on the number of kilowatt hours (kWh) a renewable energy system generates. Also known as performance-based incentives.

PV or Photovoltaics: A device that generates electricity directly from sunlight via an electronic process that occurs naturally in certain types of material; the solar energy frees electrons and induces them to travel through an electrical circuit, producing electricity.

PV Capacity: Rated power of PV array when the solar irradiance is 1000 watt per square meter (W/m^2) and PV module temperature is 25°C (77°F).

REAP or Rural Energy for America Program: A USDA program that provides grants and loan guarantees for energy efficiency and renewable energy systems to qualified farms, ranches, and rural businesses. It was originally established in the 2002 Farm Bill under the name ***Energy Systems and Energy Efficiency Improvement Program*** and is administered by Rural Development in USDA.

Rebates: Discounts for solar energy system installations.

REC or Renewable Energy Certificate: Represents the environmental attributes of one (net) megawatt hour of electricity generated from an eligible renewable energy resource and can be sold unbundled from the generated electricity. It is alternatively called a green certificate, green tag, or a tradable renewable certificate.

Remote Location: For agriculture, a remote location where an off-grid PV system that will be used can be several miles away or as little as 50 feet from a power source. It all depends on the location, the application, the economics, and the original energy fuel used.

Retail Electricity Price: The price the customer pays for electricity. Depending on the utility's available rate schedules and the farmer's electricity uses, the famer might pay farm, residential, commercial, or industrial retail prices. Industrial electricity rates are comparable to irrigation rates.

RPS or Renewable Portfolio Standard: The RPS is a policy adopted by a number of States and considered at the Federal level that imposes a minimum amount of renewable energy generation or capacity that electricity providers must meet, propelling them to support the installation of renewable energy systems.

SARE or Sustainable Agriculture Research and Education: A USDA program that provides competitive grants for sustainable agriculture research and education.

Solar Electric: Uses the energy of the sun to produce electricity.

Solar Energy: Radiant light and heat energy from the sun.

Solar Irradiance: Amount of solar energy per unit area (units usually watts per square meter — W/m^2).

Solar Resource: A measure of the amount of solar energy at various locations on Earth (units usually kilowatt per square meter per day—$kWh/m^2/day$).

Solar Thermal: Uses the energy of the sun to heat air, water, another liquid, or a solid. Solar thermal can either be passive or active. An example of passive would be the sun heating stone, cement, or water during the day in a building, and the heat being released at night through natural convection. An example of active would be using a collector on the roof for sun-heated water or glycol liquid that is circulated with a pump through or into a hot water tank to for later domestic use.

Tax Incentives: Used by States, the Federal Government, and localities to promote renewable energy. They include tax credits, deductions, and exemptions and can be personal, corporate, sales, or property tax incentives.

TOU or Time of Use: The pricing of electricity based on the estimated cost of electricity during a particular time block. Time-of-use rates are usually divided into three or four time blocks per 24-hour period (on-peak, mid-peak, off-peak, and sometimes super off-peak) and by season (summer and winter).

Wind Energy: Kinetic energy from the movement of air on the Earth's surface.

Useful Links

ASSOCIATION, GOVERNMENT, AND CENTER LINKS

Solar Energy Industries Association (SEIA) is the national trade association of solar energy industry. http://www.seia.org/

American Solar Energy Society (ASES) is the U.S. section of the International Solar Energy Society, publisher of Solar Today magazine, and organizer of the National Solar Tour. http://www.ases.org/

Solar Electric Power Association (SEPA) is a trade group representing utilities in the solar energy arena. http://www.solarelectricpower.org/

U.S. Department of Energy's (DOE) Office of Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/solar/.

U.S. Department of Energy's (DOE) Energy Information Administration (EIA), http://www.eia.doe.gov/.

U.S. Department of Agriculture (USDA), http://www.usda.gov/wps/portal/usda/usdahome.

Database of State Incentives for Renewable and Energy (DSIRE), http://www.dsireusa.org/, provides information on State, local, utility, and selected Federal incentives that promote renewable energy.

Florida Solar Energy Center, http://www.fsec.ucf.edu/en/index.php.

SOLAR ENERGY IN AGRICULTURE WEBSITES

ATTRA is the National Sustainable Agriculture Information Service managed by the National Center for Appropriate Technology (NCAT) and is funded under a grant from the U.S. Department of Agriculture's Rural Business-Cooperative Service. It hosts a dedicated solar energy page at http://attra.ncat.org/farm_energy/solar.html and a directory for alternative energy per State at http://attra.ncat.org/attra-pub/farm_energy/search.php.

FarmEnergy.org, sponsored by the Environmental Law & Policy Center (ELPC), provides information on the Energy Title programs of the Federal Farm Bill and energy efficiency and renewable energy opportunities that benefit farmers, ranchers, and rural communities. It hosts a dedicated solar energy page at http://farmenergy.org/clean-energy-guide/solar.

National Renewable Energy Laboratory's (NREL) Renewable Energy for Farmers and Ranchers hosts a webpage for PV http://www.nrel.gov/learning/fr_photovoltaics.html and a webpage for solar hot water http://www.nrel.gov/learning/fr_solar_hot_water.html.

Department of Energy's (DOE) Solar Energy Applications for Farms and Ranches is available at http://www.energysavers.gov/your_workplace/farms_ranches/index.cfm/mytopic=30006.

Up with the Sun: Solar Energy and Agriculture is a dedicated solar energy and agriculture webpage hosted by the Union of Concerned Scientists. http://www.ucsusa.org/clean_energy/technology_and_impacts/impacts/up-with-the-sun-solar-energy.html.

SOLAR ENERGY IN AGRICULTURE DOCUMENTS

An Introduction to Solar Energy Applications for Agriculture: http://www.nyserda.org/programs/pdfs/agguide.pdf.
This publication by the New York State Energy Research and Development Authority includes information on space and water heating, greenhouse heating, and solar electric (photovoltaic) systems.

Electricity When and Where You Need It: From the Sun. NREL's Publication on Photovoltaics for Farms and Ranches, http://www.nrel.gov/docs/gen/fy97/21732.pdf.

Farming the Sun: Small Scale Farming Techniques for Agriculture.
A fact sheet provided by Wisconsin Focus on Energy at http://www.focusonenergy.com/files/Document_Management_System/Renewables/farmingthesunsmallsolar_factsheet.pdf.

Guide to Solar Powered Water Pumping Systems in New York State: http://www.nyserda.org/publications/solarpumpingguide.pdf.

Solar Energy Applications for Farms and Ranches: http://www.energysavers.gov/your_workplace/farms_ranches/index.cfm/mytopic=30006.
Basic information about using solar energy on farms and ranches from the U.S. Department of Energy (DOE).

Agricultural Applications of Solar Energy: http://www.p2pays.org/ref/24/23989.htm.
This U.S. Department of Energy publication explains agricultural uses of solar power, including crop drying, space/water heating, greenhouse heating, electric production and water pumping.

The USDA, Agricultural Research Service (ARS), Conservation and Production Research Laboratory in Bushland, TX, hosts a webpage with publications on Renewable Energy and Manure Management Research. A number of publications on solar energy and water pumping are included. http://www.cprl.ars.usda.gov/REMM_Publications.htm

INDUSTRY DATA

Solar Energy Industries Association' (SEIA) U.S. Solar Industry Year in review. http://www.seia.org/cs/about_solar_energy/industry_data

Solarbuzz. Solar energy news developments worldwide, including current prices, ongoing projects, and news articles. The site also offers industry statistics and advice on purchasing solar energy systems. http://www.solarbuzz.com/

Installation and Financing

Solar resource data are collected at http://rredc.nrel.gov/solar/old_data/nsrdb/ for most locations in the U.S. and U.S. territories.

Solar-Estimate.org, estimates the price, savings, and size of a solar power system based on location and specifications.

The RETScreen Clean Energy Project Analysis Software is a free decision-support tool that can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability, and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). http://www.retscreen.net/ang/home.php.

Find Solar, supported by Department of Energy (DOE), American Solar Energy Society (ASES) and Solar Electric Power Association (SEPA) is a resource for finding an installer near you. http://www.findsolar.com/

NABCEP is the North American Board of Certified Energy Practitioners and hosts a search engine for certified installers at http://www.nabcep.org/installer-locator.

Build It Solar offers free plans, tools and information for renewable energy and conservation projects at http://www.builditsolar.com/.

Solar Rating and Certification Corporation provides information about certification, rating, and labeling for solar collectors and complete solar water heating systems at www.solar-rating.org.

Go Solar California provides a clean power Estimator, http://www.consumerenergycenter.org/renewables/estimator/index.html.

DOE's Borrower's Guide to Financing Solar Energy Systems is available at http://www.nrel.gov/docs/fy99osti/26242.pdf.

Database of State Incentives for Renewable and Energy (DSIRE), http://www.dsireusa.org/, provides information on State, local, utility, and selected Federal incentives that promote renewable energy.

Solar Energy International offers training (hands-on and online workshops) in renewable energy and sustainable building technologies,
http://www.solarenergy.org

Technology and Basics

Solar Energy Basics, http://www.nrel.gov/learning/re_solar.html.
Basic information about solar technologies.

U.S. Department of Energy Solar Energy Technologies Program,
http://www1.eere.energy.gov/solar/technologies.html

A Consumer's Guide: Heat Your Water with the Sun: http://www.nrel.gov/docs/fy04osti/34279.pdf.

U.S. Department of Energy Consumer's Guide: Solar Water Heaters, http://www.energysavers.gov/your_home/electricity/index.cfm/mytopic=12850. Basic information about solar water heating for the home.

U.S. Department of Energy Consumer's Guide: Solar Swimming Pool Heaters, http://www.energysavers.gov/your_home/water_heating/index.cfm/mytopic=13230. Basic information about using solar energy for pool heating.

Passive Solar Design, http://passivesolar.sustainablesources.com/ and http://www.energysavers.gov/your_home/designing_remodeling/index.cfm/mytopic=10250.

FURTHER RESOURCES

State Energy Office

Agricultural Extension Agent

Department of Energy's (DOE) Energy Efficiency and Renewable Energy (EERE) Information Center, https://www1.eere.energy.gov/informationcenter/.