The Analysis of Solar Photovoltaic Power System on a Large Central Valley Dairy Farm

A Senior Project

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Abstract

The objective of this paper was to determine the financial benefits of installing a PV solar system on a dairy farm in California to create a more efficient and profitable business. The data used was based off Fernoak Farms electrical bills from Southern California Edison before and after solar installation. The background knowledge of how PV solar systems work and their design was incorporated, along with the research of the past, present, and future solar markets. The characteristics of energy consumption on an average dairy farm is given to show the amount of electricity needed to keep the dairy facility running daily. The significance of government, state, and utility incentives were examined in order to determine the benefits. Fernoak Farms chosen system design was described to help evaluate the efficiency of the solar system, as well as the evaluation of leasing the solar system from Farm Credit West for ten years. It was determined that installing a solar system on a dairy farm can offset electricity costs and cover 100% of electrical usage on the dairy farm. Fernoak Farms will save $102,307.12 after the first year with solar activation and $1,145,396 in accumulative savings on their electricity bill over ten years. Leasing the solar system allowed Fernoak Farms to avoid any upfront costs, and at the end of 25 years the solar system will save the business $6,210,726 in accumulative savings.

Key Words: solar, dairy, farm, photovoltaic,

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Introduction

In present times, dairy farms deal with challenges and opportunities powered by rapidly increasing energy costs and concerns about the environmental impact. Dairy farms use more energy than nearly any other agricultural operation. Large amounts of energy are needed in the milking parlor, for cooling and storing milk, heating water, lighting, ventilation, and flush pumps. With dairy farms operating 24/7, 365 days a year, the operating costs add up quickly especially with increasing electricity costs.

Fernoak Farms decided to determine the best way to be energy efficient and utilize energy management opportunities on the dairy farm, in order to reduce energy costs and improve environmental quality while still increasing productivity and profitability. After much research Fernoak Farms found that solar energy was the most feasible and efficient option that could offset the instability in milk prices, high in-put costs, hedge against the increase in utility rates, and overall increase sustainability.

Harnessing the sun's free energy is an efficient and clean way to minimize the use of costly electricity, which would result in a reduction on the dairy farms electricity bill. Solar energy has a small environmental impact, which would help reduce dairy farm's carbon footprint. With the incorporation of state and governmental programs pushing for an increase in renewable energy requirements, along with rebates and incentives, Fernoak Farms thought it would be beneficial to invest in a PV solar system. The objective of this paper was to determine if the PV solar system installed on Fernoak Farms dairy, would create a more efficient and profitable dairy farm and result in large electrical savings.

Literature Review

History of Solar Photovoltaic

The conversion of sunlight into electricity starts with the photovoltaic cell. The phrase “photo” originates from the Greek word phos meaning “light” and “voltaic” refers to the measure of electricity (voltage). The term photovoltaic literally means light-electricity. In history, Edmond Becquerel was the first to discover the photoelectric effect in 1839. The photovoltaic technologies used today are based from the photoelectric effect found by Becquerel. Then in 1883, Charles Fritts invented the first working solar cell, using amorphous selenium wrapped in an extremely thin-film of cuprous oxide. He observed a current in the prototypes that achieved almost 1% conversion efficiency (Khaligh and Onar, 2010). Although the first working solar cell was discovered, major steps toward commercializing photovoltaic cells did not occur until many years later. However, as the years passed there was the discovery of quantum physics, the importance of single-crystal semiconductors was acknowledged, and the p/n junction behavior in the solar cell was explained (Fraas and Partian, 2010). By 1954, Daryl Chaplin, Calvin Fuller, and Gerald Pearson had the technology to create the first silicon single-crystal solar cell (Khaligh and Onar, 2010). The solar cell had conversion efficiencies of 6% (Mousazadeh et al., 2009). Over the next few years following the first invention of silicon crystal solar cell, researchers brought the conversion efficiency of the solar cells up to 15% (Frass and Partian, 2010). The breakthrough marked the fundamental change in the generation of power. The silicon solar cell became recognized as an inexhaustible clean energy source that could contribute to the sustainability of the earth.

Suns Energy

The sun supplies all the energy needed to sustain life on earth (Messenger and Ventre, 2010). The Earth's stored energy reserves such as oil, natural gas, and coal is all matched by the energy from only twenty days of sunshine. In one hour, the earth obtains enough energy to fulfill all the earth's energy requirements for an entire year (Messenger and Ventre, 2010). The sun's output of energy every second, of every single day, is 386,000,000,000,000,000,000,000,000 watts. Scientists write this number as 3.86×10^{26} watts or just 3.86 followed by 26 zeros (Johnson et al., 2010). The sun's output of energy will travel 93 million miles to the earth, but only 1.74×10^{17} or roughly 1368 watts per square meter (W/m^2) of energy will reach the earth. To compare, in 2005 the overall power production by all mankind was about 1.5×10^{13} watts, which is a measly 0.009 percent of what the sun sends to the earth every second (Johnson et al., 2010). However only 1000 (W/m^2) hits the earth's surface with clear conditions because some energy will reflect back into space, along with the absorption by the atmosphere, resulting in almost 30 percent energy loss. Of these 1,000 watts per square meter, each square meter of the earths surface during a 24-hour day for a year collects the same amount of energy as one years worth of oil, or 4.2-kilowatt hours of energy a day (Renewable Energy Technologies, 2011). The energy equivalent can be higher depending on the location on earth. The sun's abundance of energy sent to the earth every day represents an inexhaustible clean energy source for the planet.

Measurement of Electricity

Electricity is a measured unit of energy and power. Kilowatt (kW) is a measure of power, and kilowatt-hour (kWh) is a measure of energy. A unit of power is the measurement of energy generated or used. The watt (w) is the measurement of electric power. A kilowatt (kW) unit of electrical power equals 1,000 watts, which is the basic unit of electrical demand. A megawatt (MW) is the unit of electrical power that equals 1,000 kW or 1 million watts. A gigawatt (GW) is the unit of electrical power equal to 1,000 MW or 1 billion watts.

- (kW) kilowatt = 1000 watts
- (MW) Megawatt = 1 million watts = 1,000 kW
- (GW) Gigawatt = 1 billion watts = 1,000 MW
- (TW) Terawatt = 1 trillion watts= 1,000 GW

Energy is the ability to do action, and the measurement is the amount of energy being generated and used over time. A watt-hour (Wh) is the energy measurement of one watt of power used in an hour. The generation or use of electric power is a measurement in kilowatt-hours (kWh), megawatt-hours (MWh) or gigawatt-hours (GWh). Kilowatt-hour (kWh) is a unit of electricity that is equivalent to the use of 1 kilowatt of electricity for one full hour. Utilities measure customer's electric energy usage on the basis of the kilowatt-hour and electricity rates are most commonly calculated in cents per kilowatt-hour (Go Solar California, 2009).

Photovoltaic Cell Effect

The photovoltaic (PV) effect is the physical process where photovoltaic cells convert sunlight directly into electricity. This process starts at the photovoltaic cell, also known as the solar cell (Khaligh and Onar, 2010). The sunlight that shines on the PV cell can be absorbed, reflected or passed through, but only the absorbed light generates electricity. The PV effect can occur in liquid, solid, or gaseous materials. However, solids have the best energy conversion, especially in semiconductor materials (Foster et al., 2009). Two layers of semiconductor material produce the PV cell and are the most important components. Silicon crystals are the main semiconductor material used. Alone the crystallized silicon is not a good conductor of electricity because it has no net electrical charge. There is no electrical charge since there is an equal number of protons and electrons in silicon. As a result, impurities need to be added to create a built-in electrical field within the PV cell (Khaligh and Onar, 2010). The procedure of adding impurities is called "doping." An electrical field created through the doping process changes the electronic properties by controlling the electrons in the conduction band (Foster et al., 2009).

The bottom layer of the cell is doped with boron, which bonds with silicon to make a positive charge. This occurs because boron has only three electrons available in the bonding shell and silicon has four. As a result, holes are created in the silicon crystal with each hole having a positive charge because only three covalent bonds can form. Although boron gives the base of the silicon layer a positive charge, the two atoms together have an equal number of protons and electrons giving the layer a neutral charge. The top layer is doped with phosphorus that also bonds with silicon but makes a negative

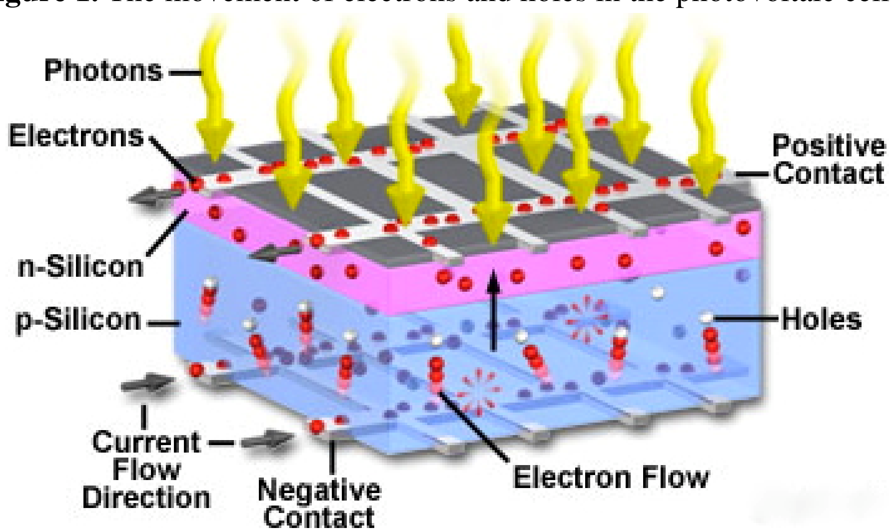
charge. This occurs because phosphorus has five electrons available in the outer shell and silicon has four, meaning only four covalent bonds can form. Therefore resulting in an excess of free electrons from the phosphorus atom that can move around the crystal giving the top layer a negative charge (Larganent and Wennan, 2003). However the sum of the electric charges in the doped material are also zero because all the free electrons in the material are equal to the number of positive charges from the phosphorus in the crystal. Regardless of the neutral charge, the silicon layer takes on the negative form because of the excess electrons (Largent and Wenham, 2003).

The two layers are now referred to as p-type layer (positive) and n-type layer (negative) silicon semiconductors. Although both layers are electrically neutral, the p-type silicon still has excess holes, and the n-type silicon has excess electrons. The area between the n-type and p-type silicon when sandwiched together at their interface is called the p-n junction, which creates the electric field. The electric field is created through the electron movement at the surface when the n-type and p-type silicon semiconductors come into contact, which causes the extra electrons from the n-type layer to move to the p-type layer (Cabtree and Lewis, 2007).

The movement from the holes causes a buildup of a positive charge along the n-type side of the interface, and a buildup of a negative charge along the p-type side from the electron movement. This separation of charges causes the current to flow across the junction because the silicon semiconductors act as a battery by creating an electric field at the surface where they meet. Therefore, when the PV cell comes into contact with the sun the positively charged photons of light are absorbed. The n-type silicon layer of the PV cell absorbs the energy from the photons and energizes the electrons, knocking them free

of their atoms (Stone, 1993). The freed electrons are attracted to the positive charge on the n-type side and repelled by the negative charge of the p-type silicon. The holes are attracted to the negative charge on the p-type surface and wait for incoming electrons. The electric field provides momentum and direction toward the negative surface for the freed electrons, resulting in a flow of current. Conducting wire is connected the p-type silicon to an external load and then back to the n-type silicon. This forms a complete circuit for the electrons to be pushed through by the electric field and creating an electric current (Parry-Hill et al., 2012). The movement of electrons and holes in the PV cell is illustrated in Figure 1.

Figure 1. The movement of electrons and holes in the photovoltaic cell.



Reprinted from Olympus America Inc. (Parry-Hill et al., 2012)

Semiconductor Type and Purity of Material

The PV cell is typically made from silicon as a mono-crystalline, polycrystalline, or amorphous solids. Crystalline silicon cells are made from silicon atoms connected together to form a crystal lattice. This lattice contains the solid material that forms the PV cell's semiconductors. The crystalline silicon material contains perfectly arranged

structured atoms that can be manipulated into three different types of structures to optimize absorption and be cost efficient in manufacturing (Harmon, 2000).

Mono-crystalline silicon or Single crystal silicon is the most efficient of the three types because the material does not contain any grain boundaries. Grain boundaries are imperfections in the crystal structure that are caused by variation in the lattice that can decrease the electrical and thermal conductivity of the semiconductor material. The grain boundaries can be thought of as barriers to the electron flow. The mono-crystalline cells are uniform in structure because they are grown from a slab of the single crystal in a high-tech lab. These long crystal cylinders are then sliced into round or hexagonal wafers, doped, and etched. The cells efficiency ranges from 15-20%, being the most efficient cell on the market. Unfortunately, the processes of making these cells are highly intensive and wasteful of materials, therefore making these cells the most expensive because of manufacturing costs (Khaligh and Onar, 2010).

Polycrystalline silicon is made up of many silicon crystals that are melted into slabs, or drawn into sheets and sliced into squares. They then go through the same doping and etching process. The number of single crystals in the material is visible to the eye, meaning there are obvious grain boundaries. This type of silicon has a conversion efficiency of 12-15%, which is slightly lower than mono-crystalline cells. These cells also have a lower production cost and can be packed more closely together because of the way they are cut into squares (Razykov et al., 2011).

Amorphous silicon is the non-crystalline form of silicon because the atoms are arranged in random order. Amorphous means to lack of any geometric shape. Due to the nature of the material, the structure has dangling bonds because there are no bonding

neighbors for the atom. These unbound atoms disrupt the flow of electrons. Another limiting aspect that affects efficiency is the "traps" in the semiconductor material. These traps are impurities that greatly increase the recombination of electrons and holes, which will reduce electron flow and the refilling of holes with new electrons. The amorphous silicon is sprayed onto glass or a metal surface making the whole module in one step. This type of silicon has the lowest conversion efficiency of 6-7% and is the least expensive material to manufacture (Razykov et al., 2011).

Alternative to Silicon PV Technology- Thin Film Technology

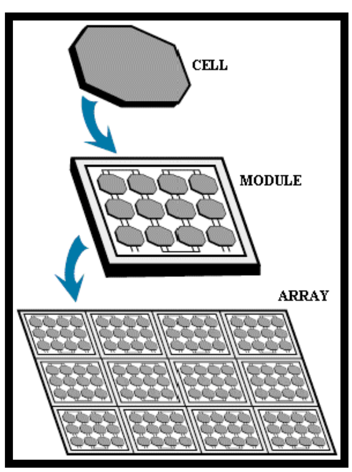
The alternative to crystalline-based PV cells is the thin film technology. Thin films are made from a variety of semiconductor materials, such as amorphous silicon, cadmium-telluride and copper indium gallium diselenide (Timilsina et al., 2012). Depositing thin layers of the material on glass or stainless steel substrates creates the thin films. The manufacturing and material costs of this type of PV module is cheaper than crystalline silicon. However, thin films are not used as often because the layers of material are very thin resulting in less PV material to absorb the incoming sunlight. This leads to lower efficiencies compared to the crystalline silicon PV cells (Chaar et al., 2011).

Photovoltaic Conversion Systems

Modules and Arrays

PV cells alone are typically very small and can only produce about 1 or 2 watts of power. In order to higher the output of power the solar cells are connected together to form a larger unit called modules. The PV module converts the solar energy directly into direct-current (DC) electricity. Individual PV modules can range in power output of 10 watts to 300 watts (Johns et al., 2009). A PV module typically consists of a glass front sheet, and a plastic or glass back sheet that sandwich the PV cells together. This protects the cells from the weather damage and potential breakage. An aluminum frame is usually fixed around the modules to enable easy attachment and support the structures. The modules can then be connected to make a larger unit called arrays. The PV array consists of any number of modules and panels that increase power output as displayed in Figure 2. The PV array is the completed power-generating unit ready to be installed (Messenger and Ventre, 2010).

Figure 2. Break down of a photovoltaic solar array.



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PV System Components

Even though the PV module can produce energy from sunlight, there are still a number of other components needed to properly conduct, manage, distribute, and store the energy that is produced by the array. The PV system contains the balance of system (BOS), which is one of the main components of the PV system. The BOS refers to all the other system components except the PV module that is needed to carry out the direct current (DC) into electricity. Therefore combining the modules with the BOS components completes the PV solar system (Brooks and Dunlop, 2012).

PV systems are made up of a variety of components. The system can include the wire connectors, fuses and circuit breakers, junction and combiner boxes, controls, batteries, trackers or mounting system, inverters, disconnect switches to protect the system, switch gears, ground fault detectors, charge controllers, racking system to support modules, and dials and meters to monitor performance. The components vary based on the application such as grid-connected or stand-alone systems (Kiatreungwattana et al., 2013).

The first of these components is the power inverter. The power inverter is needed because the PV modules only produce direct current (DC) rather than alternate current (AC). Direct current is the electric current that flows in only one direction, while alternating current is the electric current that can reverse the direction of flow. Direct current has to be converted to alternating current because the AC is the electricity that powers utilities, businesses, residential areas, appliances and electronics. There are also DC/DC converters that are used to change the level of voltage by either increasing or decreasing the DC current (Shubui et al., 2011).

The PV system normally has two safety disconnects. The first is the DC disconnect, also called the PV or array disconnect. The DC disconnect controls the DC current between the modules and allows the current to be stopped before reaching the inverter. The second disconnect is the AC disconnect. The AC disconnect separates the inverter from the electrical grid. In the PV system, the AC disconnect is typically placed between the inverter and utility meter. The AC disconnect can be a breaker on a service panel or a stand-alone switch. The size of the AC disconnect is based on the output current of the inverter (Messenger and Ventre, 2010).

Most PV systems have battery systems and charge controllers but these components are not necessary depending on the system design. PV systems cannot store electricity; therefore batteries are added for energy storage. The inverters are connected to a battery bank and to the load. The load is any electrical appliance that is connected to the PV system such as lights, radio, TV, etc. During the daytime or when sunlight is present the PV array charges the battery bank, which will supply power to the load whenever electricity is needed. The charge controller keeps the battery properly charged, and manages the flow of electricity from the array to the battery and then to the loads. This will prolong the battery life by protecting it from completely discharging or being overcharged (Messenger and Ventre, 2010).

Net meters on PV solar systems can be classified as being installed as either behind the meter or in front of the meter. These meters refer to the electric meters that measure the electricity used by customers from the grid to serve on-site electric demand. A behind-the-meter display is connected on the customer side of the meter where the electricity generated is mainly used to sustain on-site electrical needs rather than being

exported to the grid. The on-site need for electricity can differ from the amount of electricity actually being made by the system, therefore, the customer at times is pulling electricity from the grid and exporting electricity to the grid. The delivery of electricity to the customer and from the customer is accounted for by net metering. The utility company uses net metering for billing calculations. Behind-the-meter connections are usually on PV systems located on residential or commercial buildings. In front of the meter arrangement is when the meter is on the utility side of the meter. This arrangement is characterized as a single bi-directional electricity meter, meaning that the meter rolls forward when the customer is taking electricity from the grid and rolls backward when the customer is exporting electricity to the grid. The customer may be compensated for the excess of electricity exported onto the grid at the end of the billing period (Barnes et al., 2013).

Basic Types of PV Systems

The two types of PV systems are the stand-alone systems and the grid-connected systems. The main characteristic that is difference between the two systems is that one system is connected to the utility grid, while the other is not.

Grid-connected systems are made to operate with the national electric utility grid. The utility grid is a network of cables that electricity that transport electricity from the power plants to homes, schools, business and other places. The grid-connected systems are connected with the network of power lines. The main component is the inverter, or power-conditioning unit. It converts DC power into AC power to stay consistent with the voltage and power quality requirements of the utility grid. This allows the system to

deliver excess electricity to the utility grid and then draw from the grid when needed. Therefore, the grid-connected systems do not need a battery for storage (Brooks and Dunlop, 2012).

The stand-alone system is a system that is separate from the electricity supply system. It is designed to operate alone without the national electricity grid and supplies electricity to only one system. These systems usually include one or more batteries to store electricity (Brooks and Dunlop, 2012).

Government Programs and Incentives

Solar energy has experienced tremendous growth in recent years due to cost reduction and government policies that support renewable energy development and utilization (Timilsina et al., 2012). There are many advantageous programs available through the government for going solar, but Fernoak Farms was only eligible for the following financial incentives, tax incentives and government rebate programs.

California Solar Incentive

The California Solar Initiative is a rebate program designed to develop a strong solar industry and encourage solar technologies. California launched the ten-year "Go Solar California" campaign in 2007. The largest part of the campaign is the California Solar Initiative (CSI) managed by the California Public Utilities Commission (CPUC). The CSI gives out rebates and performance based incentives for customers who are in service with one of the investor owned electric utility companies, which are Pacific Gas & Electric, Southern California Edison, and San Diego Gas & Electric. California's

electric utility companies promote installation of solar power systems by rewarding customers who go solar with cash incentives. A goal set by CSI was to install approximately 1,940 MW of solar power by 2017. The CPUC, through the California Solar Initiative, provides over $2.2 billion in incentives from 2007 to 2016 for existing residential homes, existing and new commercial, industrial, and agricultural properties (Loewen et al., 2012). The CPUC divided the megawatt goal for the incentive program into ten incentive steps, meaning that over the ten years, a set amount of capacity and rebate money is given. This established amount is an incentive based on dollars per/watt or cents per/kilowatt/hour. The megawatt target in each incentive step is assigned to a specific customer class across the three service territories. The target amount is based off the group's overall contribution to electricity sales in the state. The incentive money decreases as the program progresses through the 10 steps and as more megawatts are installed. The CSI Program pays solar customers the incentive money either at one time for the smaller solar systems or over a five-year term for larger solar systems. The smaller systems receive an upfront incentive that is based off their capacity and is adjusted on the expected system performance called the Expected Performance Based Buy Down. While the larger systems receive incentives for their actual performance output over five years called Performance Based Incentive (California Solar Initiative - PV Incentives, 2013). With this goal, the state hopes to move toward a cleaner energy future and help decrease the cost of solar systems for consumers.

Property Tax Exclusion

The Property Tax Exclusion for solar energy systems is a California property tax incentive. The property tax exclusion is intended to exempt property taxes in the amount of 100% of the system value when installing solar PV systems. In section 73 of the California Revenue and Taxation Code it states that there is property tax exclusion for particular types of solar energy systems when installed between January 1, 1999, and December 31, 2016. The solar system excused of property tax is an active solar energy system. The active solar system is a solar device that provides storage, collection and distribution of solar energy. Some of these systems are solar water heating systems, active solar energy systems, photovoltaic systems, and solar thermal electric systems, and a few other types of systems. These devices have to be isolated from living spaces or any other area where energy is being used in order to receive the tax exemptions. The exclusion applies to qualified and locally assessed commercial, industrial, and utility-scale systems. Components that are included under the exclusion are storage devices, power conditioning equipment, parts and transfer equipment. However, pipes and ducts that carry energy from other sources only qualifies for the exemption at 75% of their full cash value (Guidelines for Active Solar Energy Systems, 2012).

Renewable Energy Certificates

Renewable Energy Certificates (REC) is the renewable attribute of the electricity produced by a renewable generator. The REC represents the legal rights to the environmental benefits linked to the production of renewable energy. One REC is issued for each megawatt-hour of renewable electricity produced and delivered to the power

grid. REC is increasingly being seen as the “currency” of renewable electricity and green power markets. The renewable energy credits can be bought and sold between multiple parties. REC gives owners an opportunity to keep the title on their renewable energy and acknowledgment for the environmental benefits (Renewable Energy Credits-EPA, 2008). Currently, the price for a REC is determined by the negotiation between the buyer and seller. RECs are needed to track the generation of renewable energy because when an electron from a renewable energy source is delivered to an interconnected power grid, the electron looks identical to an electron from other conventional energy sources. This makes it impossible to assure delivery of only electrons from a renewable energy source to the factory or home by an electricity provider. Every megawatt-hour of renewable electricity created reduces the need for one megawatt-hour from conventional electricity. As a result, renewable energy certificates minimize greenhouse gas emissions and other negative effects that occur from conventional electricity generation. Typically businesses, government agencies, and nonprofit organizations are the places that buy renewable energy certificates to take liability for their environmental impact and to make their operation more sustainable. Overall, REC provides owners of renewable energy with a revenue stream from purchasers who need energy credits, as well as improve renewable energy economics by increasing the competitiveness with fossil fuels (Renewable Portfolio Standard, 2013).

Modified Accelerated Cost recovery System

Modified Accelerated Cost recovery system is a federal incentive for renewable energy. MACRS is the depreciation method, which allows the owner of qualifying equipment, which includes qualifying solar equipment that can deduct 85 percent of their tax basis with the use of commercial energy investment tax credit (ITC). The 85 percent depreciation can be claimed over a five-year period (MARCS, 2013). The federal American Taxpayer relief act of 2012 includes 50 percent first-year bonus depreciation for eligible renewable energy systems installed and in service within 2013. The allowable first year deduction is 50 percent of the adjusted basis. In the case of 50 percent first year deduction the remaining 50 percent of the newly adjusted basis of the property is depreciated over the ordinary MARCS depreciation schedule (MARCS, 2013).

Federal Investment Tax Credit

The Federal investment tax credit (ITC) is a reduction of the overall tax liability for individuals or business that make investments in the solar energy generation technology. The investment tax credit supplies policy assurance to the private sectors that fund solar manufacturing and installation, while ensuring the growth of the solar industry in the United States. The ITC is a 30% uncapped tax credit for commercial solar systems under Section 48 of the Internal Revenue Code. The ITC is in action till December 31, 2016 (Business Energy Investment Tax Credit, 2013).

Solar PV Market

The market for PV solar systems in the United States is driven largely by national, state, and local government incentives, which include cash rebates, production based incentives, renewable portfolio standards, and federal and state tax benefits. These programs are motivated by the popular appeal of solar energy. As well as the positive aspects that solar PV possesses, such as a small environmental impact, reduction of fuel price risks, avoiding high electrical demands, and the capability to install PV for particular uses (Barbose et al., 2012). The solar photovoltaic market is constantly growing because of its ability to harness the sun's free energy to provide large-scale, nationwide security, and environmentally friendly electricity (Solangi et al., 2011). Solar is expected to keep thriving in the Unites States because of the decrease in photovoltaic prices, high consumer demand, and financial incentives from the federal government, state, and utilities (Sherwood, 2012).

Capacity and Installations

PV installations are separated into three groups. These groups are residential, non-residential, and utility sector. Distributed installations are the customer side of the meter and create electricity used on-site, both residential and non-residential are included in distribution installations. A homeowner or building owner owns residential installation. The third party, who sells the electricity to the homeowner or building owner, is also considered a residential installation. Residential or small commercial installations are usually less than or equal to 10kW in capacity. A building owner can own the non-residential sectors installations (commercial), or the sector can be owned by a third party

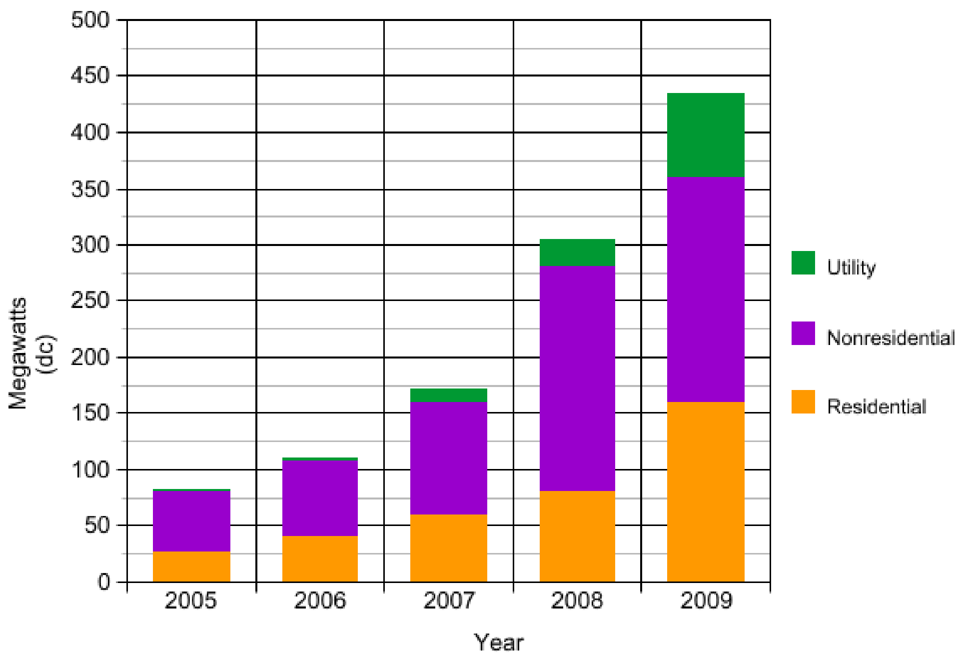
that sells the electricity to the building owner for onsite use. Non-residential installations include retail stores, military installations, and government buildings. These installations have a capacity greater than 100kW (Feldman et al., 2013). Utility installations mean that it is connected on the utilities side of the meter and produce large amounts of electricity to the grid, with an overall system capacity greater than 2 megawatts (Feldman et al., 2013). The utility installation can be owned by the utility, a third party, or by the building owners (Sherwood, 2013).

Capacity is a measure of maximum power that the system can create. The capacity output for a solar energy system is measured under perfect sun conditions. The capacity is usually measured in watts (W) or kilowatts (kW). In the following reports, the PV capacity is measured in direct current (DC) watts under the Standard Test Conditions (Wdc-stc). This unit is typically used when measuring system capacity by manufactures, general reports, and used as the basis when establishing rebate money in many states (Sherwood, 2013).

The solar electricity market showed a remarkable 33% growth each year from 1998 to 2002 (Hoffmann, 2006). Since 1998 installed system prices have declined by about 5-7% on average every year depending on the system size. However, the price decrease did not happen at a fixed rate. Installed prices decreased noticeably until 2005 and then the installed price stayed the same until 2009. However, since 2009 the installation prices fell steeply because of the reduction in PV module costs, and from state and utility incentive programs (Feldman et al., 2013). Even though 2009 was a bad economic year, the solar market continued to rise in the U.S. because of consumer interest in green technologies, troubling energy prices, and the available financial

incentives. More than 107,000 new solar heating, cooling, and solar electric installations were finished in 2009, which was an 18% increase from the previous year. The number of PV grid-connected installations increased by 40% in 2009, opposed to the amount installed in 2008. The cumulative installed grid-connected capacity was raised 1.25 GW, resulting in an overall capacity of 435 MW installed in 2009. The installed PV capacity tripled in the utilities division and doubled in the residential division (Figure 3). However, poor economic circumstances and financing situations resulted in no growth in the non-residential division (Sherwood, 2010).

Figure 3. The grid-connected photovoltaic capacity installed by sector during 2009.

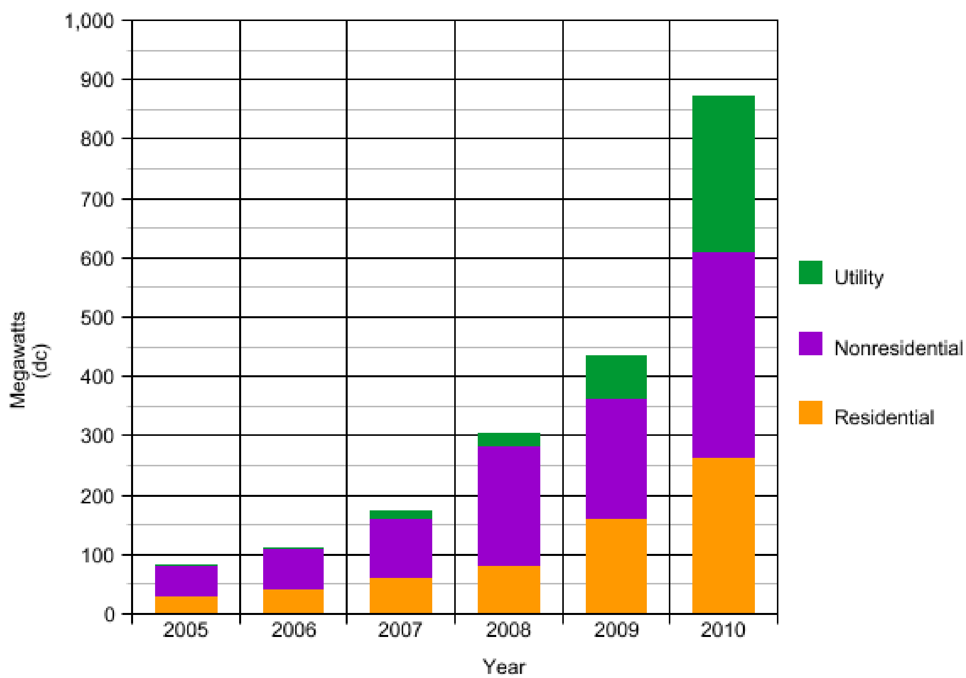


Recreated From U.S Solar Market Trends (Sherwood, 2010)

The amount of solar installations in 2010 grew 22%, with 124,000 installations of solar heating, cooling, and solar electricity. The grid-connected PV installations doubled compared to 2009 installations with more than 50,000 PV systems installed in 2010,

resulting in a 45% increase over the number installed the year prior. The cumulative installed grid-connected PV systems had an increase in capacity by 2.15 GW, resulting in 890 MW of installed capacity in 2010. The overall capacity consisted of 262 MW added to the residential sector, 347 MW added to the non-residential, and 284 MW added to the utility sector (Figure 4). The PV capacity quadrupled in the utility division and there was a 60% increase in the residential and non-residential sectors. The state renewable portfolio requirements were one of the vital reasons for the increase in the utilities division (Sherwood, 2011).

Figure 4. The grid-connected photovoltaic capacity installed by sector during 2010.

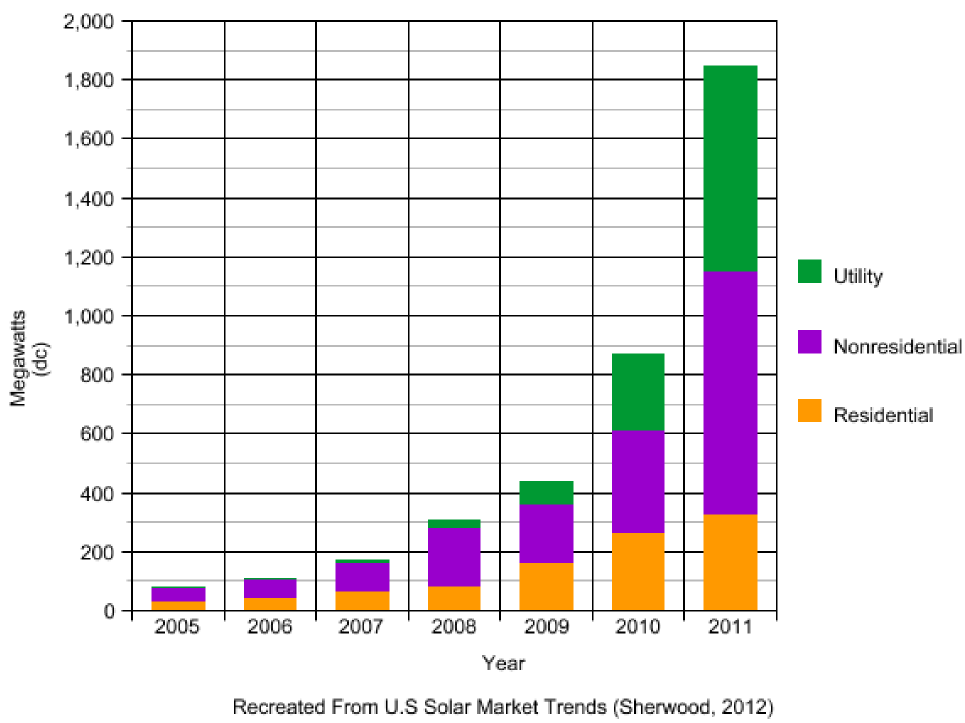


Recreated From U.S Solar Market Trends (Sherwood, 2011)

The solar market had an excellent year in 2011 with significant increases in the number and average size of PV installations. The amount of PV installations more than doubled for large systems in the utilities division with a 145% increase in capacity and a

132% increase in capacity for the non-residential division, while the residential capacity only increased by 24%. There were over 64,000 grid-connected PV installations completed, resulting in a 30% increase over installations in 2010. The cumulative installed grid-connected PV capacity increased by 4 GW, ending 2011 with 1,845 MW of installed PV capacity. Of the overall capacity (Figure 5), 324 MW was installed in the residential sector, 822 MW was installed in non-residential sector, and 698 MW was installed in the utilities sector (Sherwood, 2012). There were many factors like the Federal Investment Tax Credit, U.S. 1603 Treasury Grant Program, State Renewable Portfolio Standards, State and Utility rebate programs, and decline in PV module costs, that helped drive the solar market in 2011 (Sherwood, 2012).

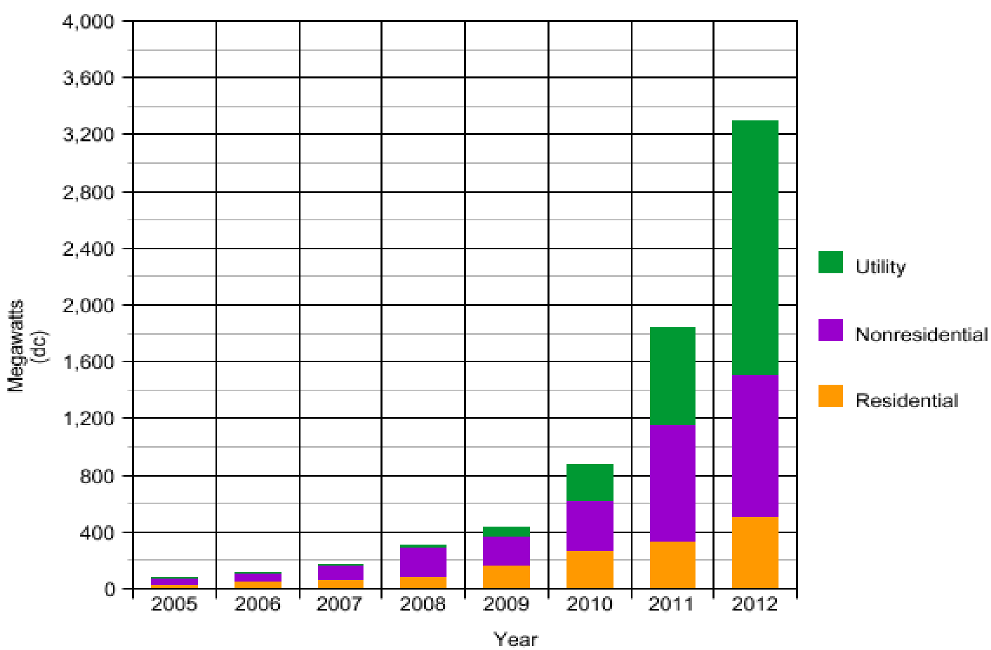
Figure 5. The grid-connected photovoltaic capacity installed by sector during 2011.



The solar energy market in 2012 was a very successful year with 95,000 grid-connected PV installations established, resulting in a 36 percent increase from 2011. The installation capacity increased by 80 percent, and over 50 percent of the capacity was in the utilities division. Of the 50 percent, more than 80 percent of the utility capacity was located in California, Arizona, New Jersey, Nevada, New Mexico, Colorado, Texas, and North Carolina (Barbose et al., 2013). The cumulative installed grid-connected PV capacity increased by 7.4 GW, resulting in an overall installation capacity of 3.3 GW (3300 MW) in 2012 (Figure 6). Of the overall capacity installed in 2012, 0.5 GW (500 MW) was added to the residential sector, 1.0 GW was added to the non-residential sector, and 1.8 GW (1800 MW) was added to the utilities sector. Almost half the capacity installed was at 61 locations, with the capacity size being 5 MW or bigger. The biggest installation in 2012 was almost 290 MW. Also, four installations were larger than 100 MW. This shows that during 2012 PV installations and capacity grew. The residential installations increased by 61 percent because of leases and third-party ownership of the solar systems. The federal Investment Tax Credit (ITC), which equals 30 percent of expenditures, provided a big opening for most installations. The ITC caused the installed prices for distributed PV installations to fall by a minimum of 12 percent in 2012 and has decreased by 33 percent ever since 2009. Some of the individual system components, particularly modules, have fallen by $2.60/W from 2008 to 2009. The decrease in prices resulted in an increase in consumer demand for solar installations (Sherwood, 2013). Overall the installed price for PV systems fell in 2012 from a range of 6-14% or $0.30/W to $0.90/W varying on the size of the system. Galen Barbose stated that, “This marks the third year in a row of significant price reductions for PV systems in the U.S” (Barbose et

al., 2013). Barbose also reported that the average installed price of PV systems in 2012 was $5.30/W for residential and small commercial systems that were smaller than 10kW in size. Commercial systems that were 100 kW or more in size were approximately $4.60/W, and the utility-scale systems installed recorded even lower prices with systems larger than 10,000 kW priced from $2.50/W to $4.00/W (Barbose et al., 2013).

Figure 6. The grid-connected photovoltaic capacity installed by sector during 2012



Recreated From U.S Solar Market Trends (Sherwood, 2013)

The most recent date available on the solar market is from the third quarter of 2013. However based off the growth from the first, second, and third quarters, the solar market is already predicted to have an overall exceptional year at the conclusion of the fourth quarter. By the third quarter of 2013, the 10 GW cumulative installations had already been achieved and over 400,000 solar projects will be in service by the end of 2013. The United States installed 930 megawatts of PV in the third quarter of 2013, resulting in a 20% increase compared to the second quarter of 2013, which makes the

second largest quarter in United States solar history. The Solar Energy Industries Association (SEIA) and GTM Research predict that 1,780 megawatts of PV and 800 megawatts of concentrating solar will be installed in the fourth quarter of 2013, increasing the year total of new solar electric capacity over 5,000 megawatts. The SEIA also forecasts that a total of 4,300 megawatts of new PV will be installed throughout 2013, resulting in a 27 percent increase over 2012 installations (Kann et al., 2013). Even though more than half of the new PV capacity installed was in the utility sector, the residential market displayed considerable growth with 186 megawatts installed, which is the best quarter in the sectors history. Almost 31,000 residential installations in the third quarter were completed, bringing the overall total of residential installations to 360,000 in the United States. It is anticipated that there will be 52% added growth at the end of the fourth quarter for the residential sector. The non-residential sector, however, was having market difficulty in both quarterly and annual installations during 2013. The utility sector has experienced a strong and consistent growth through the third quarter of 2013. SEIA expects the fourth quarter to have over 1,000 megawatts of installation, which will be the first time any market sector has exceed that amount of electricity in one quarter. There were 52 utility PV projects finished in the third quarter with a total capacity of 539 megawatts. The majority of these large projects were in California (Kann et al., 2013).

The third quarter of 2013 continued to see system prices decline on average across all market sectors compared to last year. The residential sector prices have fallen 9.7% from $5.22/W to $4.72W, since the third quarter of 2012 till the third quarter of 2013. From quarter to quarter installation costs have decrease by 2 percent. Nonresidential sector prices fell 6.1% from $4.22/W to $3.96/W year to year. Utility

systems have decreased quarter-to-quarter, as well as year-to-year. Utility prices were at $2.40/W during the third quarter of 2012, and then $2.10/W in the second quarter of 2013. By the end of the third quarter in 2013 the price had fallen to $2.04/W. However, the prices can vary depending on the state and type of project being installed. Generally residential systems can range from system costs being less than $3.00/W to slightly above $7.00/W. Nonresidential prices can be as low as $1.85/W and high as $7.75/W. Utility prices show large variability depending on the type of solar system installed. A 50MW system with a fixed tilt will be less expensive than the 1 MW system with dual-axis tracking (Kann et al., 2013).

California Solar Market

In the United States, the solar market is being lead by California. With an overabundance of sunny days joined with supportive solar policies, California has created an ideal solar market. All three market segments: residential, non-residential (commercial), and utility, all have advantageous programs and incentives. California leads the nation with 199,087 solar projects and 1,950 megawatts installed. Currently, more than 1,672 solar companies are at work throughout California and are employing 43,700 people. California is currently still ranked first in the nation through 2012 and 2013, with 43,167 megawatts of installed solar capacity. There was an adequate amount of solar energy installed to power 900,100 homes. Just in 2012, 2.6 billion dollars was invested into solar installation on homes and businesses in California (State Solar Policy, 2013).

The California Solar Initiative was launched in 2007, and the main goals are to finance 1,940 megawatts of installations over a ten-year span within the largest investor owned utility territories in California. In July of 2013, the California Public Utilities Commission gave its annual report on the growth of California Solar Initiative. The report showed that the program had installed 66% of the total goal, with another 19% in pending projects. This estimates a total of 1,629 megawatts of installed solar capacity at 167,878 customer sites in the investor-owned utility territories at the end of the first quarter of 2013. The amount of electricity added was enough to power almost 150,000 homes and helped avoid building three new power plants (Drew et al., 2013). The government subsidies are meant to help the growth and promotion of clean renewable energy. Helped is needed from the government because solar on average costs more to create compared to nonrenewable energy sources such as burning coal and natural gas. It is essential that the cost of producing solar energy continues to decline, and that the investment of solar is resulting in profitable financial returns in order to increase solar contribution to United States overall power supply. The use of net metering requires the three utility companies to buy the excess renewable electricity generated from their customers at retail rates. The federal tax credit that covers 30% of the price of a solar energy system has also helped keep solar appealing in California. Although renewable electricity can come from solar, wind, fuel cells or biogas systems, the most popular option has been solar (Drew et al., 2013).

Future Market

The U.S. Energy Information Administration (EIA) projects that the total U.S. electricity production will average 11.2 terawatt-hours per day in 2014, which will be an increase of 1.0% from the previous year. The increasing cost of fuel, mainly natural gases, adds to the projected increase of residential electricity prices. The EIA expects an average of 12.4 cents per kilowatt-hour during 2014 for residential electricity, resulting in a price increase of 2.2% from 2013. EIA also predicts that the residential electricity prices will increase 1.9% in 2015. Even though electricity production in the utility sector remains to be a small part of the electricity generation in the United States, the overall generation is to increase 0.4% by 2015. Solar in the past has grown significantly in the customer-sited installations, but the utility-scale solar capacity grew 96% in 2013. The EIA currently predicts that there will be a 47% increase in utility-scale solar capacity from the end of year 2013 through the end of 2015 (EIA, 2014). The utility sector is driven by installation prices but also prices of electricity and natural gas prices. With a predicted increase in both electricity and gas prices, the solar utility sector is expected to have a growing future (Eurek et al., 2013).

Solar energy is predicted to have an important role in meeting the future energy demands through clean energy resources. Especially with the renewable energy portfolio standards, that requires utilities to generate a set amount of green energy. The solar industry also has an economic impact on the United States, with almost 143,000 solar workers currently employed, according to the Solar Foundation’s Solar Job Census 2013. This was a 13.2 percent increase over the total employment in 2011. All these workers were employed at 6,100 operating businesses at 7,800 places in the United States (Solar

Industry Data, 2013). In the United States, large utility-scale solar projects are making up more than 5,700 megawatts of generated electricity. There are approximately 26,842 megawatts of large-scale solar systems under development and construction in the United States, which could result in the industrial utility solar sector making enough electricity for more than 4.5 million U.S. homes (Major Solar Projects, 2014).

The United States has put into action many trends for the future of installed solar power, but the industrial utility solar sector is looking to benefit the most. The first of these trends is the rapidly declining cost and the increasing efficiency of the PV cell and solar technologies. The second trend is the probability that state and federal policies, including renewable energy portfolio standard (RPS) mandates and federal tax incentive will be extended (Dutzik and Sargent, 2013). The U.S. Department of Energy started the SunShot Initiative in 2011. The Sunshot Initiative's goal is to lower the cost of solar energy systems so that the prices will be competitive with tradition energy sources, therefore, making clean renewable energy more available and affordable to Americans. The Sunshot Initiative Vision Study was done by the U.S. Department of Energy, and forecasts a scenario where the solar system costs will continue to decline dramatically (DOE, 2012). The study explores the future where the price of solar energy systems decreases 75% from 2010 to 2020. The goal is to reduce the total installed cost of solar systems to $.06 per kilowatt-hour (kWh) by 2020.

Since the program launched in 2011, the Sunshot Initiative has reached 60 percent of their goal. The average price of utility-scale photovoltaic electricity per kilowatt-hour has dropped from about $0.21 to $0.11 since 2011. Also by achieving the SunShot Initiative's goal of $.06 per kWh, there could potently be 390,000 new solar jobs added in

the United States by 2050 (DOE, 2012). The study implied that meeting the goal could result in almost 330,000 GW of cumulative installation into the power supply, fulfilling 14% of United States electricity demand by 2030. The study also implied that 715 GW of cumulative installation into the power supply by 2050 would make up 27% of the demand (Eurek et al., 2013). Even though meeting the Sunshot Initiatives goals will require evolutionary and innovative technology changes, the United States Department of energy are focused on researching, manufacturing, and finding market solutions to make solar energy more affordable in the United States. Therefore, as long as there is an increase in electricity demands and prices, decrease in the price of PV technology, and the help of government and state programs, the solar generation has a bright future.

Dairy Energy Consumption

Farmers are the caretakers of the land; therefore investing in renewable energy can help support the farmer's role by assisting in the protection of the air, land, and water. Solar energy offers opportunities for stabilized energy costs, and a decline in pollution and greenhouse gases. Solar panels have been the most outstanding way on the farm to produce renewable energy according to the USDA On-Farm energy Production Survey (Xiarchos and Brian, 2011). California leads the nation with 24% on farm solar operations, with over half of them being located in the western part of California. In 2011, there were about 1825 solar farms, with a cumulated capacity of 20,492,925 watts. The financial help received for solar PV systems was 44% of the project costs from federal, state, and utilities (Xiarchos and Vick, 2011).

Today energy usage on dairy farms has increased greatly due to larger dairy herd, around the clock operations, and automatic equipment. Modern dairies in California use energy on major categories such as milk harvesting, milk cooling, circulation and ventilation, lighting, washing and water heating, and compressed air systems (Ludington et al., 2004). The dairy farm management guide states that about 50% of energy used on a dairy farm is used in the milking parlor to run the milk cooling, electrical water heater, and vacuum pumps. The remaining energy is needed for the housing area to supply electricity for lighting, feeding equipment, ventilation, and manure handling (von Keyserlingk et al., 2013). The dairy farm management report also states that energy usage among dairy farms vary greatly on the size of the operation from 300 to 1,500 kWh per cow annually (von Keyserlingk et al., 2013).

A group of analyst put together a "Dairy Farm Management Guide" for Southern California Edison company. The management guide analyzes energy consumption on California dairy farms and the researchers developed an Energy Utilization Indices (EUIs), to provide a measurement of how electrical energy is being used on the dairy farms. This energy index will be used in discussing the primary energy usage on an average dairy farm in California (Ludington et al., 2004).

Milk harvesting is the most important technology on the modern dairy and has more hours of use than any other piece of equipment on the dairy. The milking process occurs 2-3 times a day, for 365 days a year, and requires a significant amount of energy needed to extract the milk from a cow and transport the milk to storage. The milk harvesting process alone accounts for 12% of electricity used on the dairy. The focus of the milking system is the vacuum pump, which is the primary component that utilizes the

most electricity in the milking parlor. The vacuum pump runs every time milking or washing the milking equipment occurs. On large-scale 3000-cow dairy, the pump runs for 24 hours a day, seven days a week. The total energy used by the vacuum pump can make up 26% of all electrical energy used on a California dairy (Ludington et al., 2004).

The milk cooling process consumes the most energy on California dairy farms, representing 30% of electrical energy used. It is vital to cool the milk immediately after milking to maintain high levels of quality until processing. Most California dairies cool milk to 45 degrees Fahrenheit. The cooling system must have a refrigeration cycle in order to get the milk that is usually 99 degrees Fahrenheit when harvested to 45 degrees. The refrigeration cycles equipment includes compressors, condensers (air and water cooled), thermostatic expansion valve, evaporator, and milk cooling heat exchangers. This entire process requires a lot of electricity to run the equipment involved. Based of the Energy Utilization Indices (EUIs), a cooling system that's maintained averages between 0.8 and 1.2 kWh per hundredweight of milked cooled (Ludington et al., 2004).

Lighting is the next component that is often overlooked but is a large energy factor on a dairy farm operation, representing 16% of the total electricity used. The three categories of light usage on a dairy farm are task lighting, livestock handling lighting and general lighting. The intensive farm task lightening requires the highest level of light because it includes the milking parlors and holding pens, equipment washing, equipment maintenance and repair, office lighting, maternity and veterinary treatment area, and utility room lighting. The livestock handling lighting requires high to moderate levels of light because it is used for the holding area, feeding area, animal sorting and observations, and general cleanup. The general lighting is low to moderate levels of light

and includes livestock resting area, passageway lighting, general room lighting, and security lighting. The Energy Utilization Indices (EUIs) calculated lighting costs by using kilowatts-hours used per cow for operating all lights on the dairy. The range of electricity used for lighting on a dairy is about 30-75 kWh per cow a year. This range could be higher if the operation is using extra lighting in freestall barns to increase milk production, which can result in 100-175 kWh per cow a year (Ludington et al., 2004).

Air circulation and ventilation are extremely important on California dairy farms. It's essential to provide a comfortable environment and avoid heat stress on high producing cows. Heat stress can cause decreased milk production, reduced feed intake, susceptibility to mastitis and other diseases, and reduced conception rates and other reproductive problems. Therefore, natural ventilation from the freestall barn's structure and circulation fan systems with misters or soakers, are important on a dairy farm operation. They are needed in the freestall barns, holding pens, and milking parlor, which accounts for about 10% of electrical energy on the dairy farm. A typical range for air circulation is about 100-175 KWh per cow a year on a California dairy with freestall barns and circulating fans. Also, the electricity used normally falls in the range of 10-20 kWh per cow-year for just the air circulation in the milking parlor and holding areas. The air circulation system is recommended to have fans that are at least 4 feet in size for every 100 cows in a freestall barn. The 10 fans would have a total connected load of 9325 watts or an installed fan capacity of 93 watts per cow. This standard suggests that a freestall barn housing 500 cows will need 50 fans with a connected load of 46.6 kW (Ludington et al., 2004).

For washing and water heating there must be a reliable and adequate supply of hot water to achieve high quality milk production on any dairy farm. Water on the dairy is used for cleaning milking systems, which contains milking units, pipelines, receivers, and bulk storage tanks for the milk. An adequate amount of water must be available in larger quantities and at required temperatures for each cycle in the cleaning process. Failure to have a supply of hot water at needed temperatures could lead to bacterial contamination and reduce milk quality. The reduction in milk quality can lead to a loss in premiums and refusal to take the contaminated milk. The requirements for hot water vary on the farm and number of milking units. In general, the minimum hot water requirement is 4 gallons of 170-degree Fahrenheit water for each milking unit used during every rinse and wash cycle. There are certain water temperatures required for rinsing, washing, and sanitizing. Pre-rinse cycle is between 95-110 degrees Fahrenheit. The washing cycle is between 155-170 degrees Fahrenheit. Acid rinse cycle is 95-110 degrees Fahrenheit and the sanitize cycle is a minimum of 75 degrees Fahrenheit. California dairies that have automated equipment have reduced the volume of hot water used to about one half gallon per cow per day, using 33.5 kWh per cow-year, with a typical range of 22-44kWh (Ludington et al., 2004).

Water systems and pumping water are critical areas to consider when operating any dairy and water represents about 8% of the total electric energy used on the dairy. The pump water is a major energy user on a California dairy farm. Milking dairy cow consume typically 25 to 50 gallons of water per day. Also, secondary uses of water can equal a total water usage of 175 gallons or more of water per cow per day. Total water usage is comprised of cows drinking water, cleaning water for parlor and milking system,

washing milking parlor surfaces and general sanitation, partial cooling of milk, water cooled refrigeration equipment, water for vacuum pumps, wash pen water, cooling spray such as soakers and misters, flush water for manure removal from lanes, holding pens and milking parlors, and for fire protection. The electricity consumption used for supplying water on dairies in California is determined by water volume, distribution system pressures, and design, size and water system components all determine. The typical kilowatt-hour for water consumption per cow a year on California dairy ranges from about 35-75 kWh (Ludington et al., 2004).

Compressed air systems operate many devices in the automatic milking system, and provide a controlled force to assist animals in movement without causing them harm. California dairies utilize compressed air for holding areas, parlor stall entry and exit, milk claw detacher system, operate wash values, operate flush valves for water removal, and other uses depending on the dairy. Electricity is the power source that makes the compressed air used for air-powered equipment in the milking parlor. The air compressors operate viable systems and utilize different types of compressors, storage tanks, air treatment, delivery systems, and other devices. The addition of compressed air operated equipment to the milking parlor has increased the level of automation and has increased labor efficiency in milk harvesting. On most California dairies the general quantities of compressed air range from 15-50kWh per cow-year (Ludington et al., 2004).

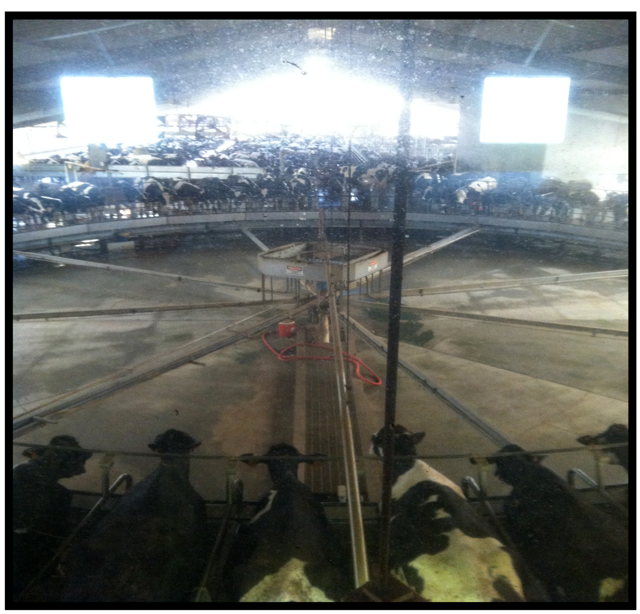
Solar can be used on farms to help with water pumping, which includes irrigation in fields, watering livestock, pong management, and aquaculture. PV systems can be used to pump water from underground wells or from the surface for farm usage (Xiarchos and Brain, 2011).

Materials and Methods

Description of Fernoak Farms Dairy

In the heart of the California's central valley, Fernoak Farms is located in Tulare County. Fernoak Farms is a three-generation family owned business. Fernoak Farms' goals are to efficiently produce high quality milk for the consumer while leaving a small environmental impact and striving to achieve optimal cow comfort for their animals. There are approximately 3,000 cows on the dairy operation and 1,000 acres of farmland. The dairy operation raises their calves and grows a large portion of their feed. The large-scale dairy uses a considerable amount of energy to run the operation and water wells for irrigation. The major components that require electricity on the dairy is the milking parlor, flush pumps, lights, fans, aerators, wells, and air compressors. Cows are milked on a rotary style-milking parlor that can milk 72 cows at a time (Figure 7). The operation milks 3000 cows, three times a day. This results in the milking parlor running for approximately 21 hours per day, with an hour of down time between each milking.

Figure 7. Fernoak Farms rotary milking parlor.



The milking parlor costs Fernoak Farms approximately $164,464 total/year and consumes 1,835,039 kWh or 1835 MWh of energy/year. Fernoak Farms' aerator pump costs approximately $41,501 total/year and the pump consumes 482,841 kWh or 483 MWh of energy/year. Fernoak Farms' 100 horse powered (HP) well pump costs approximately $17,195 total/year and consumes 140,130 kWh or 140MWh of energy/year. These calculations are based off of the rate plan TOU-PA-B Fernoak Farms had with SCE before installation. Fernoak Farms' other 75 horse powered (HP) well pump costs approximately $22,071 total/year and consumes 125,118 kWh or 125 MWh of energy/year, and is calculated off the PA-2 rate plan used before the installation. Overall the operation in 2012 cost Fernoak Farms $245,231 and consumed 748,089 kWh of electricity (Table 1).

Table 1.

Fernoak Farms Total Utility Costs (2012)		
	kWh	Cost
Milking Parlor	1,835,039	$164,464
Aerator Pump	482,841	$41,501
100HP Well Pump	140,130	$17,195
75HP Well Pump	125,118	$22,071
Total	748,089	$245,231

The yearly average temperature is typical high of 79 degrees Fahrenheit and a low of 54 degrees Fahrenheit. In 2013, the highest temperature reached 108 degrees Fahrenheit in July, and the lowest temperature of the year was 27 degrees Fahrenheit in January. There was 154 days of clear weather with no cloud coverage from May to October. During the year there was approximately 193 days of sunshine and 71 partly sunny days, making a total of 264 days of sun throughout the year. The months from

November to February are the times in the year with the least visibility due to fog and clouds. However, the sun makes up for the winter months with the long days of sunshine during the summer. Overall the central valley has an abundant amount of sunny days year round, which makes the area one of the most optimal environments for a PV solar system (Historical Weather, 2013).

SPG Solar

Fernoak Farms is a costumer of Southern California Edison Company and has chosen SPG Solar to install the solar system. Fernoak entered into a contract with SPG Solar on April 23, 2013. The complete installation of the solar system was completed on November 8, 2013 and went into service on December 1, 2013. Fernoak Farms decided to lease the solar system from Farm Credit West because it was the most feasible option. SPG Solar installed a grid-connected, commercial/utility-scale solar system on five acres of property at the backside of Fernoak's dairy operation. The decision was made based off the increasing cost of electricity, the government incentives, renewable energy credits, and the overall savings on the electricity bill. SPG solar proposed that the system would provide the most efficient and cost effective design possible to maximize the return on the investment. It will offset 25% more of the peak hour energy consumption when rates are most expensive. It will also offset 100% consumption of all meters on the property with a ten year energy out-put guarantee. The proposal included that Fernoak Farms will save money over the next 30 years or more on the dairies' electricity bill and will take advantage of the existing financial incentives and tax credits available for going solar.

System Design and Capacity

The solar system chosen by Fernoak Farms is the 1 Megawatts (MW) ground mounted single-axis tracking system used for optimal efficiency, power output, durability, and long lasting reliability. The PV system shown in Figure 8 has a total size of 1,051.2 kW-DC or 923.993 kW-AC and interconnects at 480 volts. The system was estimated to produce 2,056,070-kilowatt hours (kWh) in the first year and should produce 299 megawatts (MW) of energy over the systems lifetime. The chosen single axis, All-Weather SunSeeker tracker solar system, was the optimal choice for utility-scale and commercial solar projects like Fernoak Farms. The system was engineered to withstand all weather conditions encountered during the year and triggers the most kWh per motor in the industry. The solar system was quick to assemble because it required fewer posts and materials, which helped maximize Fernoak Farms' solar returns. Overall SPG has installed over 70 megawatts of single-axis SunSeeker tracker systems, and has seven years of proven field history. This has allowed for faster installations and proven reliably under all weather conditions. The SunSeeker mechanically tracks the sun through the course of the day and produces 25% more solar power at the lowest lifetime cost. The advantages of installing the All Weather tracker was that the system was designed and tested to tolerate all weather conditions, and there is 25% more power generated from the tracking system compared to fixed-tilt systems. The flexible design uses less land, concrete, steel, cabling, and wiring, that can withstand all environments and generates a lower levelized cost of energy (LCOE). The LCOE is the primary calculation used by the utility sector to determine the cost of the electricity produced by the solar system. The

calculation accounts for expected lifetime costs, and is then divided by the systems lifetime predicted power output.

The system comes preassembled, which eliminates onsite welding or cutting of material, therefore reducing labor costs. The system was built to operate with fewer moving parts, has corrosion-resistant steel, and requires minimal maintenance. The All-Weather SunSeeker tracker precisely follows the sun from sunrise to sunset with a plus or minus 45-degree range of motion. The main driveline and wings extend to either side allowing for quick installation and easy assembly of the array. The tracker is powered by a 3 horse powered (HP) A/C motor that can push up to 700 kilowatt peak (kWp) as the system simply moves from east to west. This allows for shade avoidance and backtracking, which will maximize solar-power production in the early morning and late afternoons to utilize the most sunshine. Fernoak Farms also has a ten-year warranty on the PV solar system (SPGSOLAR, 2013).

Figure 8. Fernoak Farms photovoltaic solar system.

Meters

There is a total of four meters on Fernoak Farms' dairy. One meter is located in the dairy barn, two meters are located on both water pumps, and one meter is located on the dairy's waste lagoons. The net energy metering (NEM) records the amount of electricity used and produced each month, allowing for customers to receive credit for the surplus electricity they have supplied to the grid. The electric meter spins forward as it measures the amount of kilowatt-hours of electricity consumed by the Fernoak Farms. The electric meter will spin backwards when the solar system is producing more electricity than the dairy/farm is consuming. If the solar system produces more electricity than is being consumed on the dairy/farm, the excess electricity will be pushed back onto Southern California Edison's electric grid. This excess energy is credited to Fernoak Farms account at the same rate it would have been charged if the electricity had been purchased. If the dairy/farm uses more electricity then produced by the solar system, SCE will bill Fernoak Farms for the amount of electricity consumed (NEM Fact Sheet, 2011). Net metering allows for Fernoak Farms to sell back their electricity to SCE when utility rates are the highest during the summer time, and then buy electricity from SCE in the wintertime when the rates are the lowest. The summer and winter season have different rates depending on off-peak, mid-peak, and on-peak hours. The energy consumed during on-peak hours has the highest energy charge, and mid-peak hours have the medium energy charge, while off-peak hours have the lowest energy charge. The summer season is from June 1 until 12 a.m. on October 1 each year, with off-peak hours from 11 p.m. till 8 a.m., mid-peak hours from 8 a.m. till noon and 6 p.m. till 11p.m., and on-peak hours from noon till 6 p.m. during the week. The weekends and holidays are on off-peak hours

all day. The winter season is from October 1 until 12 a.m. on June 1, with off peak hours from 11 p.m. till 8 a.m. and 9 p.m. till 11p.m, and mid-peak hours are from 8 a.m. till 9 p.m. The weekends and holidays during this time are also rated on off-peak hours (Business Rate Basics, 2014).

Modules

The system will utilize 3,504 Polycrystalline 300 watt power PV modules from Astronergy, which is one of the leading manufacturers of crystalline silicon photovoltaic modules. There are 3,504 modules installed on the entire system and each module contains 72 solar cells. The organization of the modules together in rows requires only a single central motor, which utilizes less space, resulting in higher kWh production with very low energy consumption needed. The module is based on the innovative and energy efficient casting of the mono-crystalline production process. This will boost the power levels of the module to that of a mono-crystalline cell. The line of modules used are the latest in technology that deliver extremely high conversion efficiencies of 15.4%, making the module one of the best in today's market. Before and after the lamination process, the solar panels are tested for quality guarantee. The panels are expected to lose almost 0.5% of efficiency each year and are guaranteed to produce over 90% of rated power for 10 years, and produce over 80% of power for the following 15 years through warranty (Datasheet Crystalline PV Module, 2013). The solar panels are built to survive the most severe weather conditions with a durable frame made from silver anodized aluminum that can withstand heavy winds.

Inverters

Fernoak Farms installed six grid-tied inverters that are all backed with ten-year warranties. The inverters change the direct current (DC) created by the solar panels into alternate current (AC) for utility use. There are two Advanced Energy's AE 333NX inverters, three AE 50TX inverters, and one AE 100TX inverter, which are all designed for large-scaled commercial or utility type systems. The performance of all six AE high-efficiency inverters can directly impact the energy output and make a significant change in the levelized cost of electricity (LCOE).

The two AE 333NX inverters have a voltage alternate current (VAC) of 480 units. The high amount of voltage can help achieve faster returns on the PV system for large commercial projects. The invert generates more power and adds more value to the owner, with 97.5% weighted efficiency for the 333NX, without the use of secondary power sources. The design of the inverter is outdoor ready, which reduces that initial costs of the Balance of System (BOS) since there is no need to enclose the inverter. It is also the lightest inverter and has the smallest footprint per kW, meaning that it is easy to maneuver and install. The inverter's engine does not require a transformer and has stable high-voltage, this allows numerous module units to connect in a parallel design to one medium-voltage transformer, making a decrease in the initial cost balance of system and improving levelized cost of electricity (Advanced Energy 333NX Datasheet, 2013). The two AE 333NX inverters (Figure 9) are the main inverters that send electricity to the milking parlor. They are the biggest inverters on the dairy and are essential for supplying all the electricity needed to power the milking barn 24 hr/day all year. The 333NX

inverters are also responsible for the electricity used in all freestall barns, hospital barn, maternity barn, fans, and soakers.

Figure 9. Fernoak Farms two 333NX inverters.

The three AE 50TX are commercial inverters that are smaller in size, but have been credited to have the same reliability, efficiency, easy installation, and lifetime maintainability as the larger commercial inverters. This inverter is reliable because of the ground-up design that has a 20-year or more operating life that includes a busbar power connection, card cage circuit board that communicates with the inverter, and cooling system. The system saves installers time and money because of the external mounting flanges result in fast and easy attachment that requires no pre-drilling. It also includes the AC/ DC disconnect, a large area for cable bending and has it's own isolated transformer contained all in a single cabinet. AE 50TX has a standard DC maximum power point tracker (MPPT) range from 295 to 595-volt direct current (VDC), this aspect saves money because it optimizes the match between the solar array and utility grid, meaning it can convert a higher voltage of DC output from the solar panels down to the lower

voltage if needed. The maximum input is 600-voltage direct current. The two inverters pictured in Figure 10 are used for two separate water pumps for farm irrigation. The larger 100HP well pump pictured in Figure 11 is one of the irrigation pumps that use the 50TX inverters. The other 50TX inverter is used for electrical use on the dairy. The three inverters have 96% weighted efficiency and converts direct current to 480 alternate voltage current for electrical use (Advanced Energy 50TX Datasheet, 2013)

Figure 10. Fernoak Farms AE 50TX inverters.

Figure 11. Fernoak Farms 100HP well pump.

The last inverter is the AE 100TX shown in Figure 12 is a commercial inverter that is set to the same standard as the other inverters with high reliability, easy installation, and lifetime maintainable. The 100TX is very similar to the 50TX inverters. The inverter has a 20 or more year operating life. The inverter contains a cooling system, isolated transformer, AC and DC disconnect, card cage circuit board, busbar power connections, and has 96% efficiency. The 100TX has a volt range of 295-595 volt direct current and a maximum input of 600-voltage direct current (Advanced Energy 100TX Datasheet, 2013).

Figure 12. Fernoak Farms 100TX inverter (right side).

Transformers

There are six transformers used to move electricity to and from the electrical grid, and to other places on the dairy. Four of the transformers are owned by SCE and convert all the electricity to and from the grid to the right voltage. Fernoak Farms owns the other two transformers. The two transformers had to be installed in order to move electricity from the PV system to the milking parlor. The transformer at the PV system converts the electricity to a higher voltage so that the electricity can travel further through a smaller

electrical wire. When the electricity arrives at the milking parlor the second transformer shown in Figure 13 converts the electricity back to 480-volt current so that it can be utilized. Fernoak Farms chose to install the Envirotran Solar transformer, which are specially designed for solar PV set-up function. This transformer was chosen because it is friendlier to the environment since it runs off of vegetable oil-based, dielectric coolant, and Envirotemp fluid that is made from soybeans, making it non-hazardous and non-toxic. Also, the Envirotemp dielectric fluid does not use petroleum, therefore adding to the valuable renewable energy source with a neutral carbon footprint. The transformer also has a longer insulation life, improved fire safety, little reduction in core loss, and improved payback period (Envirotran Solar Transformer, 2013).

Figure 13. Fernoak Farms transformer.

Sunspot Monitoring

The Sunspot monitoring system shown in Figure 14 is a versatile system that tracks the performance of the solar system. The performance can be viewed at anytime 24-hours/day with the online site that shows live, real-time data of the PV solar system. There are in-field sensors that accurately measure the total power consumption and solar power generation stores the updates at 15-minute intervals. The website shows historical performance, daily temperatures, and savings, as well as daily, monthly, and yearly data totals. The system will send automatic alerts if there are any problems detected with the system. SPG Solar has a team that monitors the system and will also receive alerts.

Figure 14. Fernoak Farm' Sunspot Monitoring System.

DC and AC Disconnect

There are thirteen DC disconnects located on the solar system, and are used for safety to turn off the electricity current when needed. Each disconnect is connected to three rows of solar panels and controls their electrical current. Figure 15 shows one of the DC disconnect attached to the solar system. Also as stated before the inverters on the operation have a DC/AC disconnect. AC disconnects are located at all four meters on the property to prevent back feeding from the PV system onto the public utility grid when maintenance is being performed on electrical lines.

Figure 15. Fernoak Farms DC disconnect.

Payback Period

The payback period is the length of time needed to recover from the cost of an investment. When deciding to make a large investment into a business, it is essential to look at the payback period to determine if the investment is feasible and how long it will take the business to earn back the investment. The payback period equals the cost of the initial investment divided by the annual cash inflows. When calculating the payback

period the investor must predict their future annual cash flow. The payback period is the year when the sum of the annual cash flow equals or exceeds the initial investment cost of the project.

Government and Environmental Incentives

When investing in large operations like solar systems, it is very important to look at all the available programs and incentives that are available for the type of system being installed. The availability of rebates, tax credits, and other government incentives for renewable energy sources is crucial when calculating the feasibility and net gain of the solar system.

Results and Discussion

Lease and Financial Incentive

Fernoak Farms' decision to install a solar system was established after considering the California Solar Initiative incentive, Property Tax Exclusion, Renewable Energy Certificates, and the benefits of leasing the solar system. Fernoak Farms decided to lease the solar system for ten years instead of owning it for many financial reasons. When comparing the payback period and internal rate of return it was clear that leasing the system was the most feasible choice and would result in immediate savings the first month. The system cost including sales tax equaled $2,895,043, but by leasing the system from Farm Credit West there was no upfront payment from Fernoak Farms. Farm Credit West and Fernoak Farms established a billing system that would result in a lower lease payment monthly compared to any electricity bill Fernoak Farms would receive over the next ten-years. This setup resulted in a payback period starting the first month the solar system was activated. As represented in the cash flow analysis (Table 2), the annual total for utilities in a year without solar cost about $246,523, while the solar lease payment for the first year cost $144,215. This resulted in $102,307 savings on electricity in the first year. The lease made the installation of the solar system look more appealing because Fernoak Farms will never have to pay the full amount of 2.8 million dollars, and the savings started the very first month of solar activation.

Fernoak Farms will never have to pay the full amount for the PV solar system because the lease payment has a negative interest rate because of the Investment Tax Credits that Farm Credit West received. The cash flow analysis (Table 2) is based off the locked-in nominal interest rate of -2.264%, with set payments to Farm Credit West for

the next ten years. The negative interest rate results in a total of $375,742.72 that Fernoak Farms will never have to pay back to Farm Credit West. This means that Fernoak Farms will never pay the full $2,895,043 for the solar system because $375,742.72 of the amount was subtracted from the total cost making the actual payment for the solar system $2,519,300.29. The total amount also includes the rebate money Fernoak Farms will receive monthly for five years.

Fernoak Farms will receive performance based incentive rebate money through the California Solar Initiative for a five-year period. The rebate is based off $0.032 per kilowatt-hour (kWh) produced monthly for a 1 MW solar system. The kWh production by the solar system is expected to produce 2,056,070 kWh the first year resulting in $65,794 in rebate money. The estimated total amount of $325,697 in rebate money will be received over the course of five years based off the expected system performance. These yearly rebate numbers are locked in since the system has a performance based guarantee through SPG Solar. However, the amount of rebate money received could potentially be more than the amounts shown in Table 2 if the solar system produces more kWh than expected. The performance based incentive money is one of the main reasons to keep the solar system clean in order to keep high electricity production. Also to avoid any large payments, the lease was setup so that the highest payments on the solar system are due the first five years to take advantage of the performance based rebate incentive.

The solar system is a 100% tax-deductible expense through the lease because it is considered to be a direct operating expense. Fernoak Farms can write off (deduct) 100% of the lease payment, resulting in a reduction in their taxes and saving more money by writing off the solar payment against their tax bill. Fernoak Farms simply makes their

lease payment and then deducts it as a business expense, which improves the return on the investment.

Since Farm Credit West owns the system they received the 30% investment tax credits (ITC) that Fernoak Farms would not have been able to utilize. Fernoak Farms could not fully utilize the potential of the federal tax credits because in the dairy industry there already exist federal tax exemptions that allow dairies to deduct equipment, vehicles, machinery, and facilities from their expenses. In addition, because of the constant fluctuation of the dairy industry, dairies are not able to accumulate enough net income to take full advantage of the 30% tax credit as Farm Credit West. The calculated 30% of $2,895,043 equals the investment tax credit of $868,513, which is the amount Farm Credit West received and does not have to pay taxes on or include in their net income. The federal incentive, Modified Accelerated Cost Recovery System (MACRS), deducts 85% of Farm Credit West's tax basis using the Investment Tax Credit. This means that the Investment Tax Credit amount of $868,513 to Farm Credit West is cut in half and subtracted from the overall total, which created the adjusted basis of 2.4 million dollars. Farm Credit West depreciated the solar system starting at 2.4 million dollars. This allows for 50% first-year bonus depreciation on the solar system, then after the first year the other 50% is depreciated over a five-year period on MACRS ordinary depreciation schedule.

After ten years of leasing the solar system, Fernoak Farms has the option of buying the solar system at the remaining amount or renew the lease for another five to ten years. Fernoak Farms decided to buy the system at the 20% residual cost of $579,009. This will be the only time Fernoak Farms will be paying a large sum of money upfront.

However, after year eleven Fernoak Farms will start savings even more money because there will no longer be a lease payment. Another positive factor is that once Fernoak Farms buys the solar system they are able to continue depreciating the system at the value they bought the system from Farm Credit West.

The PV solar system is exempt from property taxes in the total of 100% system value. This California state incentive is beneficial since a million dollar system could make the business property taxes increase immensely. Overall, exclusion of property taxes makes the system more feasible.

The Federal Renewable Energy Certificate (REC) is a way for Fernoak Farms to make money from the clean energy produced by the solar system. Fernoak Farms can accumulate these credits up to four years at time and then sell them off. The REC represents the generation of one megawatt-hour (MWh) of electricity. The energy credits are bought and sold to meet other business, government agencies, and utilities renewable energy goals, as well as reduce the greenhouse gas emission goals established by the Federal government.

Table 2. Fernoak Farms Cash Flow Analysis

Fernoak Farms Dairy	
Initial Financing	$2,895,043
Purchase Option at 10 years	$579,009
CA RBI Rebate paid to:	Fernoak
Solar Generated year one kWh/yr 100%	2,056,070
Nominal Interest Rate	-2.264%
CA rebate per kWatt produced	$0.032
Federal Energy Tax Credit	30%
Percent System Degradation Each Year	0.50%
First year Utility rate per kWh	$0.1199
Inflation Rate for Utility Electricity	3.00%
First Year Solar Electricity Cost per kWh	$0.0677
Inflation rate for Leased Solar Electricity	3.00%

	Avg. Cost of Electricity		Avg. Cost of Solar Electricity		25 Yr Lease Savings	Annual Rate - 2.264%	25 Yr Total Savings			
	Total Dollars	per KWh	per KWh	Total Dollars						
	$8,404,329	$0.137	$0.078	$1,614,593.40	$6,789,736	$(375,742.72)	$6,210,726			
	Avoided Utility Payment		**Solar Lease Payment**		**Annual Lease Savings**	**Re-Invested Savings**	**Cumulative Savings**	**Predicted kWh**	**CA State PBI Rebate**	**Total Lease Payment**
Year	Annual	per KWh	per KWh	Annual						
1	$ 246,523	$ 0.120	$ 0.068	$ 144,215.88	$ 102,307.12	$ 67,661.86	$ 102,307	2,056,070	$ 65,794.24	$ 210,010.12
2	$ 252,649	$ 0.123	$ 0.070	$ 147,799.56	$ 104,849.44	$ 56,058.89	$ 207,156	2,045,790	$ 65,465.27	$ 213,264.83
3	$ 258,927	$ 0.127	$ 0.072	$ 151,472.40	$ 107,454.60	$ 49,982.45	$ 314,611	2,035,561	$ 65,137.94	$ 216,610.34
4	$ 265,362	$ 0.13	$ 0.074	$ 155,236.56	$ 110,125.44	$ 43,966.10	$ 424,736	2,025,383	$ 64,812.25	$ 220,048.81
5	$ 271,956	$ 0.135	$ 0.076	$ 159,094.08	$ 112,861.92	$ 38,006.33	$ 537,598	2,015,256	$ 64,488.19	$ 223,582.27
6	$ 278,714	$ 0.139	$ 0.079	$ 163,047.60	$ 115,666.40	$ 32,881.35	$ 653,265	2,005,180		$ 163,047.60
7	$ 285,640	$ 0.143	$ 0.081	$ 167,099.40	$ 118,540.60	$ 28,441.15	$ 771,805	1,995,154		$ 167,099.40
8	$ 292,738	$ 0.147	$ 0.083	$ 171,251.76	$ 121,486.24	$ 24,008.40	$ 893,292	1,985,178		$ 171,251.76
9	$ 300,013	$ 0.152	$ 0.086	$ 175,507.44	$ 124,505.56	$ 19,580.65	$1,017,797	1,975,252		$ 175,507.44
10	$ 307,468	$ 0.156	$ 0.088	$ 179,868.72	$ 127,599.28	$ 15,155.54	$1,145,396	1,965,376		$ 179,868.72
	$2,759,990			**$ 1,614,593.40**	**$1,145,396.60**		**$ 566,387**			**$ 579,009**
11	$ 315,109	$ 0.16			$ 315,109		$ 881,496			
12	$ 322,939	$ 0.166			$ 322,939		$1,204,435			
13	$ 330,964	$ 0.17			$ 330,964		$1,535,399			
14	$ 339,188	$ 0.176			$ 339,188		$1,874,587			
15	$ 347,617	$ 0.18			$ 347,617		$2,222,204			
16	$ 356,256	$ 0.187			$ 356,256		$2,578,460			
17	$ 365,109	$ 0.192			$ 365,109		$2,943,569			
18	$ 374,181	$ 0.198			$ 374,181		$3,317,750			
19	$ 383,480	$ 0.204			$ 383,480		$3,701,230			
20	$ 393,009	$ 0.210			$ 393,009		$4,094,239			
21	$ 402,776	$ 0.217			$ 402,776		$4,497,015			
22	$ 412,785	$ 0.223			$ 412,785		$4,909,800			
23	$ 423,042	$ 0.230			$ 423,042		$5,332,842			
24	$ 433,555	$ 0.237			$ 433,555		$5,766,397			
25	$ 444,329	$ 0.244			$ 444,329		$6,210,726			
Totals	**$8,404,329**			**$ 1,614,593.40**	**$ 6,789,736**	**$ 375,742.72**	**$6,210,726**		**$325,697.89**	**$2,519,300.29**

Monthly Bill

Solar installation predicts immediate savings within the first year and month. Net metering allows Fernoak Farms to switch from their previous TOU-PA-B rate plan shown in Table 3, to the TOU-PA-A rate plan shown in Table 4. This switch resulted in more savings for Fernoak Farms. The TOU-PA-A rate plan is advantageous because it allows Fernoak Farms to sell their energy at higher rates during the summer time when they are over producing electricity, and buy energy at a lower rate during winter when needed. With the solar installation and switching to a new rate plan, Fernoak Farms could save at least $244,712 in one year. The total utility bill without solar was $245,231 (Table 1) and was reduced down to $524 for annual utility costs with the solar installation.

Table 3. Fernoak Farms TOU-PA-B utility rates before solar installation

TOU-PA-B Rate Plan				
		Peak	Part-Peak	Off-Peak
Summer	kWh	$0.11460	$0.07000	$0.04570
	Demand	$9.94	$2.3800	$8.83
Winter	kWh	$0.00	$0.06950	$0.04380
	Demand	$0.00	$0.00	$8.83

Table 4. Fernoak Farms TOU-PA-A utility rates with solar installation

TOU-PA-A Rate Plan				
		Peak	Part-Peak	Off-Peak
Summer	kWh	$0.23300	$0.10005	$0.04570
	Demand		$0.0000	$0.00
Winter	kWh	$0.00	$0.08580	$0.04380
	Demand	$0.00	$0.00	$0.00

Fernoak Farm's electrical usage in the dairy parlor in Table 5 was based off the TOU-PA-B rate plan the business was on prior to solar. A comparison of the utility bill with and without solar shows that in the first year the solar system will reduce the dairy parlor's utility bill from $164,464/year to $-684/year. Resulting in total savings of $165,152 while on the TOU-PA-A rate plan. The monthly electrical usage and savings with solar installation is shown in Table 6.

Table 5. Fernoak Farms dairy parlor electric usage on the TOU-PA-B rate plan

		Energy Consumption (kWh)			Demand (kW)			
Month	Consumption kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges Without
January	112,940	0	35,907	77,033	0	0	242	$8,002
February	120,937	0	40,945	79,992	0	0	248	$8,534
March	125,015	0	42,260	82,755	0	0	299	$9,197
April	128,823	0	48,309	80,514	0	0	304	$10,445
May	162,884	0	70,568	92,317	0	0	412	$12,570
June	201,015	38,208	56,017	106,794	360	425	408	$21,373
July	206,063	36,666	58,405	110,992	368	428	432	$21,854
August	198,028	36,203	61,958	99,867	354	422	422	$21,300
September	189,628	35,118	60,090	93,424	366	431	429	$21,067
October	159,735	0	70,832	88,903	0	0	442	$12,713
November	124,547	0	37,474	87,068	0	0	357	$9,694
December	105,425	0	37,146	68,279	0	0	242	$7,705
Grand Total	1,835,039	147,196	624,011	1,062,932				$164,464

Table 6. Fernoak Farms dairy parlor electrical usage with solar on the TOU-PA-A rate plan

		Energy Production (kWh)			Energy Consumption (kWh)				
Month	Production kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges With	Savings
January	54,830	0	38,334	16,497	0	-2,427	60,536	$2,440	$5,562
February	77,903	0	51,104	26,799	0	-10,159	53,193	$1,455	$7,079
March	115,099	0	79,215	35,885	0	-36,955	46,872	-$1,121	$10,318
April	146,239	0	92,413	53,826	0	-44,104	26,688	-$2,617	$13,064
May	171,075	0	96,717	74,359	0	-26,149	17,957	-$1,458	$14,038
June	178,375	64,455	49,113	64,808	-26,247	6,904	41,986	-$3,506	$24,880
July	176,968	61,769	47,433	67,766	-25,103	10,972	43,226	-$2,776	$24,631
August	163,357	58,086	43,697	61,574	-21,882	18,261	38,292	-$1,522	$22,822
September	136,345	46,427	42,734	47,184	-10,309	17,556	46,256	$1,448	$19,619
October	107,387	0	66,412	40,975	0	4,420	47,928	$2,476	$10,237
November	71,242	0	49,728	21,515	0	-7,254	60,555	$2,027	$7,667
December	49,738	0	36,340	13,398	0	806	54,881	$2,470	$5,235
Grand Total	1,448,558	230,737	693,240	524,582	-83,541	-68,529	538,350	-$684	$165,152

The utility bill for the aerator pump on the TOU-PA-B rate plan costs Fernoak Farms $41,501/year (Table 7). After the first year with solar activation and on the TOU-PA-A rate plan, the utility bill for the aerator pump will be reduced from $41,504/year to $13/year, and result in total savings of $41,491 (Table 8).

Table 7. Fernoak Farms aerator pump electric usage on the TOU-PA-B rate plan

		Energy Consumption (kWh)			Demand (kW)			
Month	Consumption kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges Without
January	44,438	0	16,859	27,579	0	1	62	$2,925
February	44,438	0	16,859	27,579	0	0	62	$2,925
March	35,752	0	13,460	22,292	0	0	62	$2,458
April	41,938	0	16,361	25,577	0	0	61	$2,744
May	45,244	0	15,938	29,306	0	0	65	$2,953
June	42,418	7,237	10,342	24,839	111	119	119	$5,126
July	39,252	6,398	9,011	23,843	107	114	114	$4,795
August	36,941	6,835	10,232	19,874	113	120	120	$4,876
September	36,885	6,281	9,672	20,932	112	120	120	$4,812
October	42,412	0	15,902	26,510	0	0	62	$2,812
November	33,237	0	10,440	22,797	0	0	69	$2,332
December	39,886	0	15,198	24,688	0	0	62	$2,683
Grand Total	482,841	26,751	160,274	295,816				$41,501

Table 8. Fernoak Farms aerator pump electric usage with solar on the TOU-PA-A rate plan

		Energy Production (kWh)			Energy Consumption (kWh)				
Month	Production kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges With Solar	Savings
January	15,247	0	9,261	5,985	0	7,598	23,594	$1,684	$1,241
February	18,821	0	12,346	6,474	0	4,513	21,105	$1,311	$1,615
March	27,807	0	19,138	8,669	0	-5,678	13,623	$109	$2,349
April	35,330	0	22,326	13,004	0	-5,965	12,573	$38	$2,756
May	41,330	0	23,566	17,964	0	-7,428	11,342	-$141	$3,105
June	43,094	15,572	11,865	15,657	-8,335	-1,523	9,182	-$1,675	$6,801
July	42,754	14,923	11,439	16,372	-8,525	-2,448	7,471	-$1,890	$6,685
August	39,466	14,033	10,557	14,876	-7,198	-325	4,998	-$1,481	$6,358
September	32,940	11,216	10,524	11,399	-4,935	-652	9,533	-$780	$5,592
October	25,933	0	16,035	9,899	0	143	16,611	$713	$2,098
November	17,211	0	12,014	5,197	0	-1,574	17,600	$635	$1,697
December	12,016	0	8,780	5,237	0	6,418	21,451	$1,489	$1,194
Grand Total	349,960	55,744	167,481	176,733	-28,993	-7,207	169,083	$13	$41,491

The utility bill for the 100HP well pump on the TOU-PA-B rate plan costs Fernoak Farms $17,195/year (Table 9). After the first year with solar activation and on the TOU-PA-A rate plan, the utility bill for the 100HP well pump will be reduced from $17,195/year to $235/year, and result in a $16,960 in electricity savings as shown Table 10.

Table 9. Fernoak Farms 100HP well pump electric usage on the TOU-PA-B rate plan

		Energy Consumption (kWh)			Demand (kW)			
Month	Consumption kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges Without
January	0	0	1	0	0	0	0	$0
February	7,104	0	4,367	2,737	0	0	59	$440
March	6,677	0	3,855	2,822	0	0	60	$421
April	13,648	0	6,275	7,373	0	0	60	$1,288
May	3,741	0	2,272	1,469	0	0	60	$752
June	28,025	4,489	6,925	16,611	60	60	60	$3,027
July	20,876	4,429	6,138	10,309	60	60	60	$2,682
August	11,839	2,817	4,019	5,003	60	60	60	$2,102
September	22,467	3,986	6,342	12,139	60	60	60	$2,725
October	14,227	0	4,090	10,137	0	0	60	$1,257
November	9	0	0	9	0	0	55	$309
December	11,517	0	5,794	5,723	0	0	61	$1,192
Grand Total	140,130	15,721	50,077	74,332				$17,195

Table 10. Fernoak Farms 100HP well pump electric usage with solar on the TOU-PA-A rate plan

		Energy Production (kWh)			Energy Consumption (kWh)				
Month	Production kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges With Solar	Savings
January	4,487	0	3,137	1,350	0	-3,137	-1,350	-$328	$328
February	6,375	0	4,182	2,193	0	185	444	$35	$904
March	9,419	0	6,482	2,936	0	-2,627	-114	-$250	$1,152
April	11,967	0	7,562	4,405	0	-1,287	2,968	$19	$1,269
May	13,999	0	7,915	6,085	0	-5,643	-4,616	-$686	$1,438
June	14,597	5,274	4,019	5,303	-785	2,906	11,308	$625	$2,403
July	14,482	5,055	3,881	5,545	-626	2,257	4,864	$302	$2,380
August	13,368	4,755	3,576	5,039	-1,936	443	-36	-$409	$2,510
September	11,157	3,799	3,497	3,861	187	2,845	8,278	$707	$2,018
October	8,788	0	5,435	3,353	0	-1,345	6,784	$181	$1,076
November	5,830	0	4,069	1,760	0	-4,069	-1,751	-$426	$735
December	4,070	0	2,974	1,096	0	2,820	4,627	$444	$747
Grand Total	118,539	18,881	56,729	42,926	-3,160	-6,652	31,406	$234	$16,960

The utility bill for the 75HP well pump on the PA-2 rate plan shown in Table 13, costs Fernoak Farms $22,071/year (Table 11). After the first year of solar activation on the TOU-PA-A rate plan, the utility bill for the 75 HP well pump is reduced from $22,071/year to $961/year, resulting in a total of $21,109 in electricity savings (Table 12).

Table 11. Fernoak Farms 75HP well pump electric usage on the PA-2 rate plan

		Energy Consumption (kWh)			Demand (kW)			
Month	Consumption kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges Without
January	0	0	0	0	0	0	0	$0
February	9,605	0	0	9,605	0	0	84	$1,465
March	10,189	0	0	10,189	0	0	83	$1,497
April	1,969	0	0	1,969	0	0	83	$913
May	7,812	0	0	7,812	0	0	83	$1,528
June	24,066	0	0	24,066	0	0	82	$3,835
July	30,380	0	0	30,380	0	0	90	$4,924
August	10,863	0	0	10,863	0	0	88	$2,475
September	27,747	0	0	27,747	0	0	82	$4,494
October	2,487	0	0	2,487	0	0	82	$940
November	0	0	0	0	0	0	0	$0
December	0	0	0	0	0	0	0	$0
Grand Total	125,118	0	0	125,118				$22,071

Table 12. Fernoak Farms 75HP well pump electric usage with solar on the TOU-PA-A rate plan

		Energy Production (kWh)			Energy Consumption (kWh)				
Month	Production kWh	Peak	Partial Peak	Off Peak	Peak	Partial Peak	Off Peak	Electrical Charges With Solar	Savings
January	4,487	0	0	4,487	0	0	-4,487	-$656	$656
February	6,375	0	0	6,375	0	0	3,230	$472	$993
March	9,419	0	0	9,419	0	0	770	$113	$1,384
April	11,967	0	0	11,967	0	0	-9,998	-$1,461	$2,374
May	13,999	0	0	13,999	0	0	-6,187	-$904	$2,232
June	14,597	0	0	14,597	0	0	9,469	$1,384	$2,651
July	14,482	0	0	14,482	0	0	15,898	$2,323	$2,600
August	13,368	0	0	13,368	0	0	-2,505	-$366	$2,841
September	11,157	0	0	11,157	0	0	16,590	$2,424	$2,070
October	8,788	0	0	8,788	0	0	-6,301	-$921	$1,861
November	5,830	0	0	5,830	0	0	-5,830	-$852	$852
December	4,070	0	0	4,070	0	0	-4,070	-$595	$595
Grand Total	118,539	0	0	118,539	0	0	6,579	$961	$21,109

Table 13. Fernoak Farms 75HP well pump utility rates before solar installation

PA-2 Rate Plan				
		Peak	Part-Peak	Off-Peak
Summer	kWh	$0.00000	$0.00000	$0.12480
	Demand	$0.00	$0.00	$12.58
Winter	kWh	$0.00	$0.00000	$0.07110
	Demand	$0.00	$0.00	$9.31

Conclusion

The choice was made by Fernoak Farms to install a PV solar system as a way to improve sustainability, provide stability and energy security, and cut down their utility bill. It was determined that installing a solar system on a dairy farm can result in huge savings and was feasible in today's market. Even though there was a large upfront cost for the solar system, with the lease agreement, financing from federal and state programs, tax credits, property tax exclusion, accelerated depreciation, and many other incentives, have allowed dairies to avoid the burdening expense of installing the solar system. The PV solar system with net metering has the potential to cut the utility bill down tremendously and even eliminate the utility bill by covering 100% of the electrical usage on the dairy. The reducing prices of the PV solar systems and need for renewable energy established by the federal government has allowed for the overall feasibility and growth of the solar market. Fernoak Farms has the potential with their newly installed solar system to save $1,145,396.60 on their annual utility bill in ten years. The solar system will also save Fernoak Farms over 6.2 million dollars in cumulative savings over a 25-year period.

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