Solar Dairy Farm

A Senior Project

presented to

the Faculty of the Dairy Science

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Bachelor of Dairy Science

by

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Abstract

The objective of this project is to determine the feasibility of adding solar panels to offset energy usage on a dairy farm. The data sources for the project will be a 12 month electric usage history gained from Pacific Gas and Electric, as well as various internet sources and in person interviews with industry professionals. Working closely with Pacific Energy and Electricraft Inc. -two companies local to San Luis Obispo, Mason Dairies energy usage was evaluated and a the most beneficial design for the system was determined. The investment was evaluated using investment measures like payback period and internal rate of return. A conclusion was drawn that the addition of photovoltaic's is a good investment.

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Introduction

Solar power is an emerging technology that has the potential to reshape the way we think about energy and where it comes from. By harnessing the free energy given off by the sun it is possible to lower or eliminate the cost of powering daily electrical needs. Looking toward the future, Mason Dairy realized that to maintain a profitable business it needed to rethink the way it operates. In the early 60's, the original herd of cow was a mixed group of breeds which were what could be afforded at the time. When dairy began shipping to a cheese plant; it became necessary to build a herd of purebred jersey cows that would produce milk better suited for cheese production. Again in the early 2000's, the small farmer was being pushed out of business due to rising input costs. Mason Dairy was faced with the choices of expanding, selling out, or transitioning organic. Organic was the path Mason Dairy chose to follow; this has led to the current choice to add solar power to the already organic dairy. The dairy feels that solar power fits the farm's mission, which is to "Produce a high quality organic product in the most profitable and sustainable manner."

Literature Review

Solar power and how it works

In 1954, D.M. Chapin, C.S. Fuller and G.L. Pearson, of Bell Laboratory patented a way of making electricity directly from sunlight using silicon-based solar cells (California, 2010). This was the beginning of collecting energy from the sun, energy that is free and does not depend on non-renewable recourses. Later, Bell Laboratories discovery would be termed photovoltaic cells or “PV cells”, which comes from the Latin for photo meaning "light" and voltaic meaning "electricity" (How Solar Cells Work, 2010). The PV cell works when light strikes the PV cell; a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor and the electrons are knocked loose, allowing them to flow freely. (How Solar Cells Work, 2010) After the electrons are knocked loose they are free to flow through the power grid or used to power any electrical item.

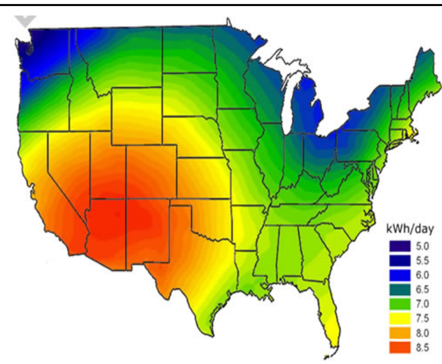

Figure 1- Map of United States outlining kWh/ day of sunlight

The sun is an amazing source of energy that has been used for over 25 years. It has been estimated that hundreds of thousands of PV installations have been made but, the true potential has not yet been tapped (Caldwell, 1994). The sun gives off approximately 1,000 watts of energy per square meter of the planet's surface (How Solar Cells Work, 2010). If this was to be harness correctly it would more than enough energy to power all homes and offices for free, forever.

The light that hits the earth's surface is measured in units of kilowatt hours per day per square meter (kwh/d/m); the average amount of sunlight at any location depends on latitude, cloud cover, and atmospheric conditions such as humidity (Caldwell, 1994). This means that there are better areas for adapting solar energy than others. An area like the Olympic rain forest in Washington receives about 3 kwh/d/m, while southern Arizona, New Mexico, and parts of Utah receive about 7 kwh/ d/m (Caldwell, 1994). Figure 1 is a map of the United States; it outlines the areas with the most kWh/d/m and the least.

As with any technology, there are draw backs, the largest in capturing solar energy is that sunlight has a very low density when compared to other power sources. Sources like diesel and nuclear power have an extremely high energy density meaning that less will yield a higher energy output but, at the cost of our environment.

Dairies and PV

While the modern dairy farm has been quick to adopt other forms of alternative energy sources, such as, methane digesters, the industry has not yet realized the potential in the sun. Currently, there are six areas on a dairy farm which are consumers of electricity these are outlined in Figure 2 and include: milk harvesting, milk cooling, electric water heating, lighting, ventilation, and other (Pressman, 2010).

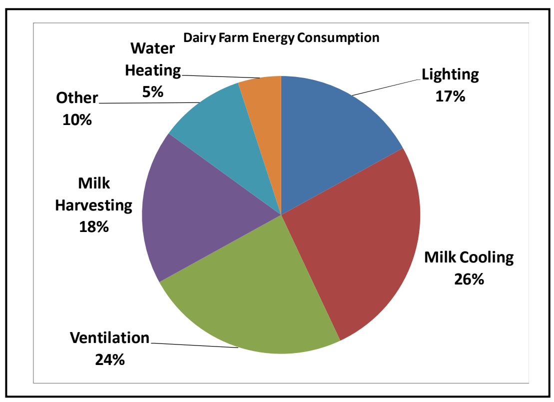

Figure 2 Dairy Energy Consumption (Pressman, 2010)

California Solar Initiative Incentives

Californians who wish to install solar power have a large advantage to them in the California Solar Initiative or CSI. This is an initiative designed to promote the expanding of solar market through monetary incentive for solar installations, CSI has the goal of helping to produce 1,750 megawatts of energy. This incentive amounts will vary depending on your solar system size, system performance, customer class, utility provider, and program deployment phase (Commission, 2007-2010).

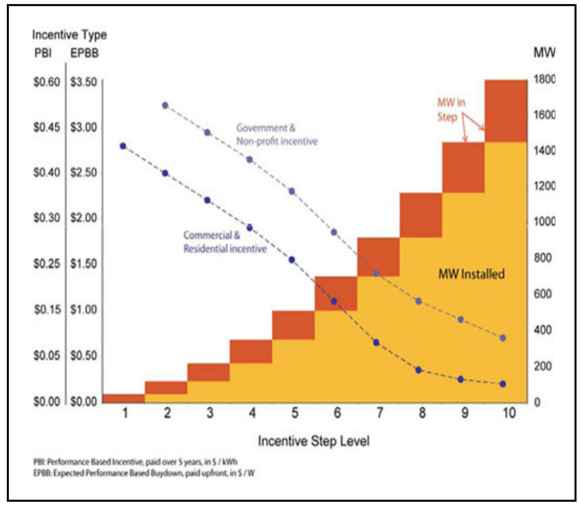

Figure 3- Solar incentive payout showing declining payouts as more PV systems are installed (Commission, 2007-2010)

This means that the larger the system the more of an incentive will be received. Californian has established this incentive to incite growth in the industry, but not to support it indefinitely. Incentive levels available for a given projects are determined by currently available incentive in each utility territory for each customer class. The CSI was designed so that the incentive level decreases over ten steps, after which it goes to $0, as the total demand for solar energy systems grows. (Commission, 2007-2010) This is illustrated in Figure 3, were you see as the number of instillations (blue dotted line) increases the amount of money available decreases, which mean that those who adopt solar practices early will benefit the most.

Government Programs

There is strong support for PV installations both from the state and national government. Solar tax credits were enacted in 2008 as part of the Emergency Economic Stabilization Act, which included $18 billion in incentives for clean and renewable energy technologies, as well as for energy efficiency improvements. The 2008 legislation extended the solar investment tax credit (ITC) through December 31, 2016 (California, 2010). Figure 5 show the increase in solar energy starting in the early 1970's, evaluation show a steady growth in gigawatts produced. Importantly, it is seen that after the 2008 solar tax credits were enacted the industry is set to double production every two years.

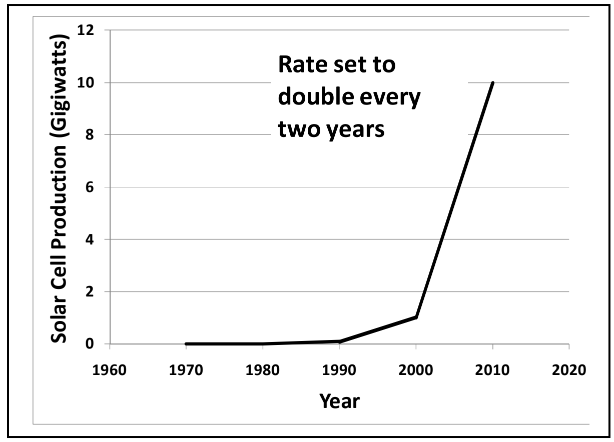

Figure 4- World Solar Cell Production (Partain, 2010)

Market for Solar Energy

The market for solar energy has grown steady over the past 30 years, in both gigawatts (GW) produced per year and total sales. Figure 4 shows the production of solar cells over the past 30 years, there has been a 100 fold increase in GW produced and the rate at which the market will continue to produce is set to double every two

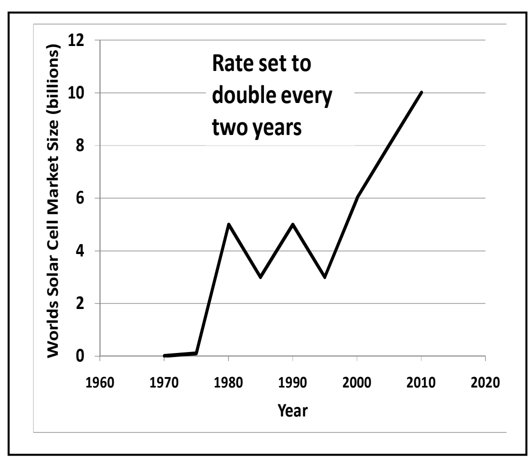

Figure 5- Market size of solar energy (Partain, 2010)

years. The last known production in 2006 saw 3.8 GW produced, up from 1 GW in 2002.

The market for solar energy is following the same pattern gigiwatt production, increasing rapidly over the past 30 years and set to double every two years for the foreseeable future. It is known that PV sales went from 1.5 billion in 2006 to 9.7 billion in 2007 (Partain, 2010).

Designing a system

The design of a PV system is relatively simple, involving very few components. The basic system is like the one, which will be installed at Mason Dairy. It includes: PV panels, mounting brackets, power inverters, and controller panel. All systems include these components; systems will only differ based on size or watts desired to be produced. Size can vary from a home system like that Mason Dairy will be installing or large commercial systems that are producing enough energy to sell. As a comparison, Nevada Solar One is a 250 acre commercial solar power plant that produces 84,000 watts using 760 PV arrays and powers 14,000 households and casinos in Las Vegas (Johnson, 2009).

Using the design illustrated in figure 7 as a template, the sun will strike the PV panel and be converted into direct current energy; then it can be stored in battery for later use or put through a power inverter and be changed into alternating current energy (AC). It is the AC energy that Mason Dairy wants because of safety and ease of use. Also the system will have a controller panel that displays the current watts being produced and if an individual panel is not performing.

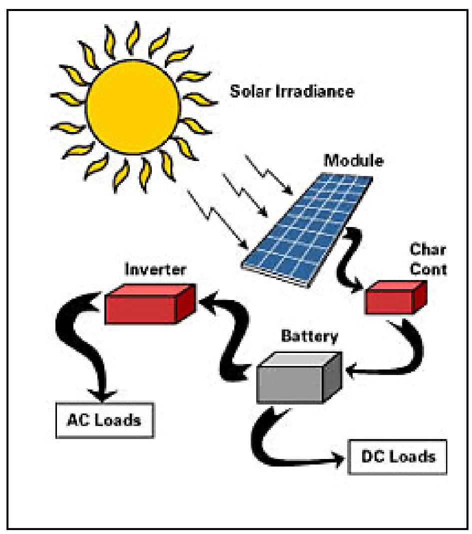

Figure 6- Basic PV system design

Materials and Methods

Description of dairy farm

Mason dairy is located in Arcata California, which is located in the North West part of the state. This is an area defined by its moderate year round temperature. Costal temperature will vary little through the course of the year. During the winter months rainfall and cloud cover are normal and seasonal totals average more than 40 inches in the driest area, and exceed 100 inches in wettest (Humboldt County Ca., 2005). Figures 1-4 demonstrate the average climate over a 12 basis

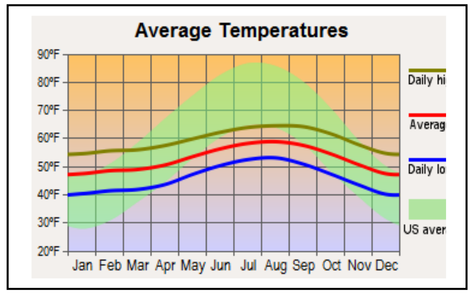

Figure 8-Average Temperature on a 12 month basis for Arcata California (Informatics, 2010)

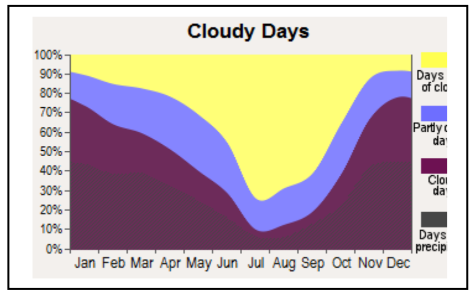

Figure 7- Days with Cloud Cover on a 12 month basis. (Informatics. 2010)

The dairy was started in the year 1960 by Jack and Helen Mason and it currently operated by John and Karin Mason. The dairy started off small only 30 cows on 40 acres; it was a family farm that supported its self and those who lived on it. In the early 80's John Mason assumed a primary role in deciding the direction the farm would take and it began to grow. Mason Dairy grew steadily over the next decade, never wanted to be the biggest farm but, it focused on producing high

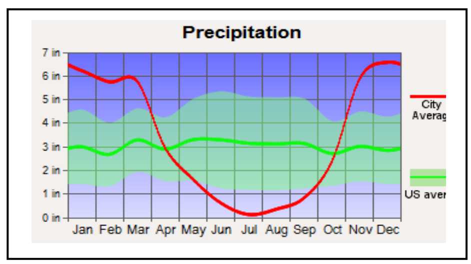

Figure 10- Precipitation on a 12 month basis for Arcata California (Informatics, 2010)

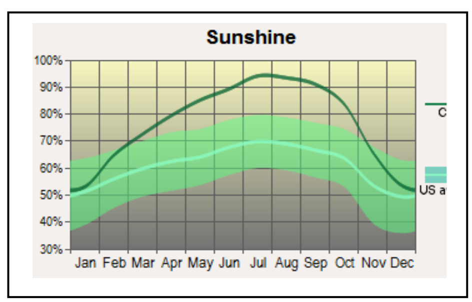

Figure 9- Days with sunshine for Arcata California on a 12 month basis, (Informatics,

quality milk and never assuming more debt then it could handle. Over the years Mason dairy has made an effort to stay modern while hanging on to its pasture based roots, in the mid 90's feed bunks and a silage pit were added. This allowed for a TMR to be fed and the cow diets to be supplemented, increasing production. The early 2000's saw the building of a free stall barn to house the cows during the wet Humboldt county winters. In 2005 the milk parlor was updated and expanded to accommodate growing cow numbers, along with the transition of the herd from conventional to organic. The change to organic was due a need for the dairy to maintain profitability, by transitioning a higher price was paid for the milk and the farm continued.

Mason Dairy is a customer of Pacific Gas and Electric and using their AV-GB rate structure (Table 1). This rate structure is designed for customers that will have 70% or more of the annual energy use on the meter will be for agricultural uses. Agricultural uses consist of: growing crops, raising livestock, pumping water for irrigation of crops and other uses which involve production for sale (Soovajian, 2010). With this rate schedule the year is divided into a summer period from May 1- October 31 and a winter part lasting from November 1- April 30. Those periods are then divided into times of the day, the summer period has two divisions: peak being the most expensive and off peak the least expensive. Peak and off peak are determined by PG&E and take into account the total load on the electric grid, the more electricity being used the more expensive it is. Mason dairy understands this and has adjusted its milking times; to take advantage of the off-peak rates. The winter months have the same off- peak price schedule,

SUMMER:	Service from May 1 through October 31.	
Peak:*		
Group I	12:00 noon to 4:00 p.m.	Monday through Friday **
Group II	1:00 p.m. to 5:00 p.m.	Monday through Friday **
Group III	2:00 p.m. to 6:00 p.m.	Monday through Friday **
Off-Peak	All other hours	Monday through Friday
	All day	Saturday, Sunday, holidays
WINTER:	Service from November 1 through April 30.	
Partial-Peak:	8:30 a.m. to 9:30 p.m.	Monday through Friday**
Off-Peak	All other hours	Monday through Friday
	All day	Saturday, Sunday, holidays

Table 1- AV-GB rate schedule (Soovajian, 2010)

the difference being the demand for electric power is less, so there is not peak power only a much less expensive partial peak.

Table 3, shows the monthly energy usage for monthly energy usage for Mason Dairy. The energy usage is fairly constant between the two time periods- summer and winter, although Mason Dairy will see higher energy usage in the summer months because of longer milking time and use of irrigation.

	AG-VB Monthly Energy Usage (Kw) w/o PV			
Billing Month	**Total**	**Off-**	**Part-**	**Pea**
May	**3,408**	3,289	0	119
Jun	**4,419**	4,112	0	307
Jul	**4,270**	4,064	0	206
Aug	**4,129**	3,842	0	287
Sep	**3,057**	2,802	0	255
Oct	**3,957**	3,618	0	338
Summer Totals	**23,239**	**21,728**	**0**	**1,51**
Nov	**3,857**	3,241	616	
Dec	**3,662**	2,341	1,321	
Jan	**3,508**	2,298	1,210	
Feb	**3,570**	2,342	1,229	
Mar	**4,154**	2,474	1,680	
Apr	**4,216**	2,599	1,617	
Winter Totals	**22,967**	**15,294**	**7,673**	**0**
Totals	**46,206**	**37,021**	**7,673**	**1,51**

Table 2- Monthly energy usage w/out PV

Payback period

When making investment into a business it is important to determine the time it will take for the business to recoup the investment, this is known as payback period. When calculating the payback period the investor must know the initial cash outlay required for the investment, and must estimate the future annual net cash flows attributable to the asset being purchased. The investor then begins to sum the net cash flows, constantly comparing the running total to the initial cash outlay. The payback period is the year in which the sum of the net cash flows equals or just exceeds the net cash outlay. (Ralph W. Battles and Robert C. Thompson, 2000)

Internal Rate of Return

The internal rate of return is a discount rate at which net present value, the sum of the present value of the cash inflows minus the sum of the present of the cash outflows, equals zero (Ralph W. Battles and Robert C. Thompson, 2000).

Results/ Discussion

Monthly Bill

Table 4 shows a financial breakdown for the AG-VB rate schedule currently used by Mason Dairy. This table includes: monthly power bill before and after the addition of solar power, the amount of energy that will be offset by solar panels, the payback period, cumulative savings over 25 years, and a lifecycle payback ratio.

Financial if on AG-VB Rate Schedule:	Results:
Monthly Power Bill Before PV	$587.78
Monthly Power Bill After PV	$373.66
% Bill Offset	36%
Pay Back Period (Yrs) 1	11
Cumulative Savings over 1st 25 Yrs 1	$114,814
Lifecycle Payback Ratio 1	308%

Table 3-Financial break down (Soovajian, 2010)

Evaluation of the AG-VB, reveals that by offsetting energy usage with PV, Mason Dairy will see a drop in their electric bill from an average of $587.78 to 373.66, which translates to an average savings of $214.12 per month or a 36% decrease Mason Dairy electric bill. Using the average savings, it can be projected that the total cost of the system will be paid for in 11 years. That same average can then be projected for 25 years (the manufactures warranted life) and Mason Dairy will save $114,814. The Lifecycle Payback Ratio is a is figured by taking the savings over 25 years and dividing cost of the system after subtracting state rebates and tax credit. This equals 308%, meaning the system pays its self off by over 300%. It is importation to remember that the PV system will not stop working after 25 years, but savings can only be projected until the manufactures warrantee ends.

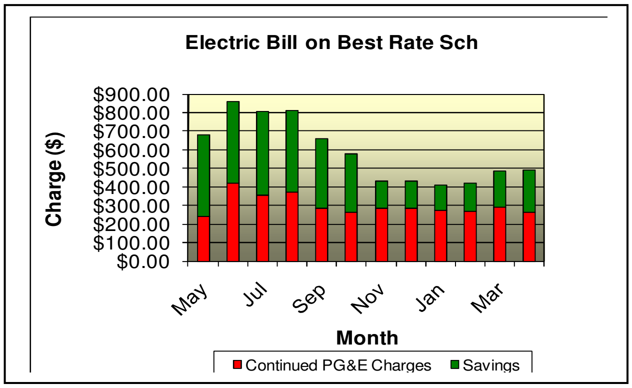

Figure 11- Monthly Bill (Energy, 2010)

The potential for savings can be represented graphically as in Figure 11, showing average year's electric bills compared to the potential savings with PV. The graph shows that Mason Dairy consumes the most energy in the summer months and least in the winter months. The difference in energy usage is due to cost of running electric irrigation pumps and that more cows are being milked.

Payback Period

Table 4 shows a year by year breakdown of energy saving, these saving are used to determine the payback period (Table 3). By adding the projected annual saving per year until the cost of the system was reached, it was determined that for an AG- VB Rate schedule the system would pay for its self in 11 years. This payback period is assuming that the system is operating at optimum performance and that weather patterns remain constant. If during the projected period, there is mechanical problem or a sever decrease in sun the system the period will be extended.

Based on 5% Annual Utility Rate Inflation for AG-VB

After Year	Annual Savings	PBI Pay Back Yr	EPBB Pay Back Yr
1	$2,569.48		
2	$2,697.96	1	
3	$2,832.85	FALSE	
4	$2,974.50	FALSE	
5	$3,123.22	FALSE	
6	$3,279.38	FALSE	
7	$3,443.35	FALSE	
8	$3,615.52	FALSE	
9	$3,796.30	FALSE	
10	$3,986.11	FALSE	
11	$4,185.42	FALSE	
12	$4,394.69	FALSE	11
13	$4,614.42	FALSE	FALSE
14	$4,845.14	FALSE	FALSE
15	$5,087.40	FALSE	FALSE
16	$5,341.77	FALSE	FALSE
17	$5,608.86	FALSE	FALSE
18	$5,889.30	FALSE	FALSE
19	$6,183.77	FALSE	FALSE
20	$6,492.96	FALSE	FALSE
21	$6,817.60	FALSE	FALSE
22	$7,158.48	FALSE	FALSE
23	$7,516.41	FALSE	FALSE
24	$7,892.23	FALSE	FALSE
25	$8,286.84	FALSE	FALSE

Table 4-Yearly savings (Energy, 2010)

Dairy farm

There are certain challenges associated with Mason's Dairy decision to convert to solar power being: geographic location, energy rate structure, and large initial investment. The location of Mason Dairy is one of its greatest assist, when cows are concerned. The dairy cow thrives in moderate to cool climates that are not subject to extreme weather conditions. The ideal location for implementing PV is a location that has long sunny days and minimal clouds. This will maximize the amount energy collected thus, decreasing the payback period. Figures 5 and 6 show the average days of sunshine and cloud cover, this will be a real challenge due to the long periods during the winter month that are prone to being sunless and cloudy.

The energy schedule is another challenge facing Mason Dairy, being a working farm producing product for sale it is required to pay for is power based off of the AG-VB rate schedule. In the terms of solar energy this is not most advantageous for Mason Dairy. The AV-VB is divided into "peak", "off peak", and "partial peak", the rate charged varies little between them. If Mason Dairy was allowed to switch to an alternate schedule like an A-6 schedule, which only has a "peak and off peak" rate the monthly savings would be greater and the payback period shorter. This is because the PV system is designed to offset the "peak" power, with the A-6 the peak power is much greater than the "off peak"; if "peak" was to be eliminated the dairy would only have to pay the inexpensive " off peak" price.

	AG-VB Monthly Energy Usage (Kw) w/PV			
Billing Month	**Total**	**Off-**	**Part-**	**Peak**
May	**1,720**	2,126	0	-406
Jun	**2,853**	3,095	0	-241
Jul	**2,587**	2,918	0	-331
Aug	**2,508**	2,773	0	-265
Sep	**1,693**	1,925	0	-232
Oct	**2,768**	2,828	0	-61
Summer Totals	**14,129**	**15,665**	**0**	**-1,536**
Nov	**2,906**	2,975	-69	
Dec	**2,731**	2,085	646	
Jan	**2,615**	2,039	576	
Feb	**2,590**	2,065	525	
Mar	**2,868**	2,065	803	
Apr	**2,732**	2,126	606	
Winter Totals	**16,443**	**13,356**	**3,087**	**0**
Totals	**30,572**	**29,021**	**3,087**	**-1,536**

Table 5- Break down on KWH divided into Off Peak/Peak/Partial Peak after the addition of PV power (Energy, 2010)

Table 6 shows the breakdown of

energy usage for a 12 month period, divided into “off-partical and peak” usage. Notice that with the addition of the PV the Peak kWh charges have been eliminated. Translating to an average of 36% saving each month.

Design

Mason Dairy will be using a “Single Line” system for installing PV, based on the recommendation of Electricraft, Inc**.** a general electrical contractor. The system will use 40- SolarWorld SW245 Mono modules, 20 Enphase micorinverters model D380, and a Power Rail top clamp mounting system.

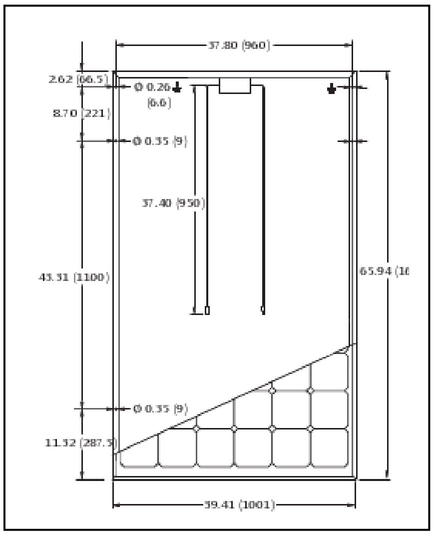

Figure 12- Diagram of Solar World SW 245 solar modules

The PV panel is outlined in Figure 12, These PV panels are constructed of Monocrystalline Silicon, incased in tempered glass and framed in aluminum. The PV panels measure 65.94 inches length, 39.41 inches width and weigh 48.5 lbs. All Solarworld products are made in the United States and have been awarded multiple times for quality (Soovajian, 2010).

The conversion form DC to AC power will be done by the Micro inverters, there will be one inverter per two PV panels as outlined in Figure 13. There was a choice to be made, whether to have one large inverter that could handle all the PV panels or to use micro inverters. On advisement from Electrocraft Inc, a system using micro inverters was decided on, because when PV panels are wired inline if one panel is not performing all others panels and total electrical output will suffer. As DC power flows through an array of PV panels toward a single inverter, it will be slowed or even stopped at a panel that is not performing. To avoid this micro inverters are placed between every two panels, limiting production losses.

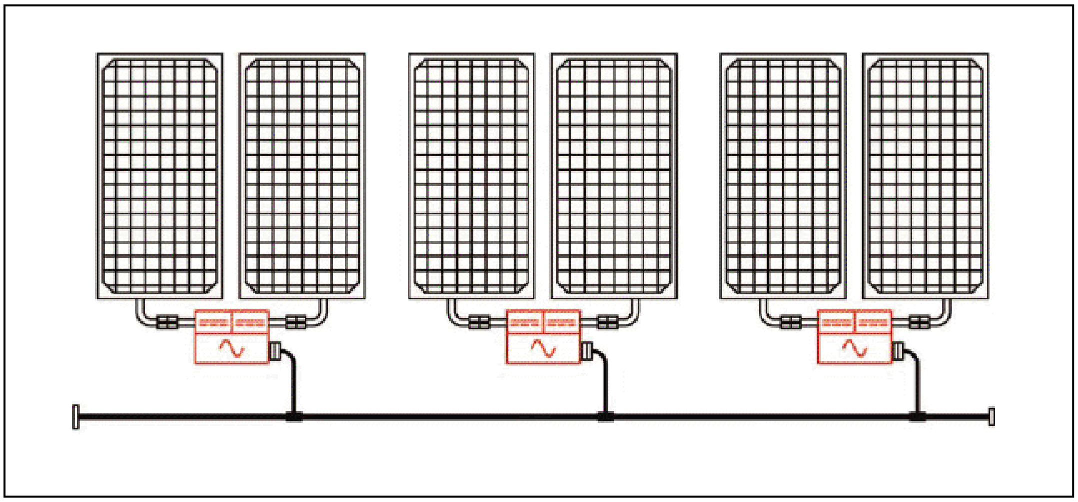

Figure 13- Basic Design of Solar system, two PV panels sharing a common micorinverter (Soovajian, 2010)

The Power Rail mounting system is an integral component, ensuring that the PV array is positioned correctly and securely fastened to the roof. The system is made up from two rails that run the length of the arrays, along with channels designed to carry all the electrical wiring and grounds.

Cost

Table 6 shows an estimate for the installation of a 40 panel PV system including all parts and accessory, as well as installation. The total out of pocket cost of the system is estimated to be $53,233.07, this is only a estimate because the installation cost tend to vary from job to job and will only be known at the end of the project (Soovajian, 2010). From the total cost, a State Rebate can be deducted along with a 30% Federal Tax Credit, leaving an estimated final cost of 37,263.15.

Item	Cost	Watt
PEC System Components	$43,653.75	$4.45
Installation (Roof Mount to be field verified)	$12,500.00	$1.28
System Installed	$56,153.75	$5.73
State Rebate 2	($2,920.68)	
Installed after EPBB	$53,233.07	$5.43
30% Federal Tax Credit 3	($15,969.92)	
Total Net after Tax Credit 4	$37,263.15	$3.80

Table 6- Cost of PV system (Soovajian, 2010)

Internal rate of return (IRR)

Through the use of Microsoft's Excel it was determined that this project has an IRR of 6%. While this is not the most promising IRR, it is important to remember that it is not zero and it's positive. Projects with zero or negative IRR have no possibly of a return or will even cost money. Also the lower the IRR the smaller the margin of error is, meaning that if installation cost increase or there is an unforeseen cost. It is encouraging to see that there is possibly to not only the investment back but, to make money on the project.

Risk

There are risks associated with any investment and these risks need to be identified and planned for. With solar panels two major risks have been identified. The first being installation costs and the second being performance of the system. Using Excel and the same function used to figure the IRR, the numbers were adjusted to reflect an increase in installation cost and a decrease in performance.

Referring back to Table 6 the installation costs were projected to be $12,500 dollars, this cost was doubled to $25,000 to simulate problems that can arise or delays is installation. The numbers were imputed into an excel function and a new IRR of 4% was determined.

	Quoted	Double Installation Cost	Quoted Installation with half yearly savings
Year	-56154	-68654	-56154
1	2569	2569	1285
2	2698	2698	1349
3	2833	2833	1416
4	2974	2974	1487
5	3123	3123	1562
6	3279	3279	1640
7	3443	3443	1722
8	3616	3616	1808
9	3796	3796	1898
10	3986	3986	1993
11	4185	4185	2093
12	4395	4395	2197
13	4614	4614	2307
14	4845	4845	2423
15	5087	5087	2544
16	5342	5342	2671
17	5609	5609	2804
18	5889	5889	2945
19	6184	6184	3092
20	6493	6493	3246
21	6818	6818	3409
22	7158	7158	3579
23	7516	7516	3758
24	7892	7892	3946
25	8287	8287	4143
IRR	6%	4%	1%

Table 7-Risk installation cost and PV performance (Soovajian, 2010)

A lower IRR was to be expected because of the increased to the total cost of the investment but, what was not expected was the minimal percentage drop effect when compared to PV performance. The same process was done for system performance, except the monthly savings from Table 4 was divided in half reflecting PV panel malfunctions or long periods without optimal sunlight. This new IRR was determined to be 1%, showing that the performance of the system has a greater affect on the success or failure of the project. These calculation are outlined in Table 7.

Conclusions

In conclusion, the addition of PV panels to a Mason Dairy Farm is a choice that must make some sense on paper, but more importantly it needs to make sense to the farmer. Entering into the project, it was known that solar power was not going to make Mason Dairy wealthy or even more profitable, but it is a choice Mason Dairy is making to move toward sustainability. Taking Mason Dairies mission statement and a desire to become more sustainable; investing in photovoltaics is the best way for Mason Dairy to utilize capital. Although it is understood there are investments which could bring a higher return on investment.

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