Alternative Energy Pros and Cons and How to Teach
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Abstract

Wind and solar energies are becoming viable alternatives for electrical energy production. Teaching such new subjects require sound technical and extensive practical background. There are many books and resources available for providing basic principles, formulas and overall understanding of the subject. However, in real world applications, basic understanding and limited technical background would not convince skeptical customers to spend revenue and financially support such activities. The initial cost of solar or wind power systems is high and prohibits an average customer to procure such systems. The impact of the high cost can be substantially reduced if proper incentives and tax breaks are implemented. The electric utilities are required to produce certain amount of their electricity from alternative renewable sources such as wind or solar. Majority of the utilities purchase electric power generated from wind or solar under the title of "Green Energy" to satisfy the quota mandated by the federal government. On the other hand, there are private entities interested in competing with utility companies in purchasing the "Green Energy" and provide fixed contract or competitive pricing per kWh of produced energy to the suppliers. A residence or a business with installed wind or solar system not only can benefit from producing its required energy but also can produce extra power and sell it either to utilities or third parties.

A balance between power rating, site selection and incentive calculation must be maintained to provide an optimum design for an alternative energy system.

This paper presents step-by-step calculation, code and ethical consideration, cost and incentive analysis to find the optimum design for a site. The students' participation in the installation and final commissioning of the project will be presented. This type of teaching prepares students for a complete project design, cost analysis, procurement, installation, codes and ethics, and commissioning of a project with a real world experience.

Keywords

Renewable Energy, design, incentives, student's involvement, industry partnership

Introduction

Renewable is a term applied to natural resources and refers to those resources that can be renewed or replenished in a short period of time. Renewable energy is also called "clean" or "green" energy because it does not pollute the air or harm the environment. As the demand for energy increases, renewable energy will play an important role in supplying the world'+s clean energy needs. Due to adverse effect of conventional fossil fuel and uncertainty in political stability of oil producing countries in Middle East, electric energy producers are looking into other alternatives for the electricity generation. A wide variety of alternatives such as wind,

solar, hydro, waves from sea or biomass are utilized to generate electricity. Private and public energy entities are leading the way in providing renewable energy. The five renewable sources used most often are: Biomass, Geothermal, Water (Hydropower), Wind, and Solar [1].

Biomass is the energy derived from plants and animals. Biomass comes in many forms, the most common being wood. Using the methane gas given off by landfills and animal waste is also becoming more common. Another increasingly popular form of biomass is in the form of biofuels such as ethanol and biodiesel, which is also derived from plants and animals [2].

Geothermal uses heat generated by the earth's interior. By drilling down into the Earth's crust, much like we drill for oil, we can use that heat to generate electricity. Geothermal is a good source for heating homes and buildings [3].

Water (Hydropower) - The energy contained in running water can be turned into electricity. Water, which is impounded or held behind a dam, is released through a turbine that spins a generator producing electricity [4].

Wind: As the wind blows it spins the large blades on a wind turbine and generates electricity [5].

Solar - The energy from the sun can be converted into heat and electricity. Sunlight can be captured using photovoltaic cells which convert the sun's energy into electricity. They are renewable and are great because they don't pollute and they provide energy from free, abundant resources. Currently only hydropower is widely used as an energy resource, while the other four types of renewable energy are not commonly used as primary energy sources. Reasons for their restricted use include the cost of specialty materials (e.g. photovoltaic panels are expensive to produce) and the fact that it can be difficult to distribute the power they generate [6].

Wave or Tidal - This energy from wave or tidal is converted into electricity in two ways: by dams that force water through turbines at high and low tidal stages, and by underwater turbines activated by tidal flows. There are several alternative sources of energy that can be tapped and utilized for electricity production. The determining factors for utilization of these alternative sources are their availability, locations and difficulty of energy harnessing.

In the following a comparison of electric energy productions in the United States for years of 2000 and 2015 are given. The percentage of total annual electricity production for years 2000 and 2015 and the contribution from each source is shown in Table 1. It can be noticed that the electricity production from the wind energy increased by more than 31 times, from the solar energy more than 48 times while the contribution from coal and oil reduced during this period [7].

Table 1 Percentage of Electric power production for different fossil and renewable sources

Year	Coal	Oil	Gas	Nuclear	Hydro	Geothermal	Solar	Wind	Wood	Bio
2000	51.3	2.9	16	19.7	7.2	0.37	0.013	0.15	1.0	*0.9*
2015	33.17	.69	27.87	19.5	6.14	0.41	0.63	4.67	1.03	*0.51*

Table 2 shows the actual electric power production from different sources for years 2000 and 2015.

Table 2 Electric power production for different fossil and renewable source (Twh)

Year	Coal	Oil	Gas	Nuclear	Hydro	Geothermal	Solar	Wind	wood	Bio
2000	1,966	111	615	754	260	14	0.49	5.6	37.6	23
2015	1,356.06	28.44	1,348.03	797.18	251.17	16.77	797.18	251.17	16.77	21

The above two tables demonstrate the growth and viability of wind and solar energy for electricity production. Students who take alternative energy courses must learn the technical principles as well as financial aspects of an alternative energy to be able to practically implement such a system. The purpose of this paper is to show step-by-step method of calculating and implementing an alternative energy project. Students are required to perform calculation, computer simulation, procurement, installation, incentive calculation, and commissioning of a real-world alternative energy project. With this approach not only technical principals are delivered but also a complete project execution will be experienced by students as well. Teaching a course with this method requires close collaboration of the instructor with students, industry, contractors and permission of the customers.

Project Description

This is an actual Solar Power System project for a 2900 ft^2 residential building located in Downers Grove, Illinois with students' involvement from beginning to the end. The objectives of this project are to:

- Design
- Perform cost evaluation
- Perform incentive calculation
- Perform payback calculation

In order to design a proper Solar Power System for this facility, the following steps must be taken.

1. Determine the loads and their total kW to be fed from the Solar Power Systems.
2. Determine the Irradiation $[W/m^2]$ for City of downers Grove, IL USA.
3. Determine the optimum angle for solar panels.
4. From a catalog select the proper solar panels for the $10kW$ solar power systems.
5. Select Controller, Inverter and other necessary hardware.
6. Calculate the federal and SREC incentives.
7. Calculate the payback.

The loads, quantities and their power requirement (Watts) and total energy requirement (Wh) for this project are shown in Table 3.

Table 3 Appliance and Lighting Power Needs for a 2800 ft² House in Downers Grove Illinois

Appliance	No.	Watts	Hours of usage/day	Total wattage [Wh]
Window fans	2	55	6	660
Microwave oven	1	750	0.5	375
Laptop	2	50	4	400
Refrigerator(after allowing for the recirculation, maintenance of interior temperature)	1	330	5	1650
Television	2	133	3	798
Vacuum cleaner	1	1000	0.5	500
Water heater	1	4500	0.25	1125
Clothes washer	1	350	0.2	70
Clothes drier	1	1800	0.2	360
Dish washer	1	1200	0.5	600
Lamp	4	40	5	800
				Total 7338 Wh

The above table does not indicate any Air-Conditioning system since it increases the size of the solar power system substantially and is only used during the summer time.

The calculated total energy requirement is $7.338\ kWh$. The layout of this house is shown in Figure 1.
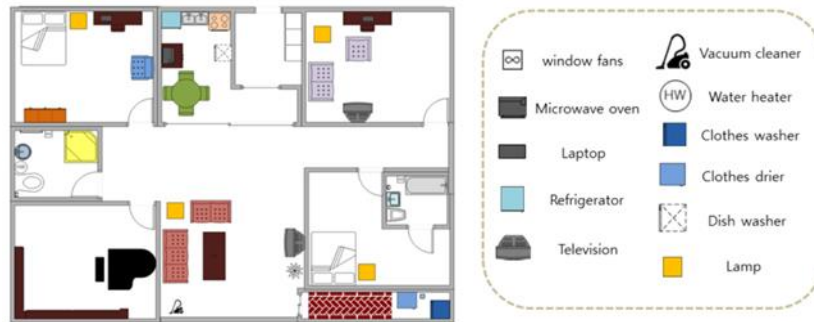

Figure 1: House Layout indicating electrical loads

Two types of solar power systems can be implemented. One system requires no battery and is directly connected to the grid and is referred to as Grid-tie type. The second solar system utilizes battery to store energy and usually is referred to stand-alone, Off-Grid or battery-backed system. The block diagram for both of these systems are shown in Figure 2.

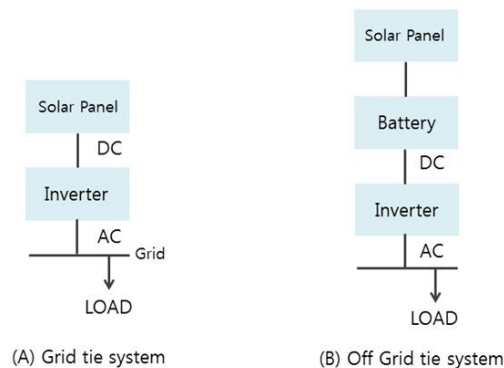(A) Grid tie system

(B) Off Grid tie system

Figure 2 Block diagrams for Grid-tie and Off-Grid Solar Power Systems

Grid-tie Systems are solar Photovoltaic (PV) systems that only generate power when the utility power grid is available. They must be connected to the grid to function. These are the simplest systems and the most cost effective and easiest to install. A safety feature implemented in the Grid-tie system prohibits the power delivery from the solar panels to the grid during a grid outage to protect the utility personal during the outage repair.

Off-Grid System allows the energy to be stored into batteries for use when the grid power is not available or if it is used as stand-alone without grid connection. The panel size for battery backed system must be slightly larger than the grid-tie system to compensate for the inefficiencies of the battery system.

In case of a grid-tie system, the total requirement would be 5% more than the calculated wattage to account for the inefficiency of the inverter. The total power requirement for off-grid system would be 10% above the calculated wattage to provide 5% (for inverter) + 5% (for battery) inefficiencies.

The total energy requirement for this project is $7338 Wh$ or 7.338 kWh. For the grid-tie system, total energy requirement will be $7.338 + 7.338 \times 0.05 = 7.7049$ kWh. On the other hand, for the off grid type system the total energy requirement is $7.338 + 7.338 \times 0.05 + 7.338 \times 0.05$ or $8.071\ 8\ kWh$.

Majority of the residential and commercial projects use the grid-tie systems due to the cost and environmental impact and service requirement of the battery pack. This design will also utilizes the grid-tie systems.

The Irradiation $[W/m^2]$ for City of Downers Grove, IL USA can be found from different available online sites [8], as shown in Table 4. This table shows the values of Estimated and Measured Irradiation for City of Downers Grove, IL USA for different months of the year.

Table 4: Monthly-Average and Annual-Average Daily Global Irradiation Measured and Estimated in Downers Grove, IL

City		Monthly-Average												Annual
		1	2	3	4	5	6	7	8	9	10	11	12	Average
Downers Grove, IL	Estimated	2.29	3.15	3.87	4.72	5.12	4.87	3.97	4.05	3.86	3.28	2.27	1.96	3.62
	Measured	1.99	2.77	3.5	4.39	4.67	4.33	3.28	3.55	3.53	3.04	2.03	1.72	3.23

The average, peak and minimum values of Estimated and Measured Irradiation for this city are shown in Table 5.

Table 5 Average, Peak, and Minimum Estimated and Measured values for Irradiation for Downers Grove, IL

Irradiation	Average $[kWh/m^2]$	Peak $[kWh/m^2]$	Small $[kWh/m^2]$
Estimated	3.62	5.12	1.96
Measured	3.23	4.67	1.72

The $\left[kWh/m^2\right]$ should converted to $[W/m^2]$ using $\left[kWh/m^2\right] \times \frac{1000}{24} = [W/m^2]$ conversion formulae. Applying the above conversion method reveals the Irradiation value of 134 $[W/m^2]$.

The optimum angle for solar panels depends on latitude, local time, season of the year, and inclination of a collecting surface in the direction of the sun. Optimally adjusting the panel angle for different time of the day results the highest power output from the panel. In order to adjust the solar panel a tracking system is required. Tracking systems require power to operate that consequently causes the power output reduction. Furthermore tracking systems require periodic service and maintenance to operate properly. Dust, dirt and ice can cause the tracking system to fail [9]. However, the cost, reliability and complexity of such system limits it uses for most of residential and commercial applications. The calculation here will focus on a fixed angle design only. There are a variety of online sites which easily provide such a calculation [10]. The Solar Angle Calculator from solarelectricityhandbook.com site is used to determine the angle of the solar panels with vertical line.
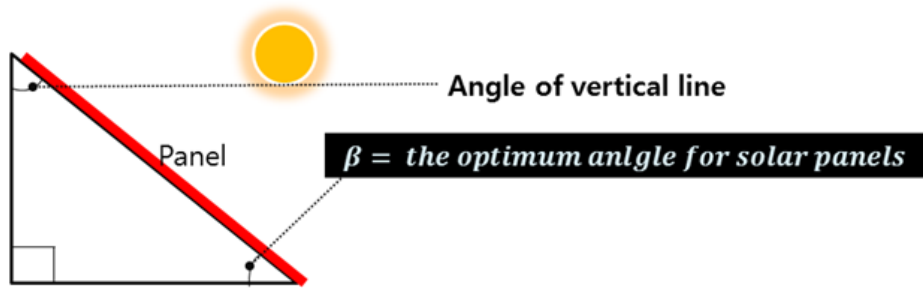

Figure 3 Optimum Solar Angle Arrangement for Solar Panel

Table 6 shows optimum angle of solar panel with vertical line in Downers Grove, IL by Month.

Table 6 Average Monthly Optimum Panel Angle with Vertical Line

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
36°	44°	52°	60°	68°	76°	68°	60°	52°	44°	36°	28°

Source: http://solarelectricityhandbook.com/solar-angle-calculator.html

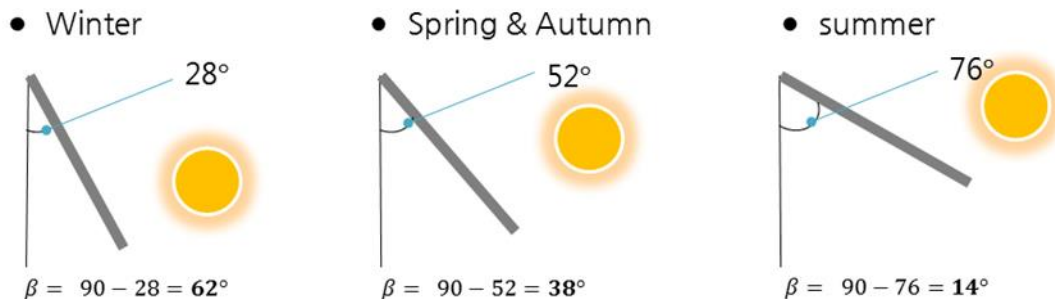The optimum angle differs depending on the time and season of the year.

Figure 4 Solar Panel Angle for different seasons of the year

Since summer daylight is long and winter daylight is short, the average value for the spring/autumn season is used to find the proper size of the solar panels for the project. The proper solar power system must be able to deliver 10 kW of power. From a catalog [11], the following panel is selected.

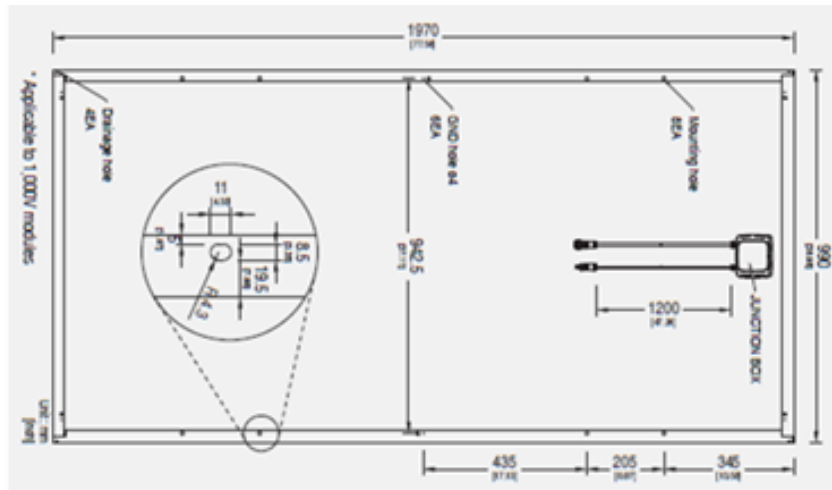| STC (Irradiance 1000W/m², module temperature 25°C, AM=1.5)	SN300P-10/15	SN305P-10/15	SN310P-10/15	SN315P-10/15
Rated Power (Pmax)	300W	305W	310W	315W
Voltage at Pmax (Vmp)	35.6V	36.0V	36.3V	36.6V
Current at Pmax (Imp)	8.44A	8.47A	8.54A	8.61A
Warranted Minimum Pmax	300W	305W	310W	315W
Short-Circuit Current (Isc)	8.88A	8.90A	8.96A	9.01A
Open-Circuit Voltage (Voc)	44.9V	45.1V	45.4V	45.6V
Module Efficiency	15.38% / 15.13%	15.64% / 15.38%	15.89% / 15.63%	16.15% / 15.88%
Operating Module Temperature	-40°C to + 85°C			
Maximum System Voltage	1000Voc (UL) / 1500Voc (UL)			
Maximum Series Fuse Rating	15A			
Maximum Reverse Current	20.25A			
Power Tolerance	0 ~ +5 W			

Figure 5(a) Electrical Characteristics

Figure 5 (b) Physical layouts

Among the type of panels, **SN315P-10/15** panel is selected since it delivers the highest power output per panel and rendering to a fewer number of panels on the roof.

Its irradiance is $1000^W/_{m^2}$ at the module temperature of 25°C, with Rated Power (P$_{max}$) of 315W. For 10 kW, it requires $\frac{10kW}{315W} = 31.74 = 32$ panels.

SN315P-10/15 panel size is $1.970 \times 0.990 = 1.95m^2$. Then, $32 \times 1.95 = 62.4m^2$ roof area is

needed. The south facing side of the roof area is measured 25ft x75ft (200 m^2) where sufficiently can accommodate the 32 panels. These panels are arranged as 2 rows of 16 panels as shown in figure 6.
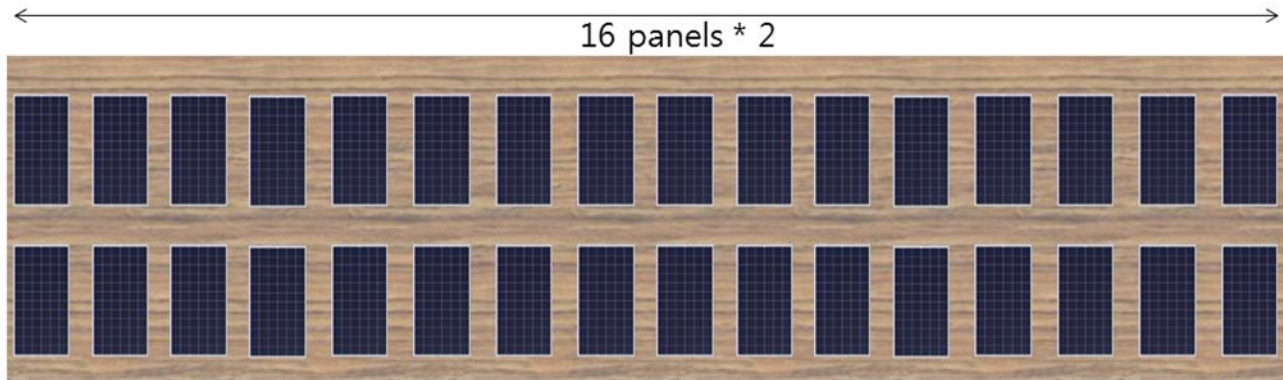

Figure 6 Panel Layout for the roof

Cost Calculation

The next step is to calculate the cost of the project. The total cost represents; labor and material cost. An engineering and architectural evaluation must be performed and proper city permits must be obtained to make sure the roof is structurally sound and is capable of handling additional load due to the installation of the solar panels. This introduces additional cost to the project. The material cost for each panel is $468 and that total cost is 32 × $468 = $14,976 ≅ $15,000 [11]. Three groups of disciplines must work to complete this project. Group 1 is to complete the roof installation of the panels, group 2 is to take care of all electrical wiring and installation and group 3 is to obtain all engineering and architectural approval and obtain the necessary permits to precede the work. These three groups and the hours needed to complete their tasks are shown in Table 7.

Table 7 Labor needed to complete the project

Group 01	2Day×4People×8Hours	64 man-hour
Group 02	4Day× 2People×8Hours	64 man-hour
Group 03	Engineering Permit	20 man-hour

The total man-hour required to complete the project will be 148 man-hours.
Considering $75/man-hour, the total labor cost is $11,100 ($75 x 148). The total cost of the project $26,100. This is the base cost and a 20% margin must be added. The project final cost to the customer will be $31,300. However the potential customer will receive some funding from federal subsidies, tax credit, and other available incentives that makes the proposed final cost substantially less than $31,300. In the following section, incentives, subsidies and tax benefits will be given.

Incentives and tax Calculation

Federal government provides certain tax credit for the one year. The customer can claim for this tax credit when filing for the federal tax. For 30% tax bracket the federal tax incentive will be $31,300 × 0.3 = $9,390. After first year, the consumer will be credited this amount which effectively reduces the price to $31,300 - $9,390 = $21,910.

Solar Renewable Energy Credit (SREC)

An SREC is a Solar Renewable Energy Credit. One SREC is created for every megawatt hour (MWh) of electricity produced by a solar generator. Keep in mind that SRECs are sold separately from the electricity they produce. In SREC state markets, the Renewable Portfolio Standard (RPS) requires electricity suppliers to secure a portion of their electricity from solar generators. The SREC program provides a means for Solar Renewable Energy Certificates (SRECs) to be created for every megawatt-hour of solar electricity created. To measure the SREC, a separate electric meter is installed for the produced energy from the solar power systems. This meter is shown in Figure 7a. The house is also equipped with a bidirectional electric meter as shown in Figure 7b.

1 SREC is $1 MWh$ of solar electricity. A $10 kW$ facility generates around 12 SRECs annually. SRECs are sold separately from the electricity. SREC price can range anywhere from $4 to $480 per SREC [12]. It is determined by market supply and demand mechanics. Facilities must be certified by a state to trade SRECs.

In the state of Illinois, the SREC is traded at $185/ MWh and $10 kW$ system can produce a peak value of $10 × 12 × 365 = 43,800$ kWh or 43.8 MWh. Usually, about 35% of this peak value is the annual solar energy production due to different hours of the day, shade, cloud, snow and so on. $10 kW$ solar power systems typically produce 15 SREC per year. SREC incentive will be $15 × $185/SREC = $2,775/year and contracted for 5 years.

Payback Calculation

In order to calculate the payback of this investment, the present value of the SRECs payment during the next five years at 2.5% interest rate will be calculated as follows:

P/A (2.5%, 5) = 4.64 × $2,775 = $12,876. Additionally there will be savings due to the elimination of the electric bill from the power company where can be calculated as 15 MWh/ at $0.1/kWh rendering to $1500 per year of saving. Table 8 shows, cost, tax incentives and final cost for this project.

Table 8 Cost, Tax Credit, Incentives and Final costs for an actual Project in Downers Grove, IL.

Initial Cost	$31,300
Federal Tax Incentive at 30%	-$9,390
SREC Incentive	-$12,876
Final Cost	$9,034

Simple Payback $= \frac{\$9034}{\$1,500} = 6$ years. After 6 years, the customer can save $1,500 per year.

Completed Project and Commissioning

A 10 kW solar power system project with the help of students was designed, calculatated, obtained all necessary certifications and permits, installed and commissioned. The students applied their acquired knowledge throughout the semester and performed an actual project for a customer. The students observed the electrical and solar equipment installations and interacted with contractors to gain additional knowledge through practice and experience. This project was feasible due to coordination with homeowner, solar energy contactor and electrical contractor.

Conclusion

A new method of teaching for alternative energy subject was presented. In this method students performed calculations, cost estimation, computer simulation, procurement, architectural and engineering evaluations, installation and commissioning of a real-world project. Implementation of this type of project requires close collaboration with industry, contractors and the customers. The instructor must coordinate all activities ahead of time and perform all scheduling, negotiation and follow all safety measures for students and involving crews. The advantage of this method of teaching is demonstrated through one semester of hands on and interaction by the students. The students' attendance, class participation and their preparedness are essential factors in the correct implementation of a project. This method requires a major preparation from instructor and collaboration with surrounding industries. Large class size, long distance from the project sites, travelling, lack of cooperation of students with each other and contractors can negatively impact the correct and efficient implementation of this method of teaching.

Figure 7 (a) Power Connection with SREC Meter   (b) Bidirectional House Electric Meter

Figure 8 (a) Workers Installing Solar Panels   (b) Monitor and Interface Box for Solar Power

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