Green Technology System for UiTM Pahang Farm Application

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ABSTRACT

Green technology or clean technology is the application of the environmental science to conserve the natural environment and resources and reduce the negative impacts of human activities to their surroundings. Hence, this study was carried out to investigate the feasibility and costs involved in applying green technologies for UiTM Pahang farm applications. In the study, only the application of a photovoltaic system was investigated. The total cost to build the full system of green technology was estimated for two potential areas; to support the requirement of maintaining 40 head goats and a sprinkler system for a 0.5-hectare vegetable garden. Based on the assessment conducted, the cost of energy for both systems based on duration of 20 years is RM 0.05/kWh and RM 2.84/kWh respectively. On the other hand, the capital cost to build the systems is calculated to be at RM 9,004.65 and RM 191,835.06 respectively. The results show that maintaining a vegetable garden is more energy intensive between the two activities, and high capital cost involved might be prohibitive. However, using a photovoltaic system to maintain goats is found to have a good potential.

Keyword: *green technology, UiTM Pahang farm, photovoltaic system*

Introduction

The availability of oil and gas resources in the next decades is increasingly questionable. There are conflicting estimates for production of the other two, oil and gas, with many industry experts predicting that it could peak before 2020, with discoveries less frequent, reserves being depleted rapidly, and world energy demand growing along with population growth. Global climate change caused by the relentless build-up of greenhouse gases in the earth's atmosphere, is already disrupting ecosystems and distributed the disaster through out the world. The solution to the future energy needs lies in greater use of renewable energy sources for both heat and power. These issues are major global environmental concerns that will causes disastrous impact on the socio-economic development in Malaysia (Lodhia & Zain-al-Abdin, 1999). However, these effects can be tackled and minimised by using renewable energy resource.

In Malaysia, the climatic conditions are favourable for the development of solar energy due to the abundant sunshine throughout the year. Malaysia is a tropical country where solar energy is available throughout the year with solar radiation in the range of 1419 to 1622kWh/m^2/year (Solar Radiation, 2008). The monthly daily solar radiation in Malaysia ranges from 4.0 kwh/m^2 to 5.0 kwh/m^2 with sunshine duration ranging 4 to 8 hour (Sopian, 1992). The yearly average of solar radiation in the Malaysia west coast was about 4.8 kwh/m^2 (Dalimin, 1995). The average solar radiation for the system design is 4.5 kwh/m^2. What this means is that the referenced titled surface will receive the equivalent of an average of 4.5 full sun-hours per day in a month

(Sandia, 2001). Under such a climatic condition, photovoltaic systems become another favourable and most promising renewable sources in Malaysia (Lim, Yun & Senga, 2008). Electricity produced by PV system is clean and silent. PV systems do not release any harmful air or water pollution into the environment, deplete natural resources, or endanger animal or human health (A. Rahman Mohamed & Lee, 2006). Naturally, the application of photovoltaic systems would have better prospect to overcome the energy problem of the future. Therefore, it is of relevance to assess the possibility of using PV system for UITM Farm application.

Methodology

PV systems produce power in proportion to the intensity of sunlight striking the solar array surface. The intensity of light on a surface varies throughout the day, as well as from day to day, so the actual output of a solar power system can vary substantially. There are other factors that affect the output of a solar power system. These factors need to be understood so that the consumer has realistic expectations of overall system output and economic benefits under variable weather conditions over time.

Solar modules produce dc electricity and rated by manufacturers under Standard Test Conditions (STC). These conditions are easily recreated in a factory, and allow for consistent comparisons of products but need to be modified to estimate output under common outdoor operating conditions. STC conditions are: solar cell temperature = 25°C; solar irradiance (intensity) = 1000 W/m^2 (often referred to as peak sunlight intensity, comparable to clear summer noon time intensity); and solar spectrum as filtered by passing through 1.5 thickness of atmosphere (ASTM Standard Spectrum). A manufacturer may rate a particular solar module output at 123 Watts of power under STC, and call the product a "123-watt solar module." This module will often have a production tolerance of (+10% / -5%) of the rating, which means that the module can produce 116.85 Watts and still be called a "123-watt module." To be conservative, it is best to use the low end of the power output spectrum as a starting point at 116.85 Watts for a 123-watt module (California Energy Commission, 2001). The number of solar panels can be determined by using equation 1 (Solar electric, 2007).

$$\text{No of module} = \frac{P}{H \times C \times A} \qquad (1)$$

where P is daily watt hour desire demand, H is PV available sun hour, C is the total net reduction factor, A is a module size in watt.

The batteries are based on the AGM UPG4D12 volt or 200 amp hours. While sizing the battery we assume at least 1 day of operation before the batteries need to be 50% recharged and discharged from full capacity. Performance of the battery greatly increases by not going below 50% charge. Storage capacity in Amp hours is

$$SC = \frac{E_B \times S_B}{V_{DC}} \qquad (2)$$

where SC is the capacity (Ah) needed, E_B is the energy (Wh) available for storage for 1 day, S_B is the period of storage required (in days) and Vdc is the required output DC voltage of the system. The number of batteries connected in parallel $N_{B,P}$ and in series $N_{P,S}$ were calculated as follows:

$$N_{B,P} = (SC \times 100\%)/(C_B \times D_B) \quad (3)$$
$$N_{B,S} = V_{DC}/V_B \quad (4)$$
$$N_{T,B} = N_{B,P} \times N_{B,S} \quad (5)$$

where C_B is the full capacity (Ah) specified for one battery, D_B is the maximum depth (in %) of charging and discharging cycles, V_B is the nominal battery voltage and $N_{T,B}$ is the total number of batteries needed.

Since the brighter the sunlight, the more voltage the solar cells produce, the excessive voltage could damage the batteries. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the solar array rises, the charge controller regulates the charge to the batteries preventing any over charging. In these task we are using Tri-Star versions TS-60 charge controller at rated solar current 60 A and at the voltage 24 V (store.solar-electric.com, 2007). The selection of charge controller derive based on the following equation.

$$CC = \frac{n_{module} A}{Vdc} \quad (6)$$

where A is the available module size in Watt, n_{module} is the n_{module} number of modules, and Vdc is the system power voltage.

Module output power reduces as module temperature increases. When operating on a roof, a solar module will heat up substantially, reaching inner temperatures of 50-75 °C. For crystalline modules, a typical temperature reduction factor recommended by the CEC is 89 % or 0.89. Dirt and dust can accumulate on the solar module surface, blocking some of the sunlight and reducing output. Although typical dirt and dust is cleaned off during every rainy season, it is more realistic to estimate system output taking into account the reduction due to dust buildup in the dry season. A typical annual dust reduction factor to use is 93% or 0.93.

The maximum power output of the total PV array is always less than the sum of the maximum output of the individual modules. This difference is a result of slight inconsistencies in performance from one module to the next and is called module mismatch and amounts to at least a 2% loss in power system. Power is also lost to resistance in the system wiring. These losses should be kept to a minimum but it is difficult to keep these losses below 3% for the system. A reasonable reduction factor for these losses is 95% or 0.95 (California Energy Commission, 2001).

The PV system design for garden application is due to requirements of 40 heads of goats that need 1200 liters of water for drinking, cleaning & washing. On the other hand, daily volume of 500 m^3 of water is required to irrigate the 0.5 hectare (4997.86 m^2) vegetable garden twice a day. Solar water pumping systems have been selected to satisfy the design requirement.

The PV System for DC Pump and Water Supplies (Domestic and Pen)

The solar pumping system has to pump the water from the well to a watering tank located approximately 20 linear m from and 30 m above from the well base. Water is to be stored in a large tank, usually set on a hill at a point that is high relative to other locations in the farm garden. Excess water is pumped to the tank to provide water when the pump is not available. The capacity of water tank is 7200*l* (1902.0gal) and the pressure require to lift the water from the well base to the tank (system reticulation) is 293711.4Nm^{-2}. To choose the right pump we need to consider the total vertical distance that water is to be pumped,(as measured from the lowest level from the water source to the highest level of the watering tank).

In this task we suggest to use the solar slow pump model 22214 slow pumps 2507-24 with the flow rate at 3.85gal/min at 30m height. The power will be generated by two 123-watt solar panels wired in series to produce a 24-volt system (store.solar-electric.com 2007). A 24-volt slow pump at 183.4Watt supplies approximately 3.85gallons per minute of water from the well up to the water tank.

The solar panels generate their maximum power for an average of 4.5 hours per day (common). Since the tank needs to be filled twice a day, the best duration to fill the tank is less than half of 4.5 hours for each cycle, for example, 2 hours. The Refill process must begin when the level of water in tank reach the certain volume or minimum level base on automatic system to turn the pump on and off. Wattage summation is 183.4 W and, therefore, the total daily Watt-Hour desire demand to operate the pump is 825.3Wh. From calculations, the proposed PV system should consist of 2 solar Photovoltaic panels, a 24-Vdc-rated charge controller, and a control panel. The project lifetime is 20 years and the interest rate is fixed at 4%.

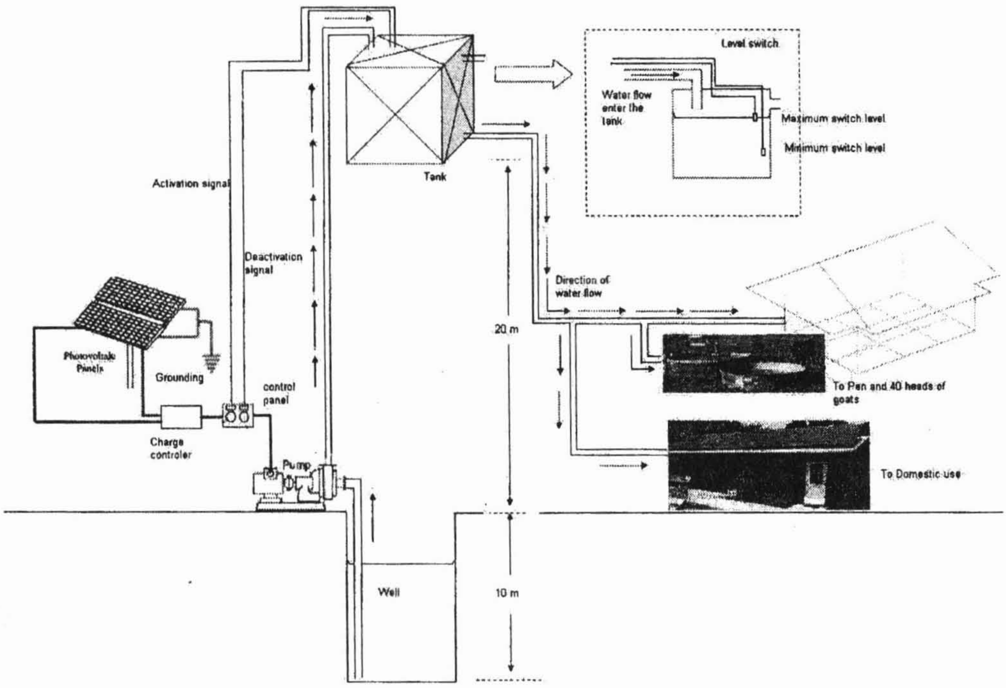

Figure 1. The Water Reticulation System

The Water Sprinkler System for 0.5 Hectare Vegetable Garden

A Solar pumping system is required to irrigate the 0.5 hectares vegetable garden at a volume 500 m^3. Solar Force Piston Pump can lift the water up to 900 feet at range 0.5 GPM up to 70 GPM. The total water suction obtainable from the 3 available pumps is 210 GPM. The system operating pressure was 55.03 PSI due to summation of the well depth and sprinkler pressure. In this system we use RHINO Model RH-2 sprinkler head at 29 PSI, radius 14.5 m with the rate flow 1.66 m^3/ hr. Although the projectile radius of the sprinkler is too long but we can reduce it by setting the sprinkler head without reducing the flow rate capacity.

Water sprinkler head operating pressure is 20.41 m and the dynamic water pressure is 10 m. System operating pressure (pressure pump require) is equal to Dynamic water pressure head plus water sprinkler head operating pressure, which is equivalent to 30.41 m or approximately 100 ft. The number of sprinkler head use is 28 round circle head at 29 PSI, setting radius is 11 m, with the water flow rate by 1.8 m^3/hr. The total of water flow rate come out from the sprinkler head is (number of sprinkler head required × the flow rate of the sprinkler) 46.48 m^3/hr or 204.6 gal/min. The 'duration of watering' is equal to the volume required for vegetable garden divide by total flow rate that comes out from sprinkler which is equal to 10.75 hour. Daily irrigation for the garden each time is 5.37 hours.

We use three Solar Force Piston Pump 3040 series 12 and 24 volt for battery systems with 735 W (1 HP) each. The daily watt hour desire demand is 23.68 kWh. The pump was powere by 58 module of 123 W solar panel based on equation 1. The system voltage selected was 24 Volt. We use 5 24-Vdc-rated charge controller at 60 amps configured in parallel. The system included 20 batteries of 12 V with the system voltage at 24 V due to configuration in series and parallel that produce 2000 Amp hours' bank capacities (solar-electric.com 2007).

During low solar radiation, 3 Solar Force Piston Pump 3040 series 12 and 24 volt for battery systems, directly provides reliable water supply for water sprinkler. The water supply is ensured by back-up batteries connected to the system via the charge controller. The system is connected as shown in fig. 2. Power will be provided by the solar panels wired to produce 24 Vdc (rated). Power from the solar panels will feed into a 24 Vdc charge controller, which will regulate the current fed to the batteries. From the charge controller, power passes into the battery bank, which consists of the number of batteries, wired in series to achieve 24 VDC (rated) output. Power is drawn from the battery bank and routed through a control panel. Control panel enables connection and disconnection of the DC voltage. Power is run from the control panel to the Force Piston Pump.

The Garden is to be watered twice a day; once in the morning and again in the evening, each for a duration of 5.37 hours. To automate the system we need to set the timer provided. When the end valve is opened due to timer setting, the pressure in the tank lowers due to the release of the stored water, and the minimum pressure switch activates the pump. The pump begins feeding water, the tank's internal pressure rises, but the pump does not stop. When the timer setting was ended, it sends the message towards control panel to switch off and deactivates the pump. The project lifetime is 20 years and the interest rate is fixed at 4%.

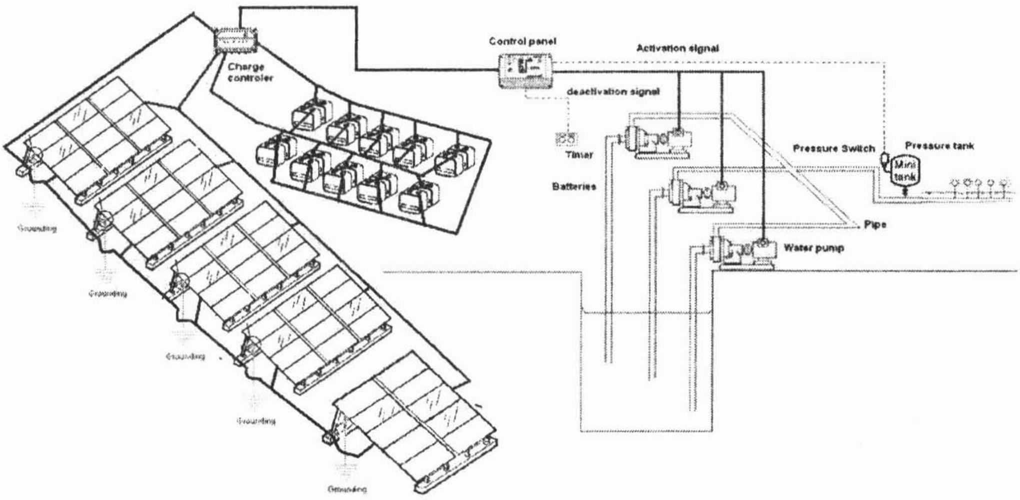

Figure 2. Water sprinkler system schematic

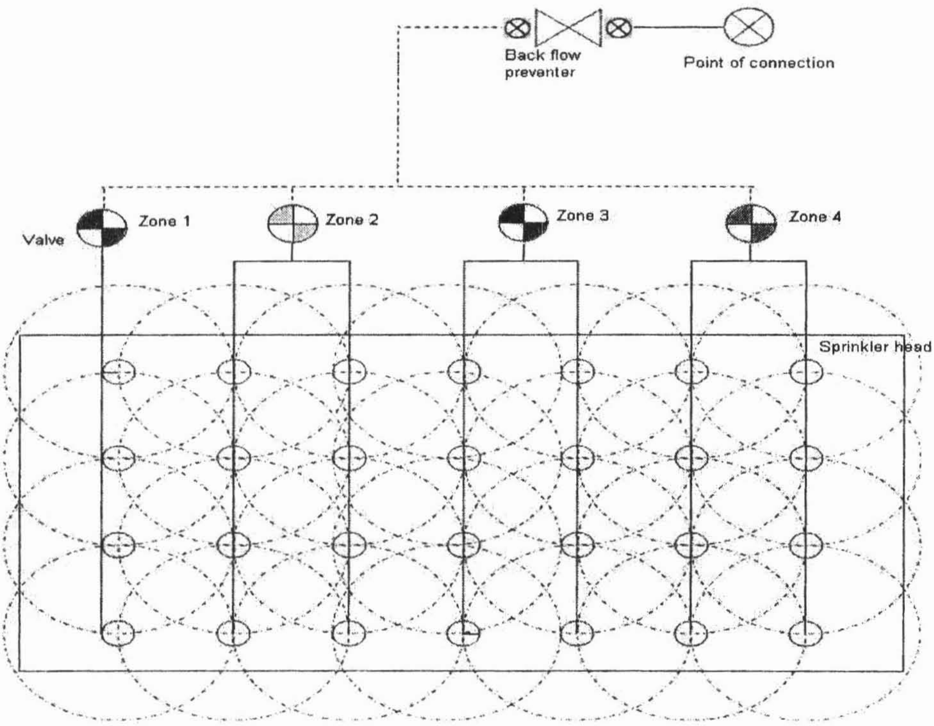

Figure 3. Water sprinkler piping diagram

Life Cycle Cost Analysis

Life cycle cost (LCC) analysis is an economic assessment of the cost for a number of alternatives considering all significant costs over the life span of each alternative. Adding each option's costs for every year and discounting them back to a common base (present worth). These costs can be categorised into two types: (i) recurring cost such as operation and maintenance PV system and (ii) non-recurring cost such as battery replacement cost. The conversion of recurring costs to present worth is as follows:

$$PWr = R\frac{\left[\frac{1+e}{1+i}\right]\left\{\left[\frac{1+e}{1+i}\right]^{n}-1\right\}}{\frac{1+e}{1+i}-1} \quad (7)$$

where i and e are the interest and escalation rate respectively. R is the recurring cost and n is the life span of the whole system. The conversion of non-recurring cost to present worth is as follows:

$$PW_{NR} = NR\frac{\left[\frac{1+e}{1+i_{adj}}\right]\left\{\left[\frac{1+e}{1+i_{adj}}\right]^{n}-1\right\}}{\frac{1+e}{1+i_{adj}}-1} \quad (8)$$

where i_{adj} the adjusted interest rate given as follows, P is the number of years between two successive payments nonrecurring costs NR

$$i_{adj} = \frac{(1+i)^{P}}{(1+i)^{P-1}} - 1 \quad (9)$$

The salvage value S expressed in present worth is given as follows:

$$PWs = S\frac{1}{(1+i)^{n}} \quad (10)$$

The total LCC may then be expressed as follows:

$$TLCC = C + PW_{R} + PW_{NR} - PW_{S} \quad (11)$$

where TLCC is the total life cycle cost and C is the initial (purchase and installation) cost. All the components in the above equation are expressed in their present worth.

The cost of energy for every kwh can be present as

$$COE = \frac{TLCC}{P_{out\,(LC)}} \quad (12)$$

$P_{out\,(LC)}$ is the $P_{out\,(LC)}$ life span power output produced by PV system and is computed using following equation:

$$P_{out} = A \times (T \times 365 \times P \times n) \qquad (13)$$

where, A is the Whole PV system size (kW), T is the period of sunlight in hour impiging on PV per day, n is the life span of PV system and P is the PV conversion factor (Christopher, 2003).

Table 2. PV system for water supplies (domestic & pen)

Item	Quantity	Cost (US $)	Total cost (US $)
o PV panel , Sharp ND-L3EJE 123 Watt	2	670.00	1340.00
o Solar slow pump model 22214 slow pumps 2507-24		475.00	475.00
o Control Panel	1	234.00	234.00
o Level switch	1	23.00	46.00
o Piping	2	500.00	500.00
		Cost Summation (US$)	2595.00
		Cost Summation (RM)	9004.65
The unit cost or purchase price of PV panel (RM/kWp)			36604.02

The cost of energy for the both PV system are shown in Tables 1 and 2 respectively. Table 1 is the Life Cycle Cost analysis (LCCA) of PV system for water supplies (Domestic & pen) due to combination of PV panels without batteries but the table 2 is the LCCA of PV PV system for water garden sprinkler. The Cost of energy for both systems in 20 years are RM 0.05/kWh and RM 2.84/kWh. Each result shows steady decrease of life cycle cost proportional to the increase of the PV system Life time.

Conclusion

From the calculation, the total cost of energy for both systems in 20 years for requirement of 40 head goat and to sprinkle a 0.5 hectare vegetable garden was estimated as RM 0.05/kWh and RM 2.84/kWh respectively. On the other hand, the capital cost to build the systems is RM 9004.65 and RM 191835.06 respectively. The results show that maintaining a vegetable garden is more energy intensive between the two activities, and high capital cost involved might be prohibitive in using photovoltaics in maintaining the vegetable garden. However, using a photovoltaic system to maintain goats is found to have a good potential.

As in all cases of photovoltaic applications, the high initial capital involved lessens their attractiveness compared to conventional systems. However, the more remote the locality, the higher the advantage of using photovoltaic systems due to their low maintenance and minimal impact on the environment. On the other hand, the cost of supplying electricity from the mains will increase with distance due to the high cost of cables. The application of other conventional systems such as diesel generators will involve high maintenance due to servicing costs and the need of regular supply of fuels. Diesel generators will also present air and noise pollution. In conclusion, the authors propose that the application of a photovoltaic system be used for maintaining goats in UiTM Pahang farm.

Table 3. PV system for water garden sprinkler

Item	Quantity	Cost (US)	Total cost (US)
o PV panel , 123 Watt	58	US $ 670.00	38860.00
o Charge controller, Tri-Star versions TS-60	5	US $ 187.48	937.40
o Batteries, AGM UPG4D12 volt	20	US $321.00	6420.00
o Pump	3	US $ 1436.00	4308.00
o Control Panel	1	US $ 234.00	234.00
o timer	1	US $ 50.00	50.00
o Pressure tank	1	US $ 300.00	300.00
o Pressure switch	1	US $ 23.00	16.00
o Sprinkler Head	28	US $ 15	420.00
o Piping		US $ 350	350.00
o Wiring		20 %	3388.48
		Cost Summation (US$)	55283.88
		Cost Summation (RM)	191835.06
The unit cost or purchase price of PV system (RM/kWp)			26890.25

Table 4(a). Life Cycle Cost Analysis for water supplies (domestic and pen)

Costing data considered in the study (1 US$=3.47 RM)	
PV size	246 kWp
PV capital cost	RM 9004.65
Reduction factor of PV system	0.75
Available Hour of solar radiation	4.5 Hours
Annual PV maintenance cost	3% of annualized PV capital cost
PV salvage value	10% of PV capital cost
PV life	20 years
Financial indicators	
• Interest or discount rate, *i*	4%
• Price escalation rate, *e*	8%
Life Cycle Cost	RM 0.05/kWh

Table 4(b). Life Cycle Cost Analysis for water sprinkler

Costing data considered in the study (1 US$=3.47 RM)	
PV size	7134 kWp
PV capital cost	RM 191835.06
Reduction factor of PV system	0.75
Available Hour of solar radiation	4.5 Hours
Annual PV maintenance cost	3% of annualized PV capital cost
PV salvage value	10% of PV capital cost
PV life	20 years
Battery capital cost for 12 V unit	RM 0.47/Wh
Nominal system voltage	240 V
Battery size for each unit	200 Ah, 12 V
Annual battery maintenance cost capital cost	15% of annualized battery
Battery life	5 years
Financial indicators	
• Interest or discount rate, *i*	4%
• Price escalation rate, *e*	8%
Life Cycle Cost	RM 2.84/kWh

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