**CACHE Modules on Energy in the Curriculum**

**Energy Topic: Solar Energy**

**Module Title:** Output and savings from Solar panel installation

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**Key concepts:** Power output, electricity consumption, interest over deposit.

**Introduction:** The cost of a solar panel lies in the range of $200/panel to $400/panel depending upon the power output of the panel and the material it is made from. The entire kit for solar energy utilization includes components like batteries, AC-DC converters, wires, mount racks etc. depending upon off-grid or grid-based utility. It costs about $15,000-$40,000 for providing energy equal to the national monthly household average electricity usage of 948 kW-hr through such installation. Before investing, it is always better to perform an economic analysis of your investment. This module will help you to calculate the power output, determine whether investing in installation is better than that in a certificate of deposit and find the payback period of your investment.

**Problem Statement:**

1) Assuming an illumination of 5 hrs of sunlight per day and a monthly consumption of 948 kW-hr, calculate the number of panels required and compare the prices for the following panels and tell which is cheaper to suffice the average monthly consumption.

a)140W , $210/panel b)240W, $260/panel

Formulae: To calculate the number of panels required, we would have to find the total output given by a single panel in kW-hr per month assuming an illumination of 5hrs per day.

$Total output per panel =Output in Watts per panel×10^{-3}×5\frac{hr}{day}×30days$ (Eq.1)

For an average monthly consumption of 948kW-hr,

$Number of panels required= \frac{Electricity Consumption}{Total output per panel}= \frac{948}{Total output per panel}$ (Eq.2)

To find the total cost of panels we can use,

$Total cost of panels=Number of panels required ×Cost per panel$ (Eq.3)

Solution:

a) Using eq.1,

$$Total output per panel =140\frac{W}{panel}×10^{-3}×5\frac{hr}{day}×30days=21\frac{kW-hr}{panel}$$

Using eq.2,

$$Number of panels required= \frac{Electricity Consumption}{Total output per panel}= \frac{948}{Total output per panel}$$

$$=\frac{948 kW-hr}{21kW-hr/panel} =45.142≈46 panels$$

Using eq.3,

$$Total cost of panels=46 ×\$210=\$9,660$$

b) Solve on your own.

2) Find the total electricity cost a solar panel installation would save in 3 years, if 20 solar panels of 240W are used. Take the cost per kW-hr to be $0.113 with an inflation of 2% per year and assume 5hr illumination per day.

Solution:

Assuming the installation to be 100% efficient, the amount of electricity saved would be equal to the electricity generated by the panels.

$Total output$ =

$$Number of panels×Output in Watts per panel×10^{-3}×5hrs×365days×3years $$

$$=20 panels×240 \frac{W}{panel}×10^{-3}\frac{kW}{W}×5\frac{hr}{day}×365\frac{days}{yr}×3 yr$$

$$=26,280kW-hr$$

The cost of electricity per kW-hr will be given by the relation:

$$C\_{n}=C\_{1}(1+i)^{n-1}$$

*n = number of years*

*i = percent inflation in decimals*

*Cn = Cost of electricity at nth year*

*C1 = Cost of electricity at year 1*

Year 1: Cost of electricity = $0.113 per kw-hr

 $Total cost saved$

$$=Cost of electricity per kW-hr×Total output of installation$$

$$=0.113\frac{\$}{kW-hr}×26,280kW-hr$$

$$=\$2,969.64$$

Year 2: $Cost of electricity$

$$C\_{2}=C\_{1}(1+i)^{2-1}=0.113(1+0.02)^{1}=\$0.115 per kW-hr$$

 $Total cost saved$

$$=Cost of electricity per kW-hr×Total output of installation$$

$$=0.115×26,280$$

$$=\$3,022.20$$

Year 3: $Cost of electricity$

$$C\_{3}=C\_{1}(1+i)^{3-1}=0.113(1+0.02)^{2}=\$0.118$$

 $Total cost saved$

$$=Cost of electricity per kW-hr×Total output of installation$$

$$=0.118\frac{\$}{kW-hr}×26,280kW-hr$$

$$=\$3101.04$$

$$Total amount saved in 3 years=Total cost saved in Year 1+Total cost saved in Year 2+Total cost saved in Year 3$$

$$=\$2,969.64+\$3,022.20+\$3,101.04$$

$$=\$9,092.88$$

Thus, installation of 20 panels of 240W power saves $9,092.88 in electricity costs in 3 years.

3) In problem 2, consider that the entire cost required for installing and running those panels (including other components like battery, racks, converters etc.) is $25,000. Would it have been beneficial to save the same amount in a bank for 3 years providing a compounded interest rate of 10% per year?

Given: The total amount including the interest over 3 years would be given by,

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| $$A=P\left(1+\frac{r}{M}\right)^{lM}$$*P = principal amount* *r  = annual rate of interest (as a decimal)**l**= number of years the amount is deposited or borrowed for.**A = amount of money accumulated after n years, including interest.* *M  =  number of times the interest is compounded per year* Solve on your own. 4) Find the payback period for the investment of $25,000 in problem 2 and compare it with lifetime of solar panel installation.Key relationship: a) In problem 2 we used the relationship $C\_{n}=C\_{1}(1+i)^{n-1}$ to find the cost of electricity in nth year and eventually we found out the total amount saved in n years. When finding the payback period, the total amount saved is equal to the investment and we have to find n given i=0.02.Let *I = the investment for which payback period is to be calculated.**W = total output of installation* $$\left(C\_{1}+C\_{2}+C\_{3}…………+C\_{n}\right)×W=I $$$\left[C\_{1}+C\_{1}\left(1+i\right)^{1}+C\_{1}\left(1+i\right)^{2}……+C\_{1}\left(1+i\right)^{n-1}\right]=\frac{I}{W}$ (Eq.A)$\left[C\_{1}\left(1+i\right)+C\_{1}\left(1+i\right)^{2}+C\_{1}\left(1+i\right)^{3}……+C\_{1}\left(1+i\right)^{n-1}+C\_{1}\left(1+i\right)^{n}\right]=\frac{I}{W}\left(1+i\right)$ (Eq.B)Subtracting Eq.A from Eq.B gives,$$\frac{C\_{1}\left[\left(1+i\right)^{n}-1\right]}{i}=\frac{I}{W}$$Rearranging this equation gives us,$$(1+i)^{n}=1+\frac{Ii}{WC\_{1}}$$$$log(1+i)^{n}=log\left(1+\frac{Ii}{WC\_{1}}\right)$$$$nlog(1+i)=log\left(1+\frac{Ii}{WC\_{1}}\right)$$$$n=\frac{log\left(1+\frac{Ii}{WC\_{1}}\right)}{log\left(1+i\right)} (Eq.4)$$Solution: Using eq.4,$$n=\frac{log\left(1+\frac{25,000×0.02}{26,280×0.113}\right)}{log\left(1+0.02\right)}=\frac{log\left(1+0.1683\right)}{log\left(1.02\right)}=\frac{log\left(1.1683\right)}{log\left(1.02\right)}=7.9 years$$Thus the payback period is 7.9 years for an investment of $25,000. A solar panel has a lifetime of 25 years which means the remaining years would lead to profits for the installer. |

Note that a simple estimate of the payback can be obtained (do on your own) by taking the $25,000  and dividing by the initial electricity cost of $2,970.