INFORMATION CIRCULAR

Date | Classification | Serial No.

13996

November 1974 | Public Health | 60

SOLAR ENERGY

Economic appraisal of a solar water heater

by

C. Richard
Public Health Engineer
South Pacific Commission

There are still too many people, particularly in the South Pacific, who do not believe that the various forms of natural energy can be effective.

And yet, this vast region of the globe is one of the best-placed in this respect. One can in fact only develop energy for domestic and industrial purposes if relatively abundant natural resources are available. The sun, water and tides - to mention a few - in conjunction with certain factors such as the nature of soils, their cover and morphology, may justify the manufacture of simple or complex equipment supplying low-cost energy.

As far as the islands are concerned, we are interested only in equipment that is easy to construct, operate and maintain.

Certain natural resources are found in several exploitable forms. Water may be used as found in rivers, lakes, the sea, or again in the form of rainfall or steam.

As for the sun, it supplies two essential elements: light and heat. These two elements vary considerably with the latitude and the altitude of the place concerned. In the South Pacific, they unquestionably are superabundant.

As regards the mean annual temperatures, two zones may be distinguished:

(1) The very hot zone: (minimum: 23°C - maximum: 30°C). Nauru, Wallis and Futuna, Western Samoa, Tokelaus, Gilbert and Ellice Islands, Trust Territory of the Pacific Islands (except the Marianas), American Samoa; and

(2) The hot zone: (minimum: 15°C - maximum: 28°C). New Caledonia, French Polynesia, Niue, Pitcairn, Norfolk, Tonga, Fiji, the Marianas, New Hebrides, Solomon Islands, and Cook Islands.

It may be noted that Papua New Guinea falls under both zones.

The time of exposure to solar heat is not recorded in all cases. But it is generally considerable. This should not be confused with the duration of sunlight, which depends essentially on the latitude of the place concerned. Finally, there is no problem nowadays in measuring the direct action of radiation and total radiation on the land surface.

Should one evaluate the radiation potential of the "earth-atmosphere" system after Remonieras (1960), it is accepted that an average of 43% of the solar radiation intercepted at the fringes of the earth's atmosphere is diffused towards the sideral spaces, making up "the albedo" of our planet. Of the remaining 57%, on a yearly average and for the earth as a whole:

- 12% is transformed into heat by the water vapour of the atmosphere;

- 5% is absorbed by Ozone, CO_2, dust and clouds; and

- 40% reaches the earth's surface, where it is partially absorbed, reflected or diffused upwards.

The term "solar constant" designates the radiant energy received per unit area of a surface, situated at the outer layer of the atmosphere, perpendicular to the sun's rays when the earth is at its mean annual distance from the sun (149.10^6 km).

According to Johnson (1954), the value of this constant is:

2 ± 0.04 calories per minute per cm^2;

i.e. 1,200 kilocalories per hour per m^2, or

1.39 kW per m^2.

The intensity of the "direct" radiation is reduced by 1.39 to 0.74 kW/m^2 but can, through "diffused radiation" or "radiation from the sky" increase by about 15%.

The measurement of solar intensity is effected by means of sunshine recorders or pyrheliometers, the sensitive element of which is usually a set of tiny thermo-couples grouped in series on a small "black surface" which is subjected to the radiation that is to be measured. Direct radiation is rarely measured. Observations generally involve "total radiation", but some stations in the South Pacific, better equipped than others, confine themselves to measuring the duration of insolation.

Appended hereto is a table summarizing in respect of all the territories:

Column 1 : Latitude

Column 2 : Daily duration (yearly average) of sunshine

Column 3 : Total radiation (June and December) in kW/m^2

Column 4 : Annual duration of insolation, in hours

Column 5 : Mean annual temperature in °C

Column 6 : Pattern of annual rainfall, in millimetres

Column 7 : Average number of rainy days in the year.

The information appearing in this table shows:

(a) that there is nowhere (except in Norfolk) a mean annual temperature below 20°C;

(b) that the total radiation, even in mid-winter, is rarely below 0.20 kW/m^2 (Norfolk);

(c) that the mean duration of insolation in each case is clearly above 2,000 hours/year;

(d) that the duration of sunlight per day is between 12 and 13 hours; and

(e) that it is countries with a high mean temperature (Equator) that have the highest mean number of rainy days.

There exist therefore all the conditions required to make the solar water heater a competitive proposition, especially in regions where the kWh of electric current is costly, because the power stations are generally small- or medium-sized thermal power stations requiring imported fuel, the cost of which is constantly increasing.

According to H. Tabor (Working Party on Solar Energy, UNESCO, Paris 27-29 June 1973), it is relatively easy to study the acceptable economic efficiency of a solar water heater as compared to that of an electric water heater with the same capacity.

The solar unit has collectors with a total area of Am^2, having a mean annual efficiency of E, and a storage reservoir. It generally has a thermostat actuating an electrical resistance if the current is available. One may assume that the cost of the reservoir and the electrical resistance is the same in both cases.

Where p is the price per m^2 of collector, the cost of a solar water heater is expressed as: $pA + a + b$

in which a = cost of installation and plumbing; and

b = cost of reservoir and electrical resistance.

Where J is the annual cost of the capital, interest and depreciation, expressed in fractions, the cost of the solar water heater system is expressed as follows:

$$J(pA + a + b) + cq + m$$

in which q is the electrical energy expressed in kWh for the supplement that is sometimes necessary, c the cost per kWh and m the annual cost involved in maintenance.

To determine the cost of a normal electrical system, it should be noted that the annual supply of heat per solar water heater is $EQ_aA + q$. In this expression Q_a is the total annual insolation expressed in kWh per m^2 and E is the average annual efficiency of solar energy recovered. To supply the same amount of heat through electricity one will have to spend:

$$(Jb) + c(EQ_a + q) + m_e$$

The first term represents the annual capital cost on the reservoir and the electrical resistance, and the last expenses involved in maintenance. The solar plant is economically feasible if:

$$J(pA + a + b) + cq + (m - m_e) < Jb + c(EQA = q)$$

or, after transformation:

$$J(p + \frac{a}{A}) < cEQ_a + (m_e - m)$$

This calculation has been made for the territory of New Caledonia on the basis of the following data:

$J = 1.19$

$p = A\$98$

$a = A\$241$

$A = 3\ m^2$

$c = A\$0.09$

$E = 0.85$

$Q_a = 2{,}400\ kW/m^2$

$m = A\$89.29$

$m_e = A\$26.79$

The result is A\$212.50 $<$ 262.85, i.e. viability of 23.7%.

It is also of interest to calculate, through a concrete example, the time needed for the amortization of a solar water heater as compared to an electric water heater.

We selected an electric 150-litre model which is priced in New Caledonia at A\$348, that we felt most comparable to a 180-litre solar water heater priced at A\$1026. The prices quoted involve cost of installation, plumbing, etc.

We assumed that the difference in cost price, i.e. A\$678 was invested at an interest of 9%, this contributing to lower the electricity bill in respect of the electrical model, by A\$61.07.

With regard to the consumption of electricity, we took into account any possible increase in charges for current: 7% per year. Maintenance costs were not taken into consideration.

The consumption of electricity for a solar model is about 10% that required by an electrical one, as per estimates valid for New Caledonia.

The curve described in the appended diagram shows that:

(1) the solar water heater proves to be economical from the 33rd month; and

(2) after 6 years, the savings effected make it possible to buy a second solar water heater.

It should also be noted that the savings concerned are even more considerable, since the 150-litre water heater may be paid for by three users, while the 180-litre one can be used by four people.

In a forthcoming circular, we shall consider how economical solar water heaters are in relation to fuel and gas models.

Territory	L	Duration of sunshine	"Total radiation"		T	Pattern of annual rainfall	Number of rainy days	Duration of insolation	Remarks
			June	Dec.					
	Degree	avg. hours	kW	kW	°C	mm	days	h/y	
Ellice Is.	8.31 S	12.25	0.25	0.33	28.1	3,864.1	n.d.	n.d.	(Funafuti)
Fiji	17.45 S	12.47	.0.22	0.36	25.4	2,066.2	n.d.	2,530	(Nandi)
Gilbert Is.	2.40 S	12.07	0.28	0.31	29.0	1,479.5	n.d.	n.d.	(Arorae)
Wallis	13.16 S	12.37	0.23	0.35	27.2	2,741.9	229	2,525	
New Caledonia	22.16 S	12.57	0.20	0.37	22.8	1,058.3	101	2,614	(Noumea)
New Hebrides	17.44 S	12.44	0.22	0.36	24.4	2,086.7	219	n.d.	(Vila)
Niue	19.02 S	12.53	0.23	0.36	24.9	2,101.9	n.d.	n.d.	
Norfolk	29.03 S	13.22	0.17	0.39	18.8	1,381.0	n.d.	n.d.	
Nauru	0.33 S	12.07	0.28	0.31	n.d.	2,236.0	n.d.	n.d.	
Ocean Is.	0.52 S	12.08	0.28	0.31	27.7	1,777.7	n.d.	n.d.	
Pitcairn	25.04 S	12.58	0.20	0.37	21.1	1,848.1	n.d.	n.d.	
W. Samoa	13.48 S	12.37	0.23	0.35	26.6	2,735.7	n.d.	2,575	(Apia)
Am. Samoa	14.20 S	12.39	0.23	0.35	26(?)	3,374.0	n.d.	2,335	
French Polynesia	17.32 S	12.47	0.22	0.36	25.3	1,609.5	104	n.d.	(Papeete)
Solomon Is.	9.52 S	12.30	0.25	0.33	26.6	2,097.0	n.d.	n.d.	
Tonga	21.08 S	12.57	0.20	0.37	24.4	1,927.4	n.d.	n.d.	
Caroline Is.	7.20 N	12.25	0.33	0.24	27.5	3,805.0	234	2,567	(Koror)
Guam/Mariana Is.	13.36 N	12.42	0.35	0.23	27.1	2,019.4	189	2,428	
Marshall Is.	7.05 N	12.30	0.33	0.24	26.8	3,747.7	223	2,489	(Majuro)
Cook Islands	21.12 N	12.57	0.20	0.37	23.7	2,118.9	n.d.	2,096	

Note: "n.d." = no data. Total radiation is a theoretical concept. It is in fact modified by microclimates and increased by diffused radiation and reverberation.

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