Usman Akram
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MENG-4349 – Introduction to Renewable Energy Systems

Module Title: Solar Thermal Energy

Assignment: Sizing Flat Plate Collector Panels for Residential Hot Water Load

Step 1: Calculate your daily household water heating load

[Volume of water (cubic meters) x Temperature rise x density of water x specific heat of water]

Volume of water (m^3) = 372.39 Gallons = $1.69\ m^3$ Density of water = $1000\frac{kg}{m^3}$

Temperature Rise = $T_h - T_c = (48°C - 6°C) = 42°C$ $C_p = 4.186\frac{J}{g°C} = 4186\frac{J}{kg°C}$

$$Q = \rho V C_p (T_h - T_c)$$

$$Q = 1.69\ m^3 * 1000\frac{kg}{m^3} * 4186\frac{J}{kg°C}(48°C - 6°C)$$

$$Q = 297649716\ J = \mathbf{82.6804766667\ kWh}$$

Step 2: Determine your locations 's average daily insolation and equivalent SRCC "Sky Type Category."

[Use the online Global Solar Atlas https://globalsolaratlas.info/map to determine average daily insolation. Type in the address of your location and determine DNI in kWh/m2 per day. Handy conversion: 1 kWh/m2/day = 317.1 Btu/ft2/day].

Woodlands, TX → $DNI = \mathbf{4.331}\ \frac{\boldsymbol{kWh}}{\boldsymbol{m^2}}\ \boldsymbol{per\ day} * 317.1 = \mathbf{1373.3601}\ \frac{\boldsymbol{BTU}}{\boldsymbol{ft^2}}\ \boldsymbol{per\ day}$

STANDARD COLLECTOR POWER OUTPUT (W)			
Based on Standard Rating Conditions (SRC) and mean temperature (T_m) in accordance with ISO 9806-2017			
T_m-T_a (°C)	**Blue sky** G_b = 850, G_d = 150 (W/m²)	**Hazy sky** G_b= 440, G_d= 260 (W/m²)	**Grey sky** G_b=0, G_d= 400 (W/m²)
-10	1375	973	**566**
0	1263*	861	**454**
10	1151	749	**342**
20	1039	637	**230**
30	927	525	**118**
40	815	413	**6**
50	703	301	**0**
60	591	189	**0**
* Peak Power, as defined by ISO 9806, under Blue Sky irradiance at T_m-T_a =0 and normal incidence.			

Table 1. Sky Type Category

According to the table above and in correspondence with collector performance data, the appropriate sky type will be **Hazy sky**.

Step 3: Categorize your climate.

[For all but the coldest locations in the United States, using the "C" category will give you a reasonable estimate.]

OG-100 STANDARD DAILY PRODUCTION TABLE							
Kilowatt-hours (thermal) per Collector per Day				Thousands of BTU per Collector per Day			
Climate → Category (T_i-T_a)	High Radiation (6.3 kWh/m²·day)	Medium Radiation (4.7 kWh/m²·day)	Low Radiation (3.1 kWh/m²·day)	Climate → Category (T_i-T_a)	High Radiation (2 kBTU/ft²·day)	Medium Radiation (1.5 kBTU/ft²·day)	Low Radiation (1 kBTU/ft²·day)
A (-5˚C)	7.93	6.13	4.34	A (-9˚F)	27.04	20.93	14.81
B (5˚C)	6.48	4.69	2.90	B (9˚F)	22.11	16.00	9.90
C (20˚C)	4.68	2.98	1.32	C (36˚F)	15.96	10.17	4.52
D (60˚C)	1.93	0.59	0.00	D (90˚F)	6.58	2.02	0.00
E (80˚C)	0.22	0.00	0.00	E (144˚F)	0.75	0.00	0.00

Using the "C" category which is considered for the Water Heating (warm climate) the Woodlands, TX DNI falls closest to Medium Radiation where the value will correspond to **2.98 kWh per panel per day** or **10.17 kBTU per panel per day**.

Step 4: Obtain collector performance data from the SRCC website and determine the number of collectors required.

[Choose a flat plate, glazed or unglazed collector: https://solar-rating.org/programs/og-100-program/ OG-100 CERTIFICATION PROGRAM. Hint: Assume system losses of about 20%] **Note: Attach the specification sheet of the collector you decided to choose]**

How much Energy is required?

$$= \frac{Load(Q)}{kWh\ per\ panel\ per\ day}$$

$$= \frac{82.6804766667\ kWh}{2.98\ kWh\ per\ panel\ per\ day}$$

$$= 27.75\ panels\ per\ day \approx \mathbf{28\ panels\ per\ day}$$

Below is the attached specification sheet for the Glazed flat plate and the pdf.

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https://solar-rating.org/wp-content/uploads/10002138.pdf