Renewable and Alternative Energies

Topic 2. Solar thermal energy project

Pablo Castro Alonso

Department of Electrical and Energy Engineering

- **Description:**
  - 5 floors. 40 homes (20 of 2 bedrooms and 20 of 3 bedrooms). Residential building in Valencia.
- **Objective:**
  - Design of an FPC installation on the building roof for Domestic Hot Water (DHW). Energy production and demand. Storage system volume.
  - Closed forced system.
- **Normative:**
  - Código Técnico de Edificación. Documento “Ahorro energía” (CTE-HE4) (09/2013).
  - Reglamento de instalaciones térmicas en los edificios (RITE) (09/2013).
  - Instalación eléctrica (REBT).
  - Normas UNE.

Geographic and environmental data

City	Valencia
Latitude	39.48°
Altitude. m	10
Minimum winter T. °C	0
Historical minimum T. °C	–8
Climatic zone	IV

	Water T	Ambient average T	Absorber average T	Incident solar radiation kWh/(m² · day)
Month	°C	°C	°C	
1	10	10.0	15	2.96
2	11	11.0	15	3.80
3	12	13.0	20	4.76
4	13	15.0	20	5.08
5	15	18.0	25	5.21
6	17	22.0	30	5.57
7	19	24.0	30	6.08
8	20	24.0	30	5.92
9	18	22.0	30	5.57
10	16	18.0	25	4.63
11	13	14.0	20	3.67
12	11	11.0	15	2.75

Technical specifications of the solar equipment

- **Ibersolar2122 Flat Plate Collector:**
  - Fluid capacity: 55 L/collector m^2.
  - Useful area: 2.16 m^2.
  - Efficiency: η = 0.72.
  - U: 4.5 $W/(m^2 \cdot K)$.
  - Position. Latitude: Φ = 39°48 N.
  - Orientation: South direction Z_s = 0°. Inclination β = 45° (used the whole year).
  - N° of collectors: 25.
  - T_{out}: 60°C.

Energy demand: 40 homes (20 of 2 bedrooms and 20 of 3 bedrooms)

- **Código Técnico de Edificación. Documento "Ahorro energía" (CTE-HE4. 4.1):**
  - Total people: 3 · 20 + 4 · 20 = **140**.
  - Average of daily consumption:
    140 · 28 · 0.85 = **3332 L/day**.
  - Solar minimum contribution: **50%**.

Tabla 4.2. Valores mínimos de ocupación de cálculo en uso residencial privado

Número de dormitorios	1	2	3	4	5	6	≥6
Número de Personas	1,5	3	4	5	6	6	7

Tabla 4.1. Demanda de referencia a 60 °C[1]

Criterio de demanda	Litros/día·unidad	unidad
Vivienda	28	Por persona
Hospitales y clínicas	55	Por persona
Ambulatorio y centro de salud	41	Por persona
Hotel *****	69	Por persona
Hotel ****	55	Por persona
Hotel ***	41	Por persona

Tabla 4.3. Valor del factor de centralización

Nº viviendas	N≤3	4≤N≤10	11≤N≤20	21≤N≤50	51≤N≤75	76≤N≤100	N≥101
Factor de centralización	1	0,95	0,90	0,85	0,80	0,75	0,70

Tabla 2.1. Contribución solar mínima anual para ACS en %.

Demanda total de ACS del edificio (l/d)	Zona climática I	II	III	IV	V
50 – 5.000	30	30	40	50	60
5.000 – 10.000	30	40	50	60	70
>10.000	30	50	60	70	70

Energy demand calculation

$$\dot{Q}_{needed} = c_p * \dot{m} * (T_{out} - T_{in})$$

Q_{needed}=$\dot{Q}_{needed}$ *nº days

c_p = 1kcal/kg.K

$\dot{m}$ = 3332 L/day

T_{out}= 60 ºC

1 kcal= 0.001162 kWh

Month	N° days	Water T_{in} (°C)	Energy demand Q_{needed} (kWh)
1	31	10	6006.430
2	28	11	
3	31	12	
4	30	13	
5	31	15	
6	30	17	
7	31	19	
8	31	20	
9	30	18	
10	31	16	
11	30	13	
12	31	11	

Energy demand calculation

$$\dot{Q}_{needed} = c_p * \dot{m} * (T_{out} - T_{in})$$

Q_{needed}=$\dot{Q}_{needed}$*n° days

c_p = 1kcal/kg.K

$\dot{m}$ = 3332 kcal/dia

T_{out}= 60 °C

1 kcal= 0.001163 kWh

Month	N° days	Water T_{in} (°C)	Energy demand Q_{needed} (kWh)
1	31	10	6006.430
2	28	11	5316.659
3	31	12	5766.173
4	30	13	5463.914
5	31	15	5405.787
6	30	17	4998.900
7	31	19	4925.272
8	31	20	4805.144
9	30	18	4882.646
10	31	16	5285.658
11	30	13	5463.914
12	31	11	5886.301

Energy production calculation

$$Q_{produced} = G_g - Q_{conv} - Q_{rad}$$

$$G_g = \eta * \text{Incident solar radiation} * S_{abs} * n^{o}\ days$$

$$Q_{conv} = U * (T_{absor} - T_{amb}) * S_{abs} * 60 * 60 * 24 * n^{o}\ days * 2.78x10^{-7}$$

$$Q_{rad} = \varepsilon_{abs} * \sigma * (T^4_{absor} - T^4_{amb}) * S_{abs} * 60 * 60 * 24 * n^{o}\ days * 2.78x10^{-7}$$

1 J= $2.78x10^{-7}$ kWh

U = 4.5 W/(m^2.K)

$\varepsilon_{abs} = 1$

$\sigma = 5.67x10^{-8}$

$\eta=0.72$

$S_{abs} = 2.16 * 25 = 54$

Month	N° days	Ambient T °C	Absorber T_{absor} °C	Incident solar radiation kWh/(m^2 · day)	Energy demand Q_{nedeed} (kWh)	G_g kWh	Q_{conv} kWh	Q_{rad} kWh	Q_{prod} kWh	% solar production
1	31	10.0	15	2.96	6006.430	3567.629	904.683	1061.155	1601.791	27
2	28	11.0	15	3.80	5316.659					
3	31	13.0	20	4.76	5766.173					
4	30	15.0	20	5.08	5463.914					
5	31	18.0	25	5.21	5405.787					
6	30	22.0	30	5.57	4998.900					
7	31	24.0	30	6.08	4925.272					
8	31	24.0	30	5.92	4805.144					
9	30	22.0	30	5.57	4882.646					
10	31	18.0	25	4.63	5285.658					
11	30	14.0	20	3.67	5463.914					
12	31	11.0	15	2.75	5886.301					

Energy production calculation

$$Q_{produced} = G_g - Q_{conv} - Q_{rad}$$

G_g= η ∗ Incident solar radiation ∗ S_{abs}∗ $n^{o}\ days$

$$Q_{conv} = U * (T_{absor} - T_{amb}) * S_{abs} * 60 * 60 * 24 * n^{o}\ days * 2.78x10^{-7}$$

$$Q_{rad} = \varepsilon_{abs} * \sigma * (T^4_{absor} - T^4_{amb}) * S_{abs} * 60 * 60 * 24 * n^{o}\ days * 2.78x10^{-7}$$

1 J= $2.78x10^{-7}$ kWh
U = 4.5 W/(m^2.K)
ε_{abs} = 1
σ = 5.67x10^{-8}
η=0.72
$S_{abs} = 2.16 * 25 = 54$

Month	N° days	Ambient T °C	Absorber T_{absor} °C	Incident solar radiation kWh/(m^2 · day)	Energy demand Q_{nedeed} (kWh)	G_g kWh	Q_{conv} kWh	Q_{rad} kWh	Q_{prod} kWh	% solar production
1	31	10.0	15	2.96	6006.430	3567.629	904.683	1061.155	1601.791	27
2	28	11.0	15	3.80	5316.659	4136.832	653.707	770.784	2712.341	51
3	31	13.0	20	4.76	5766.173	5737.133	1266.556	1549.046	2921.531	51
4	30	15.0	20	5.08	5463.914	5925.312	875.500	1081.825	3967.987	73
5	31	18.0	25	5.21	5405.787	6279.509	1266.556	1630.693	3382.259	63
6	30	22.0	30	5.57	4998.900	6496.848	1400.800	1887.547	3208.501	64
7	31	24.0	30	6.08	4925.272	7328.102	1085.620	1477.459	4765.023	97
8	31	24.0	30	5.92	4805.144	7135.258	1085.620	1477.459	4572.179	95
9	30	22.0	30	5.57	4882.646	6496.848	1400.800	1887.547	3208.501	66
10	31	18.0	25	4.63	5285.658	5580.446	1266.556	1630.693	2683.197	51
11	30	14.0	20	3.67	5463.914	4280.688	1050.600	1291.541	1938.547	35
12	31	11.0	15	2.75	5886.301	3314.520	723.747	853.368	1737.405	30

% solar yearly production = **54 %**

Heat storage system calculation

Código Técnico de Edificación
Documento "Ahorro energía" (CTE-HE4. 2.2.5)

$$50 < \frac{V}{A} < 180$$

V in L

A in m²

A = 54 m²

$\mathbf{V_{min}} = 54 \cdot 50 = 2700$ L.

$\mathbf{V_{max}} = 54 \cdot 180 = 9720$ L.

We choose a **3000 L** heat storage system.