HI-SMART

HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #4

CHAPTER 3: SOLAR THERMAL COLLECTORS – ENERGY OUTPUT CALCULATION

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SOLAR COLLECTORS – ENERGY OUTPUT CALCULATION

The purpose of solar thermal collectors is to provide heat for various purposes, which include space heating, DHW in buildings, pool heating and other. In Hungary the most widespread utilization is for DHW production. For DHW systems a simplified seasonal calculation can be done for residential buildings according to the following steps:

Determining the maximal solar collector output based on the solar collector type (flat plate / vacuum tube) and reference building floor area. The values are given inTable 4.3.1 and

- Table 4.3.2.
- Calculating the reduction factor for the actual orientation of the solar collectors. For determining the reduction factor Performance reduction factor (k) for solar collector systems can be taken from Figure 4.3.1 or can be calculated by using Equation 1.
- Calculating the solar collector system's yearly production and the solar fraction Equations 3 and 4.

Table 4.3.1. Maximal solar collector output for ideal placement of flat plate collectors ($Q_{coll,max}$)

$\left[\frac{kWh}{year}\right]$		Heated building area [m^2]														
		40	50	60	70	80	90	100	110	120	130	140	150	200	250	300
Gross collector area [m^2]	1,5	725	779	817	845	867	884	898	908	917	924	930	936	957	971	980
	2	844	944	1006	1053	1089	1119	1142	1160	1175	1187	1198	1207	1245	1268	1284
	2,5	911	1054	1159	1230	1283	1326	1362	1388	1411	1430	1446	1461	1517	1553	1578
	3	963	1123	1265	1373	1451	1510	1558	1595	1626	1653	1676	1696	1775	1826	1861
	4	1036	1224	1395	1547	1687	1796	1888	1948	1999	2043	2081	2115	2250	2337	2397
	5	1089	1295	1485	1661	1822	1971	2109	2206	2296	2367	2423	2472	2672	2803	2893
	6	1138	1349	1554	1745	1925	2093	2247	2377	2499	2599	2686	2765	3046	3227	3352
	7	1184	1398	1608	1813	2005	2187	2361	2502	2634	2758	2875	2979	3374	3610	3775
	8	1231	1445	1658	1868	2072	2264	2448	2605	2750	2883	3008	3126	3645	3956	4165
	10	1291	1539	1752	1968	2178	2387	2590	2762	2924	3077	3223	3360	4014	4518	4848

Table 4.3.2. Maximal solar collector output for ideal placement of vacuum tube collectors ($Q_{coll,max}$)

$\left[\frac{kWh}{year}\right]$		Heated building area [m²]														
		40	50	60	70	80	90	100	110	120	130	140	150	200	250	300
Gross collector area [m²]	1,5	904	982	1025	1057	1081	1100	1116	1127	1137	1145	1152	1159	1183	1198	1208
	2	1023	1166	1268	1326	1367	1399	1426	1446	1463	1477	1489	1500	1541	1568	1585
	2,5	1096	1279	1424	1539	1620	1668	1708	1738	1763	1785	1803	1820	1883	1924	1951
	3	1145	1356	1535	1681	1808	1902	1964	2006	2041	2071	2097	2119	2209	2266	2305
	4	1225	1454	1669	1875	2046	2196	2332	2432	2515	2579	2623	2661	2814	2912	2979
	5	1271	1532	1762	1980	2192	2390	2558	2693	2813	2927	3022	3101	3359	3506	3608
	6	1289	1581	1838	2069	2290	2504	2713	2883	3028	3164	3281	3392	3842	4053	4194
	7	1303	1603	1890	2144	2376	2599	2815	3002	3182	3345	3484	3617	4201	4554	4741
	8	1311	1619	1916	2199	2451	2683	2908	3101	3286	3463	3634	3790	4462	4963	5248
	10	1320	1639	1949	2248	2541	2813	3063	3270	3467	3655	3835	4007	4866	5525	6048

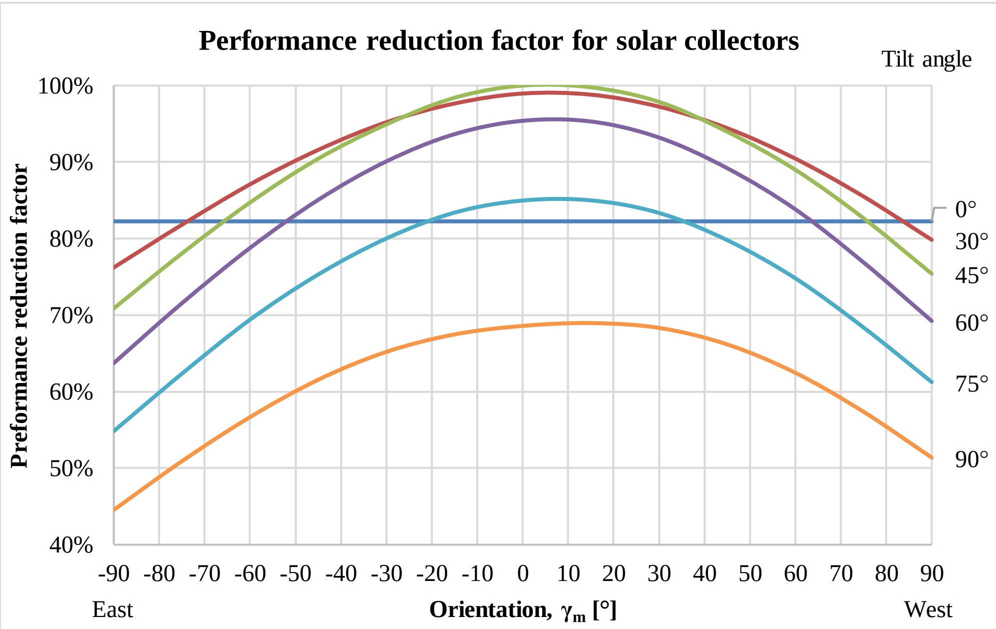

Figure 4.3.1. Performance reduction factor (k) for solar collector systems

$$k = (9.88 \cdot 10^{-9} \cdot \alpha_m{}^2 - 1.18 \cdot 10^{-6} \cdot \alpha_m) \cdot \gamma_m{}^2 + (-4.99 \cdot 10^{-8} \cdot \alpha_m{}^2 + 9.25 \cdot 10^{-6} \cdot \alpha_m) \cdot \gamma_m + (-1.17 \cdot 10^{-4} \cdot \alpha_m{}^2 + 9.11 \cdot 10^{-3} \cdot \alpha_m + 0.821) \quad 1$$

where,

α_m – is the tilt angle of the solar collectors [°]
γ_m – is the orientation of the solar collectors [°]

An exercise for the solar collector output calculation is shown in the following part. As an example a solar collector systems output shall be calculated for a single family house with the following parameters:

- Net floor area: 133 m^2
- DHW system parameters:
  - Secondary heat source: Condensing boiler: $C_k = 1.16$
  - Distribution losses: $q_{DHW,d} = 13\%$
  - Storage losses: $q_{DHW,s} = 23.4\%$
- Solar collector system
  - Flat-plate collector
  - 4 m^2 gross collector area
  - orientation, tilt angle: South, 30°

Firstly the maximal solar collector output has to be determined. The solar collector system has flat plate collector, thus Table 4.3.1 has to be used to determine the output for the system. Based on the gross collector area and the heated floor area, which equals the reference floor area the maximal collector output is 2043 kWh/yr.

The reduction factor can be calculated according to Equation 1 by using the 0° orientation (γ_m) and 30° tilt angle (α_m):

$$\begin{aligned} k = (9.88 \cdot 10^{-9} \cdot 30^2 - 1.18 \cdot 10^{-6} \cdot 30) \cdot 0^2 \\ + (-4.99 \cdot 10^{-8} \cdot 30^2 + 9.25 \cdot 10^{-6} \cdot 30) \cdot 0 \\ + (-1.17 \cdot 10^{-4} \cdot 30^2 + 9.11 \cdot 10^{-3} \cdot 30 + 0.821) = 0.98 \end{aligned} \quad (2)$$

Based on the maximal solar collector output and the reduction factor the solar collector system's output can be calculated according to the following equation:

$$q_{coll} = \frac{Q_{coll,max} \cdot k}{A_N} = \frac{2043 \cdot 0.98}{133} = \mathbf{15.05} \ \frac{\boldsymbol{kWh}}{\boldsymbol{(m^2 yr)}} \quad (3)$$

The solar fraction can be determined as a fraction of the solar collector production and the delivered DHW energy demand, which can be calculated as follows:

$$\alpha_{coll} = \frac{q_{coll}}{q_{DHW} \cdot \left(1 + \frac{q_{DHW,d}}{100} + \frac{q_{DHW,s}}{100}\right)} = \frac{15.05}{\frac{(80 \cdot 30 + 53 \cdot 15)}{133} \cdot \left(1 + \frac{13}{100} + \frac{23.4}{100}\right)} = \mathbf{0.460} \quad (4)$$

In this case the DHW heat demand, which has to be provided by the condensing boiler can be calculated and by taking into account the performance factor of the condensing boiler the final energy can be determined as well:

$$Q_{boiler} = q_{DHW} \cdot \left(1 + \frac{q_{DHW,d}}{100} + \frac{q_{DHW,s}}{100}\right) \cdot \alpha_{coll} \cdot C_{k,boiler} \cdot A_N = 24.0 \cdot \left(1 + \frac{13}{100} + \frac{23.4}{100}\right) \cdot 0.46 \cdot 1.16 \cdot 133 = \mathbf{2323}\ \frac{\boldsymbol{kWh}}{\boldsymbol{yr}} \quad (5)$$

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