Tilt, orientation and overshadowing of solar-collectors in the Netherlands

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39. TILT, ORIENTATION AND OVERSHADOWING OF SOLAR-COLLECTORS IN THE NETHERLANDS

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The results of our research on the above mentioned subject holds true for the Dutch winter season only.

It seems nevertheless worth while to present the results for an international forum, because we have not yet found a systematic approach to the problem of tilt, orientation and overshadowing in literature.

THE DUTCH CLIMATE

As was said above the results are of value for the Dutch situation and more especially for the site of the main meteorological station in *De Bilt* near *Utrecht.*

The latitude in *De Bilt* is 52°N.

The *tables 1* and *2* give information about the duration of sunshine and the radiation-energy during the heating season.

The altitude of the sun midday on the 21st of December is about 15° and on the 21st of June about 61°.

The mean monthly temperatures are given in *table 3*.

TABLE 3

Mean monthly temperature in °C 1931-1960. De Bilt

September	14.3
October	10.0
November	6.0
December	3.0
January	1.7
February	2.1
March	5.0
April	8.5
May	12.5

TABLE 1

Average percentage of sunshine according to Campbell - Stokes. 1931-1960. De Bilt

Hour	Sept.	Oct.	Nov.	Dec.	Jan.	Febr.	March	April	May
4-5									1.6
5-6								4.7	24.2
6-7	10.3	0.3					2.3	26.0	43.2
7-8	34.7	12.6	0.7			3.9	20.6	38.7	48.0
8-9	45.0	31.0	11.0	3.2	7.1	20.5	34.8	43.7	50.0
9-10	50.0	37.4	22.0	17.4	22.2	28.3	42.2	47.0	53.2
10-11	51.0	41.6	27.3	22.6	28.4	31.9	45.5	49.3	55.5
11-12	52.3	42.9	28.3	24.2	30.6	33.6	47.7	51.3	55.5
12-13	52.0	42.5	26.3	22.6	30.3	34.4	48.7	50.3	54.2
13-14	50.7	40.0	24.7	22.6	28.7	32.9	48.4	50.7	54.2
14-15	48.7	36.8	19.3	17.7	25.5	31.5	46.8	50.3	52.8
15-16	44.0	31.0	6.0	2.3	8.7	23.4	41.3	48.3	52.2
16-17	35.0	10.7				6.7	27.4	44.0	51.0
17-18	12.3						3.2	33.7	47.4
18-19								7.7	32.3
19-20									3.6

TABLE 2

Average total global radiation in J/cm². 1961-1970. De Bilt

Hour	Sept.	Oct.	Nov.	Dec.	Jan.	Febr.	March	April	May
4-5								0.4	5.2
5-6	2.1						0.2	7.8	26.0
6-7	18.5	3.1	0.1				5.6	31.7	58.1
7-8	48.8	20.2	3.1	0.2	0.1	4.8	26.4	64.7	93.6
8-9	83.8	45.5	17.3	5.6	5.7	23.3	54.5	75.5	126.9
9-10	109.7	69.9	33.5	20.8	21.0	47.0	80.2	121.5	155.1
10-11	128.6	86.2	46.7	33.4	37.1	67.1	100.7	137.3	172.2
11-12	137.9	90.7	51.0	39.9	46.1	78.2	109.9	149.6	180.4
12-13	135.4	90.2	48.7	38.9	47.1	79.9	109.5	146.9	176.7
13-14	122.2	80.0	38.3	30.4	40.8	71.4	101.1	140.0	165.1
14-15	103.8	59.8	23.3	16.3	26.4	55.6	84.7	121.0	147.3
15-16	75.3	33.9	7.8	3.7	10.3	32.4	62.3	95.0	121.5
16-17	43.2	10.1	0.5		0.8	10.5	34.7	63.4	91.1
17-18	14.7	0.7				0.7	10.2	32.5	56.7
18-19	1.2						0.4	7.8	25.2
19-20								0.3	4.2

THE APPLICABILITY OF THE RESULTS

Our research work has been directed to the use of solar energy for the heating season only.

Solar radiation in the summer months, that could be used for tap-water heating, for cooling, and for space heating with an energy-storage to bring solar energy from summer to winter, is not taken into account.

An energy-storage-vessel formed part of the installation. The size was 2,25 m³. It was connected to a collector of 30 m². This was enough to carry energy from sunny days to cloudy days in October and March and April, but in the midwinter months it's task was to bring solar energy from daytime to the evening only.

This is well illustrated by *figure 1*, taken from Report W.P.S. 3 - 76.11 R264, called « Het zonnehuis van de Technische Hogeschool Eindhoven » (in Dutch). This figure is based on a house with a heat-demand of 20 000 kWh per season, a collector of 50 m² and a storage-vessel of 5 m³.

The collector has been separated from the house. This was done because in changing the tilt of the collector as part of the house, c.q. part of the roof, one would change the design of the house. The heat demand of the house would change with the orientation of the front-facade. So even when the collector-orientation was changed, the house remained in a position in which it's front-facade was facing south.

THE DESIGN OF THE MODEL EXPERIMENT

Calculations were made of the net solar-heatgain with a computermodel that will be presented to this congress by Dr. M.H. de Wit.

In using this model one has to supply the computer with meteorological data. The so called reference-year for a heating season for the Netherlands was used for this purpose. It will be presented by Mr. R.J.A. van der Bruggen.

As heating season the period from 15 September to 15 May is used. But on the 1st of September the collector is set in operation. Solar-energy from the period 1 - 15 September is used to heat up the storage-vessel.

The meteorological data of the reference year supply us with solar-energy in the form of global radiation on a horizontal surface. These data have, for the period's of direct sunshine, to be split up in two parts, the direct- and the diffuse radiation. This is done with a formula based on information about these two forms of radiation over rather a short period. It may well be that this part of the work will have to be reviewed later. Where the sum of the two, the global radiation, is accurate, it is not felt that a later possible reveiwing will change the here presented results to an important extend.

The uncertainty in splitting up the global radiation was the reason for rounding off the percentages of loss in solar energy in comparison to the optimum solar heat-gain to the nearest full %.

The house used in the model was one out of a row of low-cost housing with a u-value of 0.8 W/m² °C for the wall's and double-pane windows. The ventilation rate was 1.

The heat-storage vessel was cylindrical in shape, as said above 2.25 m³ in size, 2.7 m in height.

The water in the vessel was stratified by temperature.

The collector circuit was pump-driven, commanded by a thermostat set at 1 °C difference in temperature between the top of the collector and the bottom of the storage.

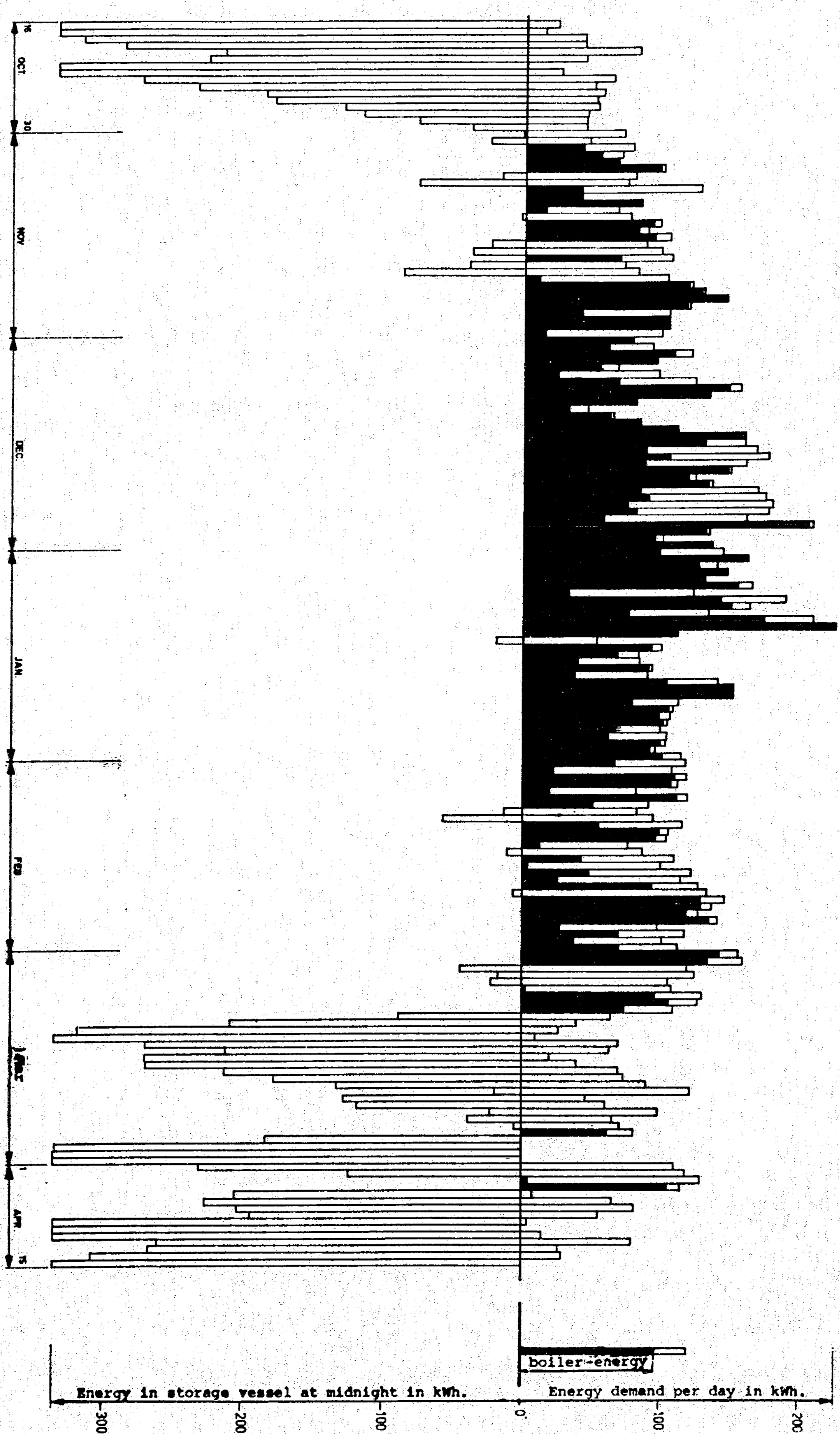

Fig. 1. — The cooperation of solar-energy storage vessel, and auxiliary-boiler in heating the solarhouse in Eindhoven

RESULTS

1. *The influence of the tilt of the collector.*

The following results were obtained in case of a collector facing South and without shadow (*table 4*).

TABLE 4

Slope of the collector	Loss in solar heat-gain in % compared to the optimum	Efficiency
0° (horizontal)	21%	0.79
35°	3%	0.97
45°	1%	0.99
50°	0%	1.00
52°	0%	1.00
54°	0%	1.00
56°	0%	1.00
58°	0%	1.00
60°	0%	1.00
70°	2%	0.98
90° (vertical)	11%	0.89
In all following results the slope will be 52°.		

2. *The orientation of the collector.*

The slope of the collector was 52°, there was no shadow on the collector (*table 5*).

TABLE 5

Orientation	Loss of solar heat-gain in % compared to a South-facing collector
SE (45°)	8%
SSE (22.5°)	1%
S (0°)	—
SSW (22.5°)	3%
SW (45°)	9%

Solar energy from the West is somewhat more absorbed in the atmosphere, perhaps because of a somewhat higher watervapour content in the afternoon. The difference between SSE and SSW is, however, exagerated by the rounding off to full percents.

3. *The shadowing.*

The following results were obtained for the situation of a collector facing South, with a slope of 52°.

The house was one in a street. The row of houses opposite the solar-house was endless to both sides, the East and the West. The ridge of the roof of the houses opposite to the solar-house had the same height above the streetlevel as the ridge of the collector-roof of the house concerned. The overshadowing angle is defined in *figure 2*.

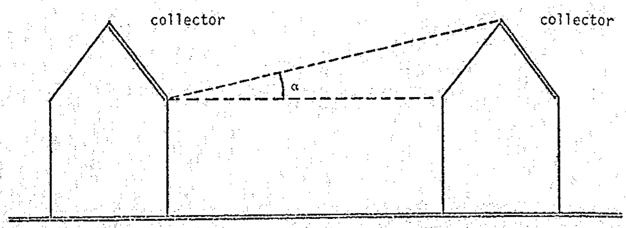

Fig. 2. — α = overshadowing angle

TABLE 6

Overshadowing angle	Loss of solar heat-gain in % compared to α = 0°	Efficiency
0°	—	
10°	0%	1.0
15°	1%	0.99
20°	5%	0.95

It was mentioned above, that the altitude of the sun in the Netherlands on the 21st of December at Midday was about 15°. If the overshadowing angle is 15°, this means that on the mentioned day and hour the shadow will just reach the lower-limit of the collector.

Where January is a month with only a small contribution to the solar-heat-gain there is practically no loss at this overshadowing angle.

Figure 3, shows the limitation in the use of the overshadowing angle. In the case of obstruction A the upperpart r-p of the collector will never be in the shade ; so table 6 holds true only for the lower part p-q.

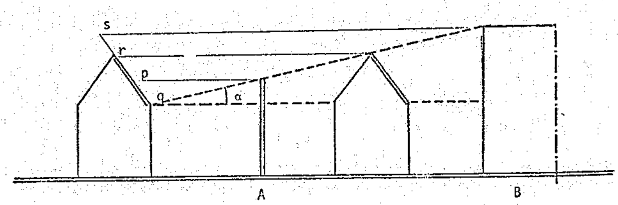

Fig. 3

The obstruction B however will have a greater effect than indicated in *table 6*. *Table 6* gives the situation for a collector q-s and of that collector the part s-r, with the smallest overshadowing is missing.

If we decide to limit the loss of efficiency to 5 %, i.e. an overshadowing angle of 20° the minimum acceptable width of an endless street with houses of the same size at both sides depends on the length of the collector. This is shown by *figure 4*.

With the collector in the roof (A) the minimum width is about 7 m. In the case of a design with a collector covering the roof and one floor (B) the minimum distance is 14 m, and in case the collector forms the frontfacade of the house (C) the minimum distance is nearly 20 m.

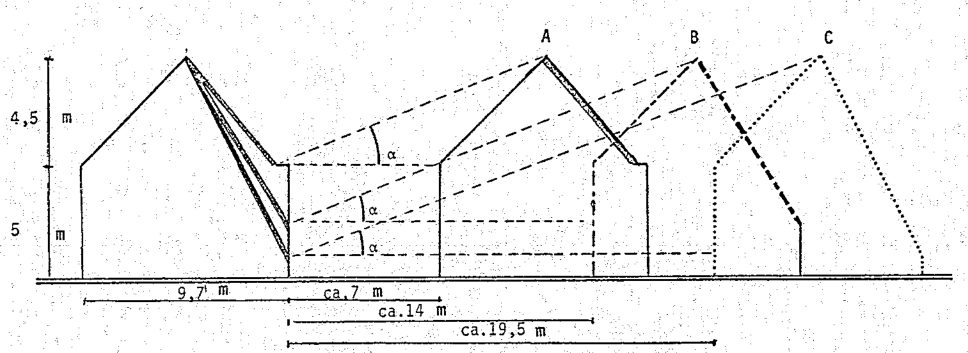

Fig. 4. — The influence of the length of the collector on the minimum acceptable width of a street in case on overshadowing angle = 20°

CONCLUSIONS

Although architects have a feeling that a solar house should be designed in such a way that it is different from normal houses, showing in it's form that it is a solar house, this is not necessary. If we take for example a house with a gable roof. The depth of the house is 10 m., the width is nearly 7 m. If we reserve a footpath of 1 m to reach the collector, this collector covers one half of 9 m. In this case a surface for the collector is available that is large enough for the collection of solar energy (See *table 7*).

In the Dutch climate where there is only a small amount a solar energy available in the winter season it seems to be necessary not to combine an overshadowing of say 20° with a collector facing S.W. and a tilt of 35°. One has to multiply the factors : 0.95 × 0.91 × 0.97 = 0.84.

A loss of 16 % could be corrected by a larger collector but this would make installations, that do not yet give a profit, even more expensive.

TABLE 7

Slope of roof	Height of roof	Roofsurface for collector	Efficiency	Minimum width of street $\alpha=15°$	$\alpha=20°$
35°	3.1 m	37 m²	0.97	6 m	3 m
45°	4.5 m	43 m²	0.99	12 m	7 m
50°	5.4 m	47 m²	1.00	15 m	10 m
55°	6.4 m	53 m²	1.00	19 m	12 m
60°	7.8 m	60 m²	1.00	24 m	16 m