



IGTE

**Institut für Gebäudeenergetik,
Thermotechnik und Energiespeicherung**
Forschungs- und Testzentrum für Solaranlagen (TZS)
Universität Stuttgart



Prüfbericht

Wärmeleistung eines Sonnenkollektors

Test Report
Thermal Performance of a Solar Collector

nach EN ISO 9806:2017
according to EN ISO 9806:2017

Prüfbericht-Nr.: 21COL1590OEM03
Test Report No.: 20COL1590OEM03

Stuttgart, den 03.11.2021
Stuttgart, November 3rd, 2021

Auftraggeber: <i>client:</i>	ECOFER OIKONOMOU Z. KOSTAS Xanthippou 150 15669 Papagou Athens Greece
Hersteller: <i>manufacturer:</i>	ECOFER OIKONOMOU Z. KOSTAS
Typ: <i>type:</i>	ECOFER SMARTEVO 20
Herstelljahr: <i>year of production:</i>	2021

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1 Beschreibung des Sonnenkollektors (gemäß Herstellerangaben) *Solar Collector Description (acc. to manufacturer)*

Hersteller <i>manufacturer</i>	ECOFER OIKONOMOU Z. KOSTAS Xanthippou 150 15669 Papagou Athens Greece
Ansprechpartner: <i>contact person:</i>	Zacharias Oikonomou Tel.: +30 2106715510 email: zachos@ecofer.com.gr
Typ: <i>type:</i>	ECOFER SMARTEVO 20 <i>ECOFER SMARTEVO 20</i>
Herstellernummer: <i>serial no.:</i>	k. A. <i>n. s.</i>
Serienprodukt oder Baumuster: <i>duplicate part or model:</i>	Serienprodukt <i>duplicate part</i>
Herstelljahr: <i>year of production:</i>	2021 <i>2021</i>

Kollektor *Collector*

Bauart: <i>collector type:</i>	Flachkollektor <i>flat plate collector</i>
Brutto-Kollektorfläche: <i>gross area of collector:</i>	2.02 m ² <i>2.02 m²</i>
Länge: <i>length:</i>	2006 mm <i>2006 mm</i>
Breite: <i>width:</i>	1007 mm <i>1007 mm</i>
Höhe: <i>height:</i>	85 mm <i>85 mm</i>
Gewicht: <i>weight:</i>	27 kg <i>27 kg</i>
Wärmeträgerinhalt: <i>heat transfer fluid content:</i>	1.6 Liter <i>1.6 litres</i>
Material Seitenwand/Rahmen: <i>material side wall/frame:</i>	Aluminium <i>aluminium</i>
Material Rückwand: <i>material back sheet:</i>	Aluminium <i>aluminium</i>
Verbindungsart der Rahmenteile: <i>frame fastening method:</i>	genietet <i>riveted</i>
Einbauweise: <i>collector mounting:</i>	Aufdach, Flachdach <i>On roof, flat roof</i>
Anzahl Anschlüsse: <i>number of connections:</i>	4 <i>4</i>
Ausführung Anschlüsse: <i>realisation of connections:</i>	22 mm Kupfer-Rohr <i>22 mm copper pipe</i>

Absorber

Absorber

Material: <i>material:</i>	Aluminiumblech mit Kupferregister <i>aluminium sheet with copper pipes</i>
Verbindung Fluidkanäle/Absorber: <i>bond between risers and fin/plate:</i>	lasergeschweißt <i>laser welded</i>
Dicke: <i>thickness:</i>	0.4 mm <i>0.4 mm</i>
Oberflächenbehandlung: <i>surface treatment:</i>	BLUE SELECTIVE <i>BLUE SELECTIVE</i>
Absorptionsgrad: <i>solar absorptance:</i>	0.95 <i>0.95</i>
Emissionsgrad: <i>emittance:</i>	0.05 <i>0.05</i>
Durchströmungsform: <i>flow pattern:</i>	Harfe <i>harp</i>
Abmessungen Absorber [L x B]: <i>dimension absorber [L x W]:</i>	keine Angabe <i>not specified</i>
Abmessungen Absorberrohre: <i>dimension absorber tubes:</i>	8.0 x 0.4 mm <i>8.0 x 0.4 mm</i>
Anzahl Absorberrohre: <i>number of absorber tubes:</i>	9 <i>9</i>
Länge eines Absorberrohres: <i>length of a single absorber tube:</i>	keine Angabe <i>not specified</i>
Abstand der Absorberrohre: <i>distance centre to centre between absorber tubes:</i>	95 mm <i>95 mm</i>
Länge eines Sammlerrohres: <i>length of header tube:</i>	keine Angabe <i>not specified</i>
Abmessungen Sammlerrohr: <i>dimension of the header tube:</i>	22 x 0.7 mm <i>22 x 0.7 mm</i>

Transparente Abdeckung

Transparent cover:

Anzahl: <i>number:</i>	1 <i>1</i>
Länge x Breite x Dicke: <i>length x width x thickness:</i>	keine Angabe <i>not specified</i>
Transmissionsgrad: <i>transmittance:</i>	0.91 <i>0.91</i>
Abmessungen Apertur [L x B]: <i>aperture dimension [L x W]:</i>	1941 mm x 942 mm (von Prüflabor bestimmt) <i>1941 mm x 942 mm (determined by test laboratory)</i>
Oberflächenstruktur innen/außen: <i>surface characteristics inside/outside:</i>	prismiert / klar <i>prismatic / clear</i>

Wärmedämmung

Thermal insulation:

	Rückseite <i>back side</i>	seitlich <i>at the side</i>
Material: <i>material:</i>	Glaswolle <i>glass wool</i>	Glaswolle <i>glass wool</i>
Hersteller: <i>manufacturer:</i>	Knauf <i>Knauf</i>	Knauf <i>Knauf</i>
Produktbezeichnung: <i>product name:</i>	keine Angabe <i>not specified</i>	keine Angabe <i>not specified</i>
Wärmeleitfähigkeit: <i>thermal conductivity:</i>	0.035 W/(mK) <i>0.035 W/(mK)</i>	0.035 W/(mK) <i>0.035 W/(mK)</i>
Dichte: <i>density:</i>	30 kg/m ³ <i>30 kg/m³</i>	30 kg/m ³ <i>30 kg/m³</i>
Dicke: <i>thickness:</i>	30 mm <i>30 mm</i>	15 mm <i>15 mm</i>

Grenzdaten

Limitations:

Stillstandstemperatur: <i>stagnation temperature:</i>	230 °C (von Prüflabor bestimmt) <i>230 °C (determined by test laboratory)</i>
maximale Betriebstemperatur: <i>maximum operation temperature:</i>	keine Angabe <i>not specified</i>
max. zulässiger Betriebsdruck: <i>maximum operation pressure:</i>	10 bar <i>10 bar</i>
Zulässiger Wärmeträger: <i>allowed heat transfer fluid:</i>	Frostschutz/Wasser-Gemisch <i>antifreeze/water mixture</i>
Nenndurchfluss pro Kollektor: <i>nominal flow rate per collector:</i>	keine Angabe <i>not specified</i>

Gültigkeit

Validity:

Der Prüfbericht ist gültig für den oben beschriebenen Kollektortyp ECOFER SMARTEVO 20.
The test report is valid for collector type ECOFER SMARTEVO 20 as specified above.

2 Prüfergebnisse Wärmeleistung

Test Results Thermal Performance

Spezifische Nutzenergie des Kollektors:

Specific useful energy extracted from the collector:

$$\dot{Q} = A_G \left[\eta_{0,b} K_b(\theta_L, \theta_T) G_b + \eta_{0,b} K_d G_d - a_1(\vartheta_m - \vartheta_a) - a_2(\vartheta_m - \vartheta_a)^2 - a_3 u'(\vartheta_m - \vartheta_a) \right. \\ \left. + a_4(E_L - \sigma T_a^4) - a_5 \left(\frac{d\vartheta_m}{dt} \right) - a_6 u' G - a_7 u'(E_L - \sigma T_a^4) - a_8(\vartheta_m - \vartheta_a)^4 \right]$$

mit/*with*

$$K_b(\theta_L, \theta_T) = K_b(\theta_L, 0) \cdot K_b(0, \theta_T)$$

	Einheit <i>unit</i>	Wert <i>value</i>	σ^*
Konversionsfaktor basierend auf der direkten Bestrahlungsstärke <i>peak collector efficiency based on beam irradiance</i>	$\eta_{0,b}$ [-]	0.739	0.002
Einfallswinkel-Korrekturfaktor für diffuse Strahlung <i>incidence angle modifier for diffuse radiation</i>	K_d [-]	0.978	0.005
Wärmedurchgangskoeffizient <i>heat loss coefficient</i>	a_1 [W/(m²K)]	3.387	0.056
temperaturabhängiger Wärmedurchgangskoeffizient <i>temperature dependent heat loss coefficient</i>	a_2 [W/(m²K²)]	0.009	0.001
windabhängiger Wärmedurchgangskoeffizient <i>wind speed dependent heat loss coefficient</i>	a_3 [J/(m³K)]	0	-
Faktor zur Berechnung der von der Himmelstemperatur abhängigen Strahlungswärmeverluste <i>factor for calculation of sky temperature dependent radiative heat losses</i>	a_4 [-]	0	-
effektive spezifische Wärmekapazität <i>effective specific thermal capacity</i>	a_5 [J/(m²K)]	9756	385
Koeffizient zur Berechnung der Windabhängigkeit des Konversionsfaktors <i>coefficient for calculation of wind dependence of zero loss efficiency</i>	a_6 [s/(m)]	0	-
Windabhängiger Strahlungsaustauschkoeffizient <i>wind speed dependence or IR radiation exchange</i>	a_7 [s/m]	0	-
Koeffizient zur Berechnung der Strahlungswärmeverluste <i>coefficient for radiation losses</i>	a_8 [W/m²K⁴]	0	-

* σ : Standardabweichung / *standard deviation*

Einfallswinkel-Korrekturfaktor der direkten Bestrahlungsstärke*Incidence angle modifier of the beam solar irradiance*

Einfallswinkel θ <i>incident angle θ</i>	0	10	20	30	40	50	60	70	80	90
$K_b(\theta_L, 0)$:	1.00	1.00	1.00	1.00	0.99	0.94	0.86	0.62	0.31	0.00
σ^*	-	-	0.00	-	0.00	0.01	0.01	0.01	-	-
$K_b(0, \theta_T)$:	1.00	1.00	1.00	1.00	0.99	0.94	0.86	0.62	0.31	0.00
σ^*	-	-	0.00	-	0.00	0.01	0.01	0.01	-	-

Maximale Temperaturdifferenz während der Prüfung

73 K

 $(\vartheta_m - \vartheta_a)_{\max}$:*maximum temperature difference during test $(\vartheta_m - \vartheta_a)_{\max}$:*

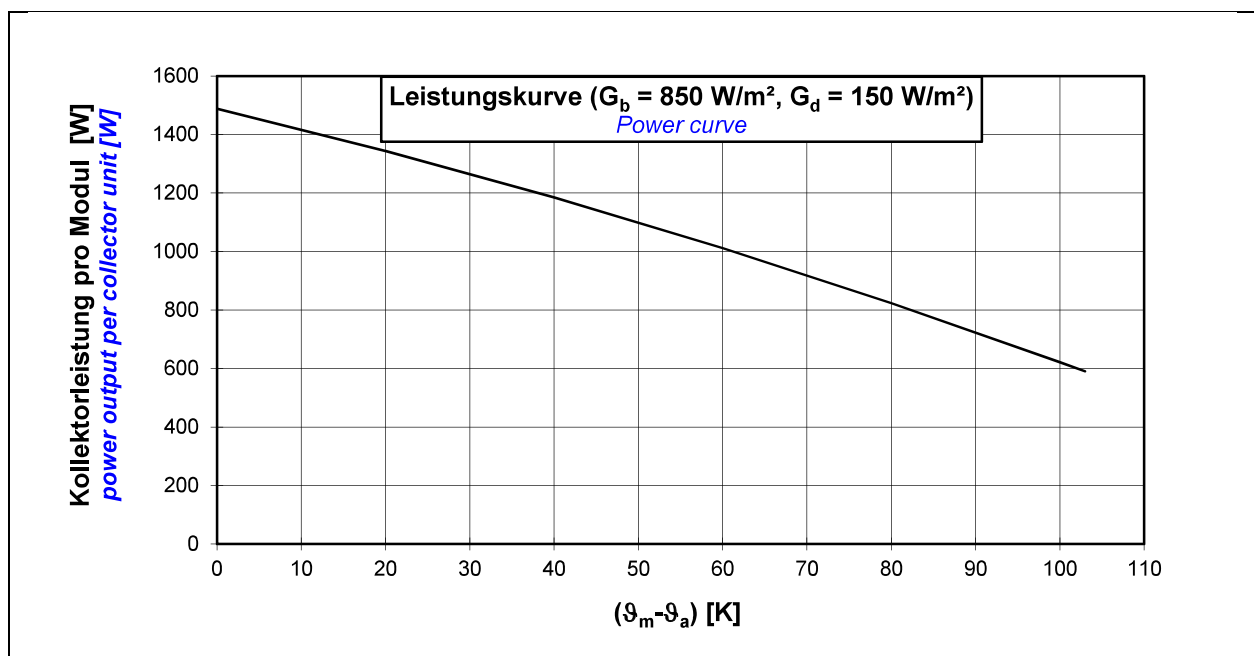
73 K

Peakleistung pro Kollektormodul $\dot{Q}_{\text{peak}}$

1488 W

 $(G_b = 850 \text{ W/m}^2, G_d = 150 \text{ W/m}^2, (\vartheta_m - \vartheta_a) = 0)$:*peak power per collector unit $\dot{Q}_{\text{peak}}$*

1488 W

 $(G_b = 850 \text{ W/m}^2, G_d = 150 \text{ W/m}^2, (\vartheta_m - \vartheta_a) = 0)$:

Kollektorleistung pro Modul [W]
Power output per collector unit [W]

$\vartheta_m - \vartheta_a$ [K]	Bestrahlungsstärke / <i>Irradiance</i>		
	$G_b = 0 \text{ W/m}^2$ $G_d = 400 \text{ W/m}^2$	$G_b = 440 \text{ W/m}^2$ $G_d = 260 \text{ W/m}^2$	$G_b = 850 \text{ W/m}^2$ $G_d = 150 \text{ W/m}^2$
0	584	1036	1488
20	440	892	1344
40	281	734	1185
60	108	560	1012
80	0 *)	373	824
100	0 *)	170	622
103	0 *)	139	590

Anmerkung: Die angegebenen Werte beziehen sich auf senkrechte Einstrahlung
Note: the reported values are for normal incidence

*) Die Kollektorleistung ist mit Null angegeben, da sich rechnerisch bei diesen Betriebsbedingungen eine negative Kollektorleistung ergibt.

**) Calculating the power output per collector unit under these operation conditions result in negative values. Therefore the calculated power output is indicated with zero.*

3 **Prüfvorkommnisse und Betriebsverhalten des Kollektors** *Test Occurrences and Operating Behaviour*

Keine Auffälligkeiten
Nothing particular

4 **Prüfverfahren** *Test Methods*

Die Bestimmung der Wärmedurchgangskoeffizienten erfolgte im Innentest nach EN ISO 9806:2017 "Solarenergie - Thermische Sonnenkollektoren - Prüfverfahren" unter Verwendung des Prüfverfahrens unter stationären Bedingungen mit einer Kollektorneigung von 45 °.
Die Bestimmung des Konversionsfaktors, des Einfallswinkel-Korrekturfaktors (IAM) und die Bestimmung der effektiven spezifischen Wärmekapazität erfolgte im Außentest nach EN ISO 9806:2017 "Solarenergie - Thermische Sonnenkollektoren - Prüfverfahren" unter Verwendung des Prüfverfahrens unter quasi-dynamischen Bedingungen mit einer Kollektorneigung von 32 °.
Als Wärmeträger wurde Wasser mit einem spezifischen Massenstrom von 72 kg/(m²h) verwendet.

The determination of the heat loss coefficients was carried out indoors according to EN ISO 9806:2017 „Solar energy – Solar thermal collectors – Test methods“ under steady state conditions and a collector tilt angle of 45 °. The determination of the conversion factor, the incident angle modifier and effective specific thermal capacity was carried out outdoors according to EN ISO 9806:2017 „Solar energy – Solar thermal collectors – Test methods“ under quasi-dynamic conditions and a collector tilt angle of 32 °. Water was used as heat transfer fluid with a specific mass flow rate of 72 kg/(m²h).

Dieser Prüfbericht darf ohne die schriftliche Zustimmung des IGTE nicht **auszugsweise** vervielfältigt werden.

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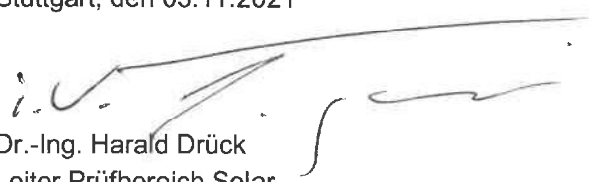
Eingang Prüfling: 27.01.2021
Arrival of test sample:

Interne Kennzeichnung des Prüflings: C1590
Internal identification of test sample: C1590

Prüfzeitraum: 10.02.2021 – 09.05.2021
Test period:

Prüfer: F. Sansonnens
Test engineer:

Stuttgart, den 03.11.2021


Dr.-Ing. Harald Drück
Leiter Prüfbereich Solar
Head of test section solar

Anhang A: Messwerte der Innenprüfung unter stationären Bedingungen

Annex A: Measured Data of Indoor Test under Steady State Conditions

	G	$\dot{m}$	ϑ_{in}	ϑ_e	$\vartheta_e - \vartheta_{in}$	ϑ_m	ϑ_a	$\vartheta_m - \vartheta_a$	$(\vartheta_m - \vartheta_a)/G$	η
Nr	[W/m²]	[kg/h]	[°C]	[°C]	[K]	[°C]	[°C]	[K]	[(m²K)/W]	[-]
1	778.28	142.59	21.07	28.11	7.04	24.59	25.49	-0.91	-0.0012	0.7413
2	778.26	142.95	21.08	28.10	7.03	24.59	25.50	-0.91	-0.0012	0.7422
3	778.06	143.46	21.11	28.15	7.04	24.63	25.56	-0.94	-0.0012	0.7468
4	777.70	143.52	21.11	28.15	7.04	24.63	25.53	-0.91	-0.0012	0.7469
5	778.17	150.35	41.48	47.38	5.90	44.43	25.52	18.90	0.0243	0.6552
6	778.39	149.96	41.48	47.39	5.91	44.43	25.51	18.93	0.0243	0.6541
7	777.55	147.43	62.47	67.51	5.03	64.99	25.56	39.44	0.0507	0.5490
8	777.38	148.36	62.57	67.59	5.02	65.08	25.56	39.50	0.0508	0.5512
9	777.28	147.38	80.85	85.00	4.15	82.93	25.50	57.42	0.0739	0.4544
10	777.31	147.76	80.87	85.00	4.12	82.94	25.54	57.41	0.0739	0.4526

Tabelle A.1: Messwerte

Table A.1: Measured values

Anhang B: Messwerte der Außenprüfung unter quasi-dynamischen Bedingungen

Annex B: Measured Data of Outdoor Test under Quasi-Dynamic Conditions

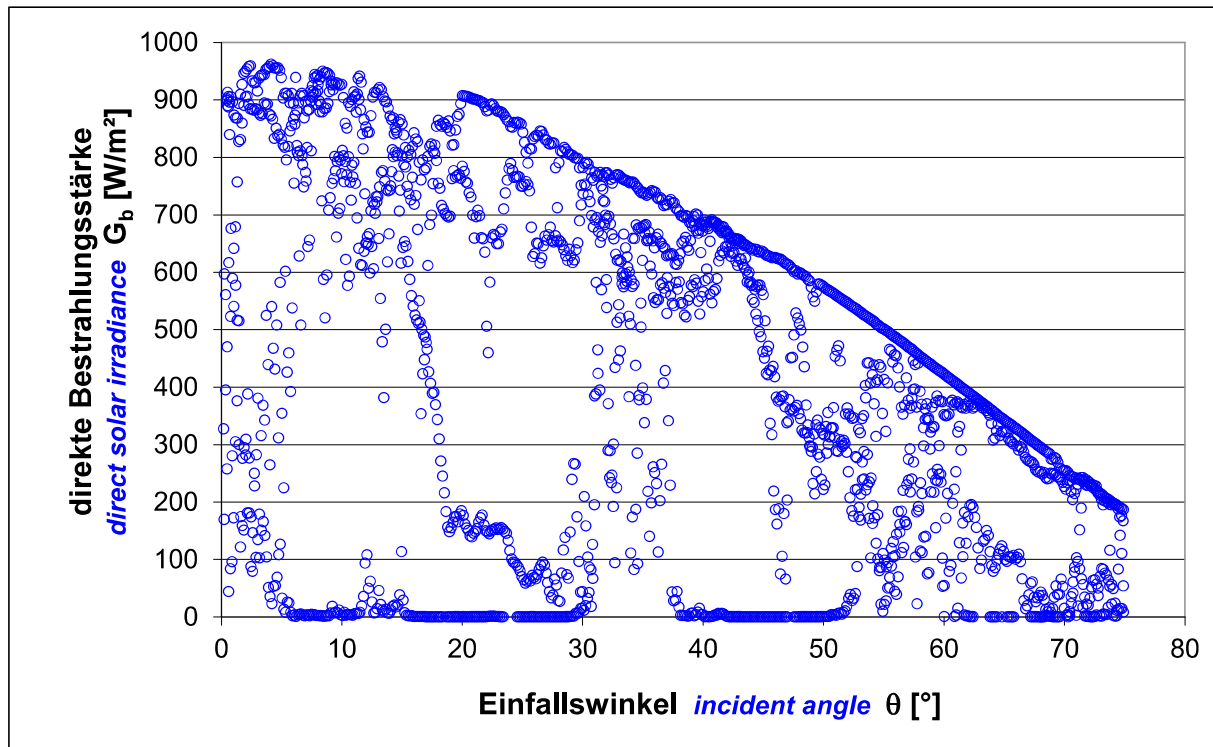


Abbildung B.1: Direkte Bestrahlungsstärke für unterschiedliche Einfallswinkel

Figure B.1: Direct solar irradiance for different incident angles

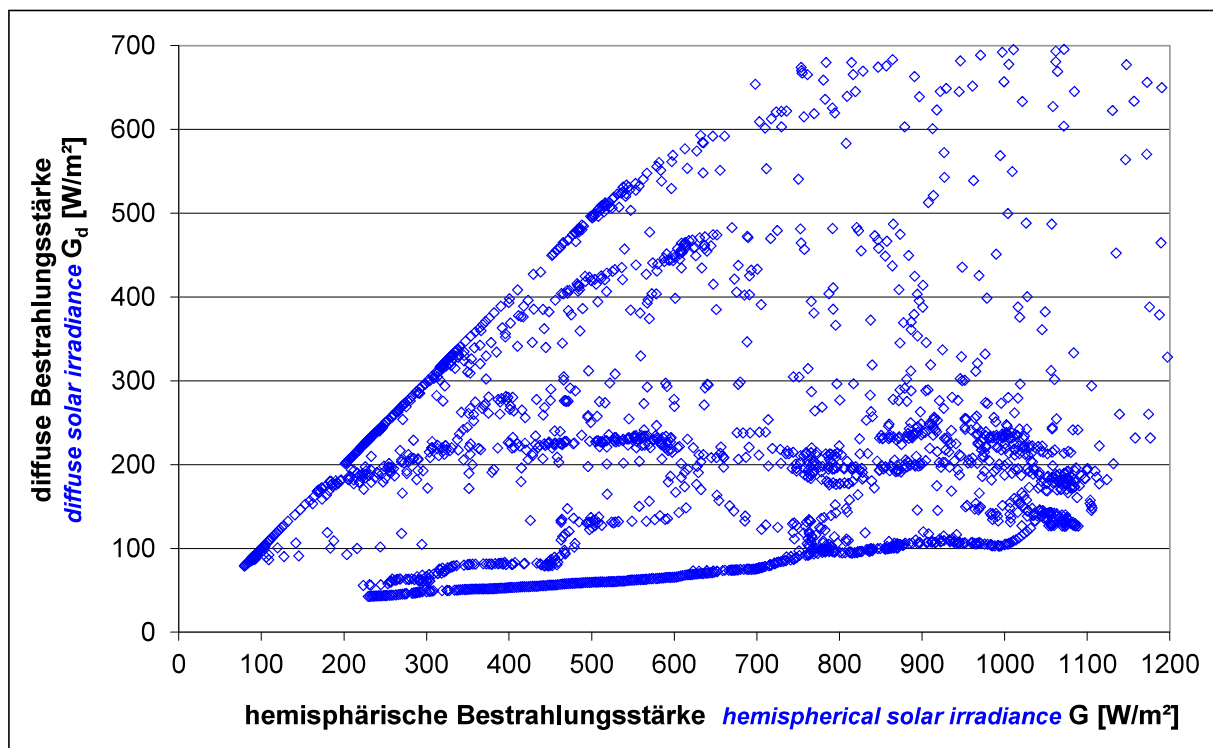


Abbildung B.2: Zusammenhang zwischen diffuser Bestrahlungsstärke und hemisphärischer Bestrahlungsstärke

Figure B.2: Relation between diffuse solar irradiance and hemispherical solar irradiance

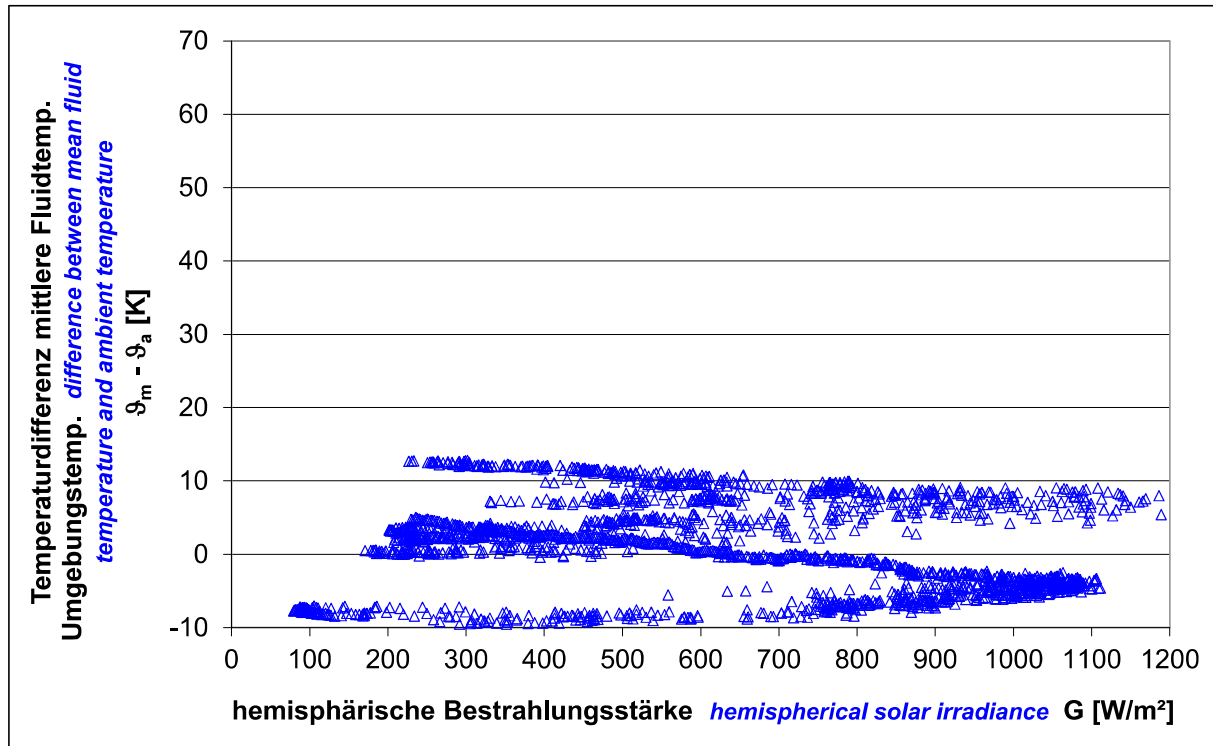


Abbildung B.3: Temperaturdifferenz zwischen mittlerer Fluidtemperatur und Umgebungstemperatur für unterschiedliche hemisphärische Bestrahlungsstärken

Figure B.3: Difference between mean fluid temperature and ambient temperature for different hemispherical solar irradiance values

Anhang C: Bezug auf Aperturfläche

Annex C: Reference to aperture area

Seit März 2014 hat die internationale Norm EN ISO 9806 die bislang gültige europäische Norm EN 12975-2:2006 abgelöst. Die EN ISO 9806 verwendet als Bezugsfläche für die Kollektorkennwerte die Brutto-Kollektorfläche. Um die Vergleichbarkeit mit Kollektorkennwerten herzustellen, die auf die Aperturfläche bezogen sind, werden in diesem Anhang die Kollektorkennwerte bezogen auf die Brutto-Kollektorfläche und Aperturfläche dargestellt.

Die thermische Leistungsfähigkeit des Kollektors ist unabhängig von der gewählten Bezugsfläche und ändert sich daher durch die hier beschriebene Umrechnung nicht!

Since March 2014 the international standard EN ISO 9806 has replaced the European standard EN 12975-2:2006 which was valid so far. The standard EN ISO 9806 uses for the collector parameters the gross area as reference area. For the comparison of collector parameters, which were determined using the aperture area as reference area, this annex presents the collector parameters based on gross collector area and aperture area.

The thermal performance of the collector is independent from the used reference area and hence is not changed by the conversion procedure described here!

Die Umrechnung von der Brutto-Kollektorfläche (A_G) als Bezugsfläche auf die Aperturfläche (A_{Ap}) als Bezugsfläche erfolgt durch das Flächenverhältnis A_G/A_{Ap} für die Kollektorkennwerte: $\eta_{0,b}$, a_1 , a_2 , a_5 , a_7 und a_8 .

Die Kollektorkennwerte K_d , a_4 sind flächenunabhängig und bedürfen keiner Umrechnung.

The conversion from the gross collector area (A_G) as reference area to the aperture area (A_{Ap}) as reference area is calculated by multiplication with the area ratio A_G/A_{Ap} for the collector parameters $\eta_{0,b}$, a_1 , a_2 , a_5 , a_7 and a_8 .

The collector parameters K_d , a_4 are independent from the reference area and need no conversion.

$$\eta_{0,b}(A_{Ap}) = \eta_{0,b}(A_G) \frac{A_G}{A_{Ap}}$$

$$a_1(A_{Ap}) = a_1(A_G) \frac{A_G}{A_{Ap}}$$

$$a_2(A_{Ap}) = a_2(A_G) \frac{A_G}{A_{Ap}}$$

$$a_5(A_{Ap}) = a_5(A_G) \frac{A_G}{A_{Ap}}$$

$$a_7(A_{Ap}) = a_7(A_G) \frac{A_G}{A_{Ap}}$$

$$a_8(A_{Ap}) = a_8(A_G) \frac{A_G}{A_{Ap}}$$

(A_{Ap}) steht hierbei für den auf die Aperturfläche bezogenen Kollektorkennwert und (A_G) für den auf die Brutto-Kollektorfläche bezogenen Kollektorkennwert.

(A_{Ap}) represents the collector parameter based on aperture area and (A_G) represents the collector parameter based on gross area.

Spezifische Nutzenergie des Kollektors:

Specific useful energy extracted from the collector:

$$\dot{Q} = A_G \left[\eta_{0,b} K_b(\theta_L, \theta_T) G_b + \eta_{0,b} K_d G_d - a_1(\vartheta_m - \vartheta_a) - a_2(\vartheta_m - \vartheta_a)^2 - a_3 u'(\vartheta_m - \vartheta_a) \right. \\ \left. + a_4(E_L - \sigma T_a^4) - a_5 \left(\frac{d\vartheta_m}{dt} \right) - a_6 u' G - a_7 u'(E_L - \sigma T_a^4) - a_8(\vartheta_m - \vartheta_a)^4 \right]$$

mit/*with*

$$K_b(\theta_L, \theta_T) = K_b(\theta_L, 0) \cdot K_b(0, \theta_T)$$

Bezugsfläche, Brutto-Kollektorfläche, Aperturfläche <i>Reference area, gross area, aperture area</i>	A, A_G, A_{Ap} [m²]	$A_G = 2.02$	$A_{Ap} = 1.83$
		Bezug A_G <i>Based on</i> <i>A_G</i>	Bezug A_{Ap} <i>Based on</i> <i>A_{Ap}</i>
Konversionsfaktor basierend auf der direkten Bestrahlungsstärke <i>peak collector efficiency based on beam irradiance</i>	$\eta_{0,b}$ [-]	0.739	0.816
Einfallswinkel-Korrekturfaktor für diffuse Strahlung <i>incidence angle modifier for diffuse radiation</i>	K_d [-]	0.978	0.978
Wärmedurchgangskoeffizient <i>heat loss coefficient</i>	a_1 [W/(m²K)]	3.387	3.739
temperaturabhängiger Wärmedurchgangskoeffizient <i>temperature dependent heat loss coefficient</i>	a_2 [W/(m²K²)]	0.009	0.010
windabhängiger Wärmedurchgangskoeffizient <i>wind speed dependent heat loss coefficient</i>	a_3 [J/(m³K)]	0	0
Faktor zur Berechnung der von der Himmelstemperatur abhängigen Strahlungswärmeverluste <i>factor for calculation of sky temperature dependent radiative heat losses</i>	a_4 [-]	0	0
effektive spezifische Wärmekapazität <i>effective specific thermal capacity</i>	a_5 [J/(m²K)]	9756	10769
Koeffizient zur Berechnung der Windabhängigkeit des Konversionsfaktors <i>coefficient for calculation of wind dependence of zero loss efficiency</i>	a_6 [s/(m)]	0	0
Windabhängiger Strahlungsaustauschkoeffizient <i>wind speed dependence or IR radiation exchange</i>	a_7 [s/m]	0	0
Koeffizient zur Berechnung der Strahlungswärmeverluste <i>coefficient for radiation losses</i>	a_8 [W/m²K⁴]	0	0

Einfallswinkel-Korrekturfaktor der direkten Bestrahlungsstärke

Incidence angle modifier of the beam solar irradiance

Einfallswinkel θ <i>incident angle θ</i>	0	10	20	30	40	50	60	70	80	90
$K_b(\theta_L, 0)$:	1.00	1.00	1.00	1.00	0.99	0.94	0.86	0.62	0.31	0.00
$K_b(0, \theta_T)$:	1.00	1.00	1.00	1.00	0.99	0.94	0.86	0.62	0.31	0.00

Anhang D: Nomenklatur*Annex D: Symbols and Units*

A_G	[m ²]	Brutto-Kollektorfläche / <i>gross area of collector</i>
A_{Ap}	[m ²]	Aperturfläche / <i>aperture area of collector</i>
a	[(mbar h ²)/l ²]	Koeffizient zur Berechnung des Druckverlusts <i>coefficient for calculation of pressure loss</i>
b	[(mbar h)/l]	Koeffizient zur Berechnung des Druckverlusts <i>coefficient for calculation of pressure loss</i>
a₁	[W/(m ² K)]	Wärmedurchgangskoeffizient bei (ϑ _m - ϑ _a) = 0 <i>heat loss coefficient at (ϑ_m - ϑ_a) = 0</i>
a₂	[W/(m ² K ²)]	temperaturabhängiger Wärmedurchgangskoeffizient <i>temperature dependent heat loss coefficient</i>
a₃	J/(m ³ K)	windabhängiger Wärmedurchgangskoeffizient <i>wind speed dependent heat loss coefficient</i>
a₄	-	Faktor zur Berechnung der von der Himmelstemperatur abhängigen Strahlungswärmeverluste <i>factor for calculation of sky temperature dependent radiative heat losses</i>
a₅	[kJ/(m ² K)]	effektive spezifische Wärmekapazität des Kollektors <i>effective specific heat capacity of the collector</i>
a₆	s/m	Koeffizient zur Berechnung der Windabhängigkeit des Konversionsfaktors <i>coefficient for calculation of wind dependence in zero loss efficiency</i>
a₇	s/m	Windabhängiger Strahlungsaustauschkoeffizient <i>wind speed dependence or IR radiation exchange</i>
a₈	W/m ² K ⁴	Koeffizient zur Berechnung der Strahlungswärmeverluste <i>coefficient for radiation losses</i>
E_L	[W/m ²]	langwellige Strahlung (λ > 3 μm) / <i>long wave irradiance (λ > 3 μm)</i>
η_{0,b}	[-]	Konversionsfaktor basierend auf der direkten Bestrahlungsstärke G _b <i>peak collector efficiency based on beam irradiance G_b</i>
η_{0,hem}	[-]	Konversionsfaktor der hemisphärischen Bestrahlungsstärke G <i>conversion factor based on hemispherical irradiance G</i>
G	[W/m ²]	hemisphärische Bestrahlungsstärke / <i>hemispherical solar irradiance</i>
G_b	[W/m ²]	direkte Bestrahlungsstärke / <i>beam solar irradiance</i>
G_d	[W/m ²]	diffuse Bestrahlungsstärke / <i>diffuse solar irradiance</i>
K_b(θ_L, θ_T)	[-]	Einfallswinkelkorrekturfaktor der direkten Bestrahlungsstärke <i>incident angle modifier of beam solar irradiance</i>
K_b(θ_L, 0)	[-]	Einfallswinkelkorrekturfaktor der direkten Bestrahlungsstärke (longitudinal) <i>incident angle modifier of beam solar irradiance (longitudinal)</i>
K_b(0, θ_T)	[-]	Einfallswinkelkorrekturfaktor der direkten Bestrahlungsstärke (transversal) <i>incident angle modifier of beam solar irradiance (transversal)</i>
K_d	[-]	Einfallswinkelkorrekturfaktor der diffusen Bestrahlungsstärke <i>incident angle modifier of diffuse solar irradiance</i>
$\dot{m}$	[kg/h]	Massenstrom / <i>mass flow rate</i>
$\dot{Q}$	[W]	Kollektorleistung pro Modul / <i>power per collector unit</i>
Δp	[mbar]	Druckverlust / <i>pressure loss</i>
t	[s]	Zeit / <i>time</i>
T_a	[K]	Umgebungstemperatur / <i>ambient air temperature</i>
u	[m/s]	Windgeschwindigkeit / <i>surrounding air speed</i>
u'	[m/s]	Reduzierte Windgeschwindigkeit / <i>reduced surrounding air speed</i>
$\dot{V}$	[l/h]	Volumenstrom / <i>volume flow</i>
ϑ	[°C]	Temperatur / <i>temperature</i>
ϑ_a	[°C]	Umgebungstemperatur / <i>ambient air temperature</i>
ϑ_e	[°C]	Kollektoraustrittstemperatur / <i>collector outlet temperature</i>

ϑ_{in}	[°C]	Kollektoreintrittstemperatur / <i>collector inlet temperature</i>
ϑ_m	[°C]	mittlere Fluidtemperatur / <i>mean fluid temperature</i>
θ	[°]	Einfallswinkel der direkten Bestrahlungsstärke <i>incidence angle of beam solar irradiance</i>
σ	W/(m ² K ⁴)	Stefan-Boltzmann-Konstante $\sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{K}^4\text{)}$ <i>Stefan-Boltzmann-constant $\sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{K}^4\text{)}$</i>



IGTE

**Institut für Gebäudeenergetik,
Thermotechnik und Energiespeicherung**
Forschungs- und Testzentrum für Solaranlagen (TZS)
Universität Stuttgart



Prüfbericht

Wärmeleistung eines Sonnenkollektors

Test Report
Thermal Performance of a Solar Collector

nach EN ISO 9806:2017
according to EN ISO 9806:2017

Prüfbericht-Nr.: 21COL1591OEM03
Test Report No.: 20COL1591OEM03

Stuttgart, den 03.11.2021
Stuttgart, November 3rd, 2021

Auftraggeber:
client:

ECOFER OIKONOMOU Z. KOSTAS
Xanthippou 150
15669 Papagou Athens
Greece

Hersteller:
manufacturer:

ECOFER OIKONOMOU Z. KOSTAS

Typ:
type:

ECOFER SMARTEVO 25

Herstelljahr:
year of production:

2021

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1 Beschreibung des Sonnenkollektors (gemäß Herstellerangaben) *Solar Collector Description (acc. to manufacturer)*

Hersteller <i>manufacturer</i>	ECOFER OIKONOMOU Z. KOSTAS Xanthippou 150 15669 Papagou Athens Greece
Ansprechpartner: <i>contact person:</i>	Zacharias Oikonomou Tel.: +30 2106715510 email: zachos@ecofer.com.gr
Typ: <i>type:</i>	ECOFER SMARTEVO 25 <i>ECOFER SMARTEVO 25</i>
Herstellernummer: <i>serial no.:</i>	k. A. <i>n. s.</i>
Serienprodukt oder Baumuster: <i>duplicate part or model:</i>	Serienprodukt <i>duplicate part</i>
Herstelljahr: <i>year of production:</i>	2021 <i>2021</i>

Kollektor *Collector*

Bauart: <i>collector type:</i>	Flachkollektor <i>flat plate collector</i>
Brutto-Kollektorfläche: <i>gross area of collector:</i>	2.52 m ² <i>2.52 m²</i>
Länge: <i>length:</i>	2006 mm <i>2006 mm</i>
Breite: <i>width:</i>	1257 mm <i>1257 mm</i>
Höhe: <i>height:</i>	85 mm <i>85 mm</i>
Gewicht: <i>weight:</i>	35 kg <i>35 kg</i>
Wärmeträgerinhalt: <i>heat transfer fluid content:</i>	1.9 Liter <i>1.9 litres</i>
Material Seitenwand/Rahmen: <i>material side wall/frame:</i>	Aluminium <i>aluminium</i>
Material Rückwand: <i>material back sheet:</i>	Aluminium <i>aluminium</i>
Verbindungsart der Rahmenteile: <i>frame fastening method:</i>	genietet <i>riveted</i>
Einbauweise: <i>collector mounting:</i>	Aufdach, Flachdach <i>On roof, flat roof</i>
Anzahl Anschlüsse: <i>number of connections:</i>	4 <i>4</i>
Ausführung Anschlüsse: <i>realisation of connections:</i>	22 mm Kupfer-Rohr <i>22 mm copper pipe</i>

Absorber

Absorber

Material: <i>material:</i>	Aluminiumblech mit Kupferregister <i>aluminium sheet with copper pipes</i>
Verbindung Fluidkanäle/Absorber: <i>bond between risers and fin/plate:</i>	lasergeschweißt <i>laser welded</i>
Dicke: <i>thickness:</i>	0.4 mm <i>0.4 mm</i>
Oberflächenbehandlung: <i>surface treatment:</i>	BLUE SELECTIVE <i>BLUE SELECTIVE</i>
Absorptionsgrad: <i>solar absorptance:</i>	0.95 <i>0.95</i>
Emissionsgrad: <i>emittance:</i>	0.05 <i>0.05</i>
Durchströmungsform: <i>flow pattern:</i>	Harfe <i>harp</i>
Abmessungen Absorber [L x B]: <i>dimension absorber [L x W]:</i>	keine Angabe <i>not specified</i>
Abmessungen Absorberrohre: <i>dimension absorber tubes:</i>	8.0 x 0.4 mm <i>8.0 x 0.4 mm</i>
Anzahl Absorberrohre: <i>number of absorber tubes:</i>	12 <i>12</i>
Länge eines Absorberrohres: <i>length of a single absorber tube:</i>	keine Angabe <i>not specified</i>
Abstand der Absorberrohre: <i>distance centre to centre between absorber tubes:</i>	95 mm <i>95 mm</i>
Länge eines Sammlerrohres: <i>length of header tube:</i>	keine Angabe <i>not specified</i>
Abmessungen Sammlerrohr: <i>dimension of the header tube:</i>	22 x 0.7 mm <i>22 x 0.7 mm</i>

Transparente Abdeckung

Transparent cover:

Anzahl: <i>number:</i>	1 <i>1</i>
Länge x Breite x Dicke: <i>length x width x thickness:</i>	Dicke 3.2 mm <i>thickness 3.2 mm</i>
Transmissionsgrad: <i>transmittance:</i>	0.91 <i>0.91</i>
Abmessungen Apertur [L x B]: <i>aperture dimension [L x W]:</i>	1942 mm x 1192 mm (von Prüflabor bestimmt) <i>1942 mm x 1192 mm (determined by test laboratory)</i>
Oberflächenstruktur innen/außen: <i>surface characteristics inside/outside:</i>	prismiert / klar <i>prismatic / clear</i>

Wärmedämmung

Thermal insulation:

	Rückseite <i>back side</i>	seitlich <i>at the side</i>
Material: <i>material:</i>	Glaswolle <i>glass wool</i>	Glaswolle <i>glass wool</i>
Hersteller: <i>manufacturer:</i>	Knauf <i>Knauf</i>	Knauf <i>Knauf</i>
Produktbezeichnung: <i>product name:</i>	keine Angabe <i>not specified</i>	keine Angabe <i>not specified</i>
Wärmeleitfähigkeit: <i>thermal conductivity:</i>	0.035 W/(mK) <i>0.035 W/(mK)</i>	0.035 W/(mK) <i>0.035 W/(mK)</i>
Dichte: <i>density:</i>	30 kg/m ³ <i>30 kg/m³</i>	30 kg/m ³ <i>30 kg/m³</i>
Dicke: <i>thickness:</i>	30 mm <i>30 mm</i>	15 mm <i>15 mm</i>

Grenzdaten

Limitations:

Stillstandstemperatur: <i>stagnation temperature:</i>	230 °C (von Prüflabor bestimmt) <i>230 °C (determined by test laboratory)</i>
maximale Betriebstemperatur: <i>maximum operation temperature:</i>	keine Angabe <i>not specified</i>
max. zulässiger Betriebsdruck: <i>maximum operation pressure:</i>	10 bar <i>10 bar</i>
Zulässiger Wärmeträger: <i>allowed heat transfer fluid:</i>	Frostschutz/Wasser-Gemisch <i>antifreeze/water mixture</i>
Nenndurchfluss pro Kollektor: <i>nominal flow rate per collector:</i>	keine Angabe <i>not specified</i>

Gültigkeit

Validity:

Der Prüfbericht ist gültig für den oben beschriebenen Kollektortyp ECOFER SMARTEVO 25.
The test report is valid for collector type ECOFER SMARTEVO 25 as specified above.

2 Prüfergebnisse Wärmeleistung

Test Results Thermal Performance

Spezifische Nutzenergie des Kollektors:

Specific useful energy extracted from the collector:

$$\dot{Q} = A_G \left[\eta_{0,b} K_b(\theta_L, \theta_T) G_b + \eta_{0,b} K_d G_d - a_1(\vartheta_m - \vartheta_a) - a_2(\vartheta_m - \vartheta_a)^2 - a_3 u'(\vartheta_m - \vartheta_a) \right. \\ \left. + a_4(E_L - \sigma T_a^4) - a_5 \left(\frac{d\vartheta_m}{dt} \right) - a_6 u' G - a_7 u'(E_L - \sigma T_a^4) - a_8(\vartheta_m - \vartheta_a)^4 \right]$$

mit/*with*

$$K_b(\theta_L, \theta_T) = K_b(\theta_L, 0) \cdot K_b(0, \theta_T)$$

	Einheit <i>unit</i>	Wert <i>value</i>	σ^*
Konversionsfaktor basierend auf der direkten Bestrahlungsstärke <i>peak collector efficiency based on beam irradiance</i>	$\eta_{0,b}$ [-]	0.750	0.004
Einfallswinkel-Korrekturfaktor für diffuse Strahlung <i>incidence angle modifier for diffuse radiation</i>	K_d [-]	0.962	0.008
Wärmedurchgangskoeffizient <i>heat loss coefficient</i>	a_1 [W/(m²K)]	3.259	0.033
temperaturabhängiger Wärmedurchgangskoeffizient <i>temperature dependent heat loss coefficient</i>	a_2 [W/(m²K²)]	0.010	0.000
windabhängiger Wärmedurchgangskoeffizient <i>wind speed dependent heat loss coefficient</i>	a_3 [J/(m³K)]	0	-
Faktor zur Berechnung der von der Himmelstemperatur abhängigen Strahlungswärmeverluste <i>factor for calculation of sky temperature dependent radiative heat losses</i>	a_4 [-]	0	-
effektive spezifische Wärmekapazität <i>effective specific thermal capacity</i>	a_5 [J/(m²K)]	9197	561
Koeffizient zur Berechnung der Windabhängigkeit des Konversionsfaktors <i>coefficient for calculation of wind dependence of zero loss efficiency</i>	a_6 [s/(m)]	0	-
Windabhängiger Strahlungsaustauschkoeffizient <i>wind speed dependence or IR radiation exchange</i>	a_7 [s/m]	0	-
Koeffizient zur Berechnung der Strahlungswärmeverluste <i>coefficient for radiation losses</i>	a_8 [W/m²K⁴]	0	-

* σ : Standardabweichung / *standard deviation*

Einfallswinkel-Korrekturfaktor der direkten Bestrahlungsstärke*Incidence angle modifier of the beam solar irradiance*

Einfallswinkel θ <i>incident angle θ</i>	0	10	20	30	40	50	60	70	80	90
$K_b(\theta_L, 0)$:	1.00	1.00	1.00	1.00	1.00	0.96	0.88	0.58	0.29	0.00
σ^*	-	-	0.00	-	0.00	0.01	0.01	0.01	-	-
$K_b(0, \theta_T)$:	1.00	1.00	1.00	1.00	1.00	0.96	0.88	0.58	0.29	0.00
σ^*	-	-	0.00	-	0.00	0.01	0.01	0.01	-	-

Maximale Temperaturdifferenz während der Prüfung

73 K

 $(\vartheta_m - \vartheta_a)_{\max}$:*maximum temperature difference during test $(\vartheta_m - \vartheta_a)_{\max}$:*

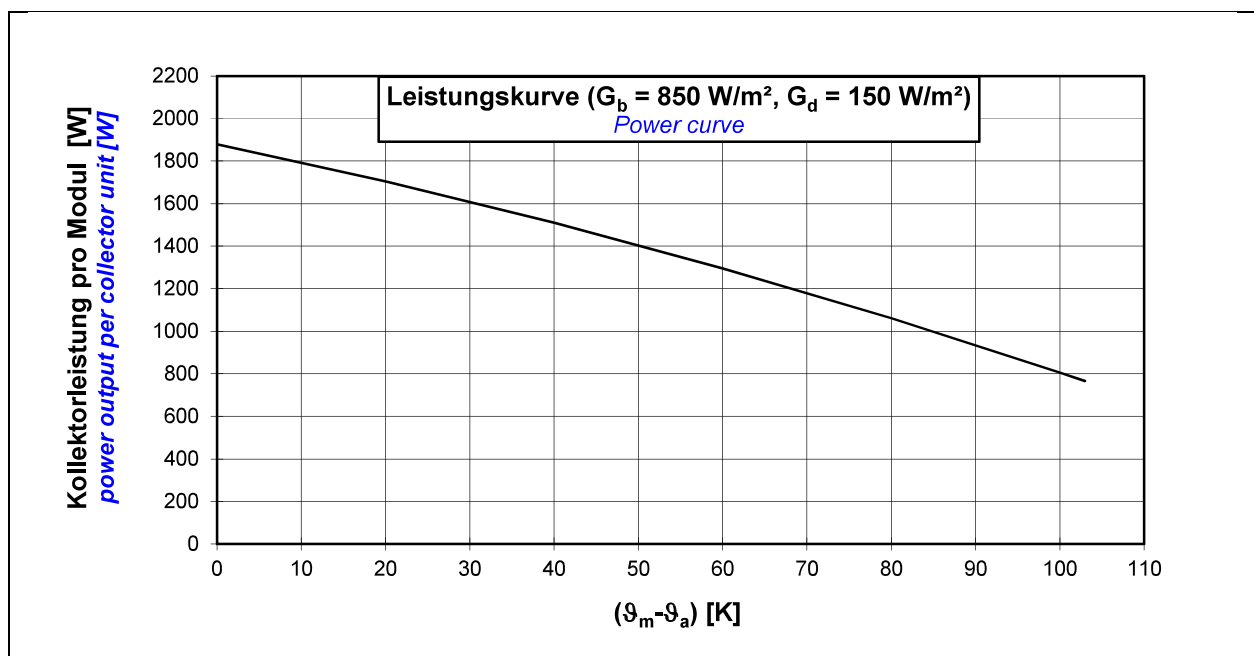
73 K

Peakleistung pro Kollektormodul $\dot{Q}_{\text{peak}}$

1879 W

 $(G_b = 850 \text{ W/m}^2, G_d = 150 \text{ W/m}^2, (\vartheta_m - \vartheta_a) = 0)$:*peak power per collector unit $\dot{Q}_{\text{peak}}$*

1879 W

 $(G_b = 850 \text{ W/m}^2, G_d = 150 \text{ W/m}^2, (\vartheta_m - \vartheta_a) = 0)$:

Kollektorleistung pro Modul [W]
Power output per collector unit [W]

$\vartheta_m - \vartheta_a$ [K]	Bestrahlungsstärke / <i>Irradiance</i>		
	$G_b = 0 \text{ W/m}^2$ $G_d = 400 \text{ W/m}^2$	$G_b = 440 \text{ W/m}^2$ $G_d = 260 \text{ W/m}^2$	$G_b = 850 \text{ W/m}^2$ $G_d = 150 \text{ W/m}^2$
0	727	1304	1879
20	553	1130	1705
40	358	935	1510
60	144	721	1296
80	0 *)	486	1061
100	0 *)	231	806
103	0 *)	191	766

Anmerkung: Die angegebenen Werte beziehen sich auf senkrechte Einstrahlung
Note: the reported values are for normal incidence

*) Die Kollektorleistung ist mit Null angegeben, da sich rechnerisch bei diesen Betriebsbedingungen eine negative Kollektorleistung ergibt.

**) Calculating the power output per collector unit under these operation conditions result in negative values. Therefore the calculated power output is indicated with zero.*

3 Prüfvorkommnisse und Betriebsverhalten des Kollektors

Test Occurrences and Operating Behaviour

Keine Auffälligkeiten
Nothing particular

4 Prüfverfahren

Test Methods

Die Bestimmung der Wärmedurchgangskoeffizienten erfolgte im Innentest nach EN ISO 9806:2017 "Solarenergie - Thermische Sonnenkollektoren - Prüfverfahren" unter Verwendung des Prüfverfahrens unter stationären Bedingungen mit einer Kollektorneigung von 45 °.

Die Bestimmung des Konversionsfaktors, des Einfallswinkel-Korrekturfaktors (IAM) und die Bestimmung der effektiven spezifischen Wärmekapazität erfolgte im Außentest nach EN ISO 9806:2017 "Solarenergie - Thermische Sonnenkollektoren - Prüfverfahren" unter Verwendung des Prüfverfahrens unter quasi-dynamischen Bedingungen mit einer Kollektorneigung von 40 °.

Als Wärmeträger wurde Wasser mit einem spezifischen Massenstrom von 72 kg/(m²h) verwendet.

The determination of the heat loss coefficients was carried out indoors according to EN ISO 9806:2017 „Solar energy – Solar thermal collectors – Test methods“ under steady state conditions and a collector tilt angle of 45 °. The determination of the conversion factor, the incident angle modifier and effective specific thermal capacity was carried out outdoors according to EN ISO 9806:2017 „Solar energy – Solar thermal collectors – Test methods“ under quasi-dynamic conditions and a collector tilt angle of 40 °. Water was used as heat transfer fluid with a specific mass flow rate of 72 kg/(m²h).

Dieser Prüfbericht darf ohne die schriftliche Zustimmung des IGTE nicht **auszugsweise** vervielfältigt werden.

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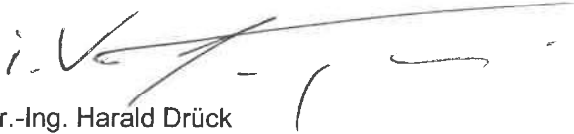
Eingang Prüfling: 27.01.2021
Arrival of test sample:

Interne Kennzeichnung des Prüflings: C1591
Internal identification of test sample: *C1591*

Prüfzeitraum: 12.02.2021 – 27.04.2021
Test period:

Prüfer: F. Sansonnens
Test engineer:

Stuttgart, den 03.11.2021


Dr.-Ing. Harald Drück
Leiter Prüfbereich Solar
Head of test section solar

Anhang A: Messwerte der Innenprüfung unter stationären Bedingungen

Annex A: Measured Data of Indoor Test under Steady State Conditions

	G	$\dot{m}$	ϑ_{in}	ϑ_e	$\vartheta_e - \vartheta_{in}$	ϑ_m	ϑ_a	$\vartheta_m - \vartheta_a$	$(\vartheta_m - \vartheta_a)/G$	η
Nr	[W/m²]	[kg/h]	[°C]	[°C]	[K]	[°C]	[°C]	[K]	[(m²K)/W]	[-]
1	777.86	180.18	21.02	28.14	7.11	24.58	25.39	-0.82	-0.0011	0.7593
2	777.79	179.67	21.03	28.17	7.14	24.60	25.42	-0.83	-0.0011	0.7600
3	777.77	182.02	21.22	28.26	7.04	24.74	25.42	-0.67	-0.0009	0.7591
4	777.48	182.28	21.22	28.24	7.03	24.73	25.42	-0.68	-0.0009	0.7594
5	777.39	180.93	41.26	47.54	6.28	44.40	25.50	18.91	0.0243	0.6734
6	777.41	181.30	41.28	47.55	6.27	44.42	25.53	18.89	0.0243	0.6734
7	776.63	178.83	63.50	68.81	5.31	66.15	25.61	40.55	0.0522	0.5643
8	776.97	179.74	63.56	68.83	5.27	66.19	25.67	40.53	0.0522	0.5623
9	777.16	181.95	81.47	85.81	4.34	83.64	25.64	58.00	0.0746	0.4699
10	777.06	181.37	81.53	85.88	4.36	83.71	25.70	58.02	0.0747	0.4706

Tabelle A.1: Messwerte

Table A.1: Measured values

Anhang B: Messwerte der Außenprüfung unter quasi-dynamischen Bedingungen

Annex B: Measured Data of Outdoor Test under Quasi-Dynamic Conditions

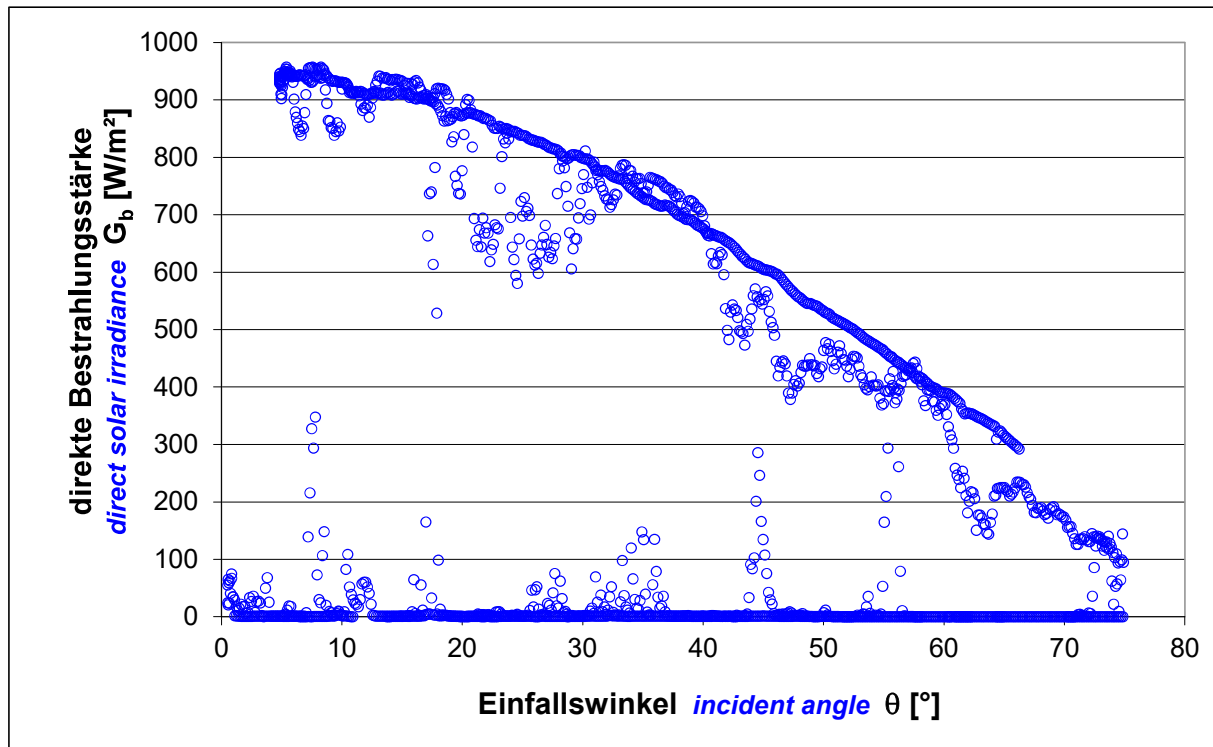


Abbildung B.1: Direkte Bestrahlungsstärke für unterschiedliche Einfallswinkel

Figure B.1: Direct solar irradiance for different incident angles

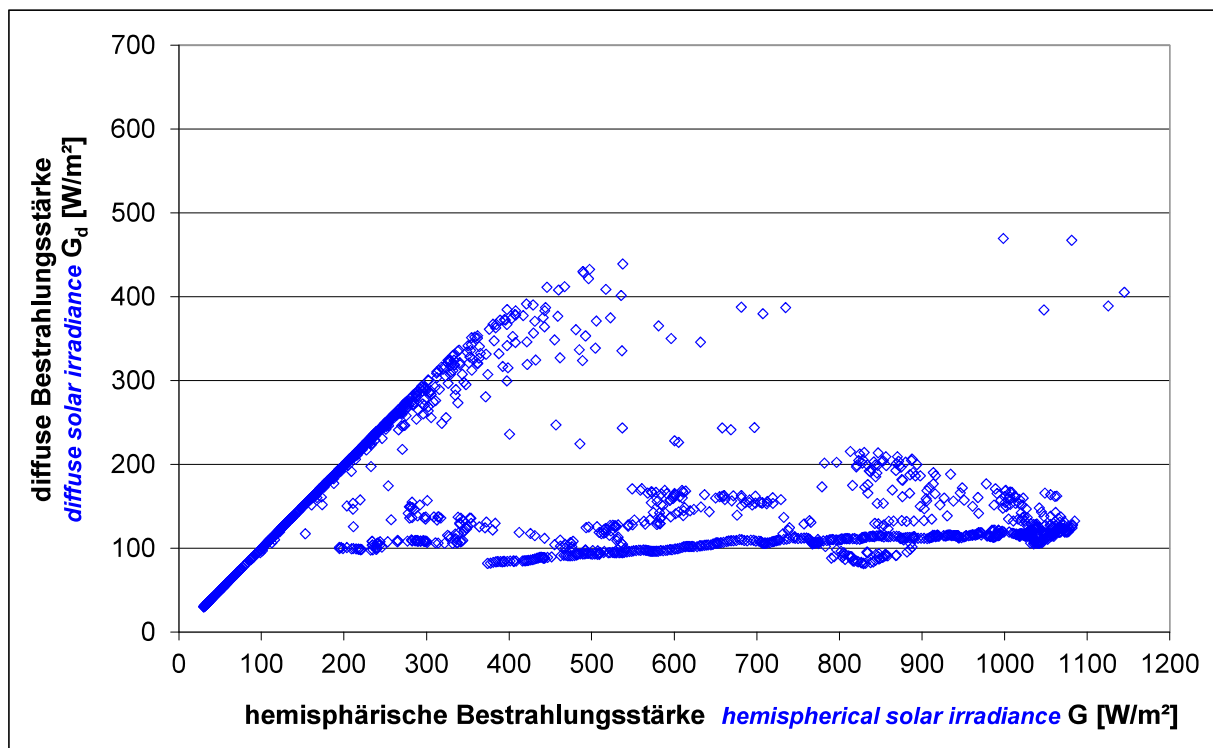


Abbildung B.2: Zusammenhang zwischen diffuser Bestrahlungsstärke und hemisphärischer Bestrahlungsstärke

Figure B.2: Relation between diffuse solar irradiance and hemispherical solar irradiance

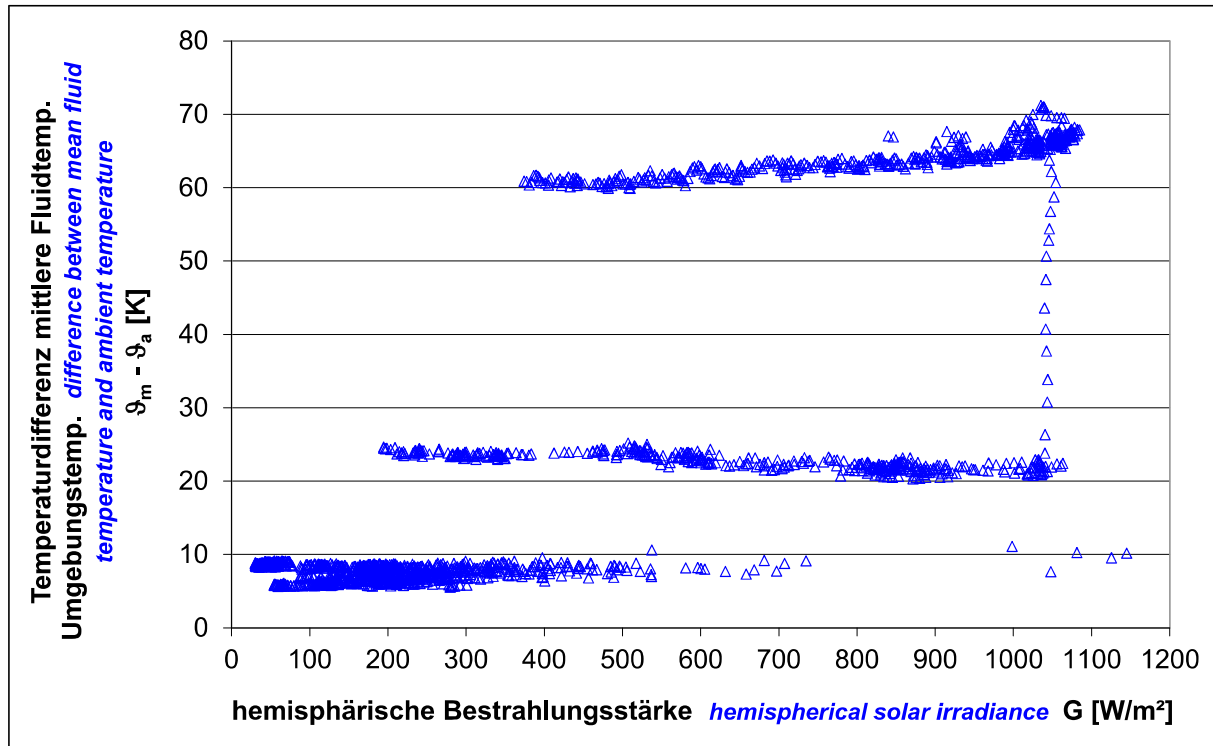


Abbildung B.3: Temperaturdifferenz zwischen mittlerer Fluidtemperatur und Umgebungstemperatur für unterschiedliche hemisphärische Bestrahlungsstärken

Figure B.3: Difference between mean fluid temperature and ambient temperature for different hemispherical solar irradiance values

Anhang C: Bezug auf Aperturfläche

Annex C: Reference to aperture area

Seit März 2014 hat die internationale Norm EN ISO 9806 die bislang gültige europäische Norm EN 12975-2:2006 abgelöst. Die EN ISO 9806 verwendet als Bezugsfläche für die Kollektorkennwerte die Brutto-Kollektorfläche. Um die Vergleichbarkeit mit Kollektorkennwerten herzustellen, die auf die Aperturfläche bezogen sind, werden in diesem Anhang die Kollektorkennwerte bezogen auf die Brutto-Kollektorfläche und Aperturfläche dargestellt.

Die thermische Leistungsfähigkeit des Kollektors ist unabhängig von der gewählten Bezugsfläche und ändert sich daher durch die hier beschriebene Umrechnung nicht!

Since March 2014 the international standard EN ISO 9806 has replaced the European standard EN 12975-2:2006 which was valid so far. The standard EN ISO 9806 uses for the collector parameters the gross area as reference area. For the comparison of collector parameters, which were determined using the aperture area as reference area, this annex presents the collector parameters based on gross collector area and aperture area.

The thermal performance of the collector is independent from the used reference area and hence is not changed by the conversion procedure described here!

Die Umrechnung von der Brutto-Kollektorfläche (A_G) als Bezugsfläche auf die Aperturfläche (A_{Ap}) als Bezugsfläche erfolgt durch das Flächenverhältnis A_G/A_{Ap} für die Kollektorkennwerte: $\eta_{0,b}$, a_1 , a_2 , a_5 , a_7 und a_8 .

Die Kollektorkennwerte K_d , a_4 sind flächenunabhängig und bedürfen keiner Umrechnung.

The conversion from the gross collector area (A_G) as reference area to the aperture area (A_{Ap}) as reference area is calculated by multiplication with the area ratio A_G/A_{Ap} for the collector parameters $\eta_{0,b}$, a_1 , a_2 , a_5 , a_7 and a_8 .

The collector parameters K_d , a_4 are independent from the reference area and need no conversion.

$$\eta_{0,b}(A_{Ap}) = \eta_{0,b}(A_G) \frac{A_G}{A_{Ap}}$$

$$a_1(A_{Ap}) = a_1(A_G) \frac{A_G}{A_{Ap}}$$

$$a_2(A_{Ap}) = a_2(A_G) \frac{A_G}{A_{Ap}}$$

$$a_5(A_{Ap}) = a_5(A_G) \frac{A_G}{A_{Ap}}$$

$$a_7(A_{Ap}) = a_7(A_G) \frac{A_G}{A_{Ap}}$$

$$a_8(A_{Ap}) = a_8(A_G) \frac{A_G}{A_{Ap}}$$

(A_{Ap}) steht hierbei für den auf die Aperturfläche bezogenen Kollektorkennwert und (A_G) für den auf die Brutto-Kollektorfläche bezogenen Kollektorkennwert.

(A_{Ap}) represents the collector parameter based on aperture area and (A_G) represents the collector parameter based on gross area.

Spezifische Nutzenergie des Kollektors:

Specific useful energy extracted from the collector:

$$\dot{Q} = A_G \left[\eta_{0,b} K_b(\theta_L, \theta_T) G_b + \eta_{0,b} K_d G_d - a_1(\vartheta_m - \vartheta_a) - a_2(\vartheta_m - \vartheta_a)^2 - a_3 u'(\vartheta_m - \vartheta_a) \right. \\ \left. + a_4(E_L - \sigma T_a^4) - a_5 \left(\frac{d\vartheta_m}{dt} \right) - a_6 u' G - a_7 u'(E_L - \sigma T_a^4) - a_8(\vartheta_m - \vartheta_a)^4 \right]$$

mit/*with*

$$K_b(\theta_L, \theta_T) = K_b(\theta_L, 0) \cdot K_b(0, \theta_T)$$

Bezugsfläche, Brutto-Kollektorfläche, Aperturfläche <i>Reference area, gross area, aperture area</i>	A, A_G, A_{Ap} [m²]	$A_G = 2.52$	$A_{Ap} = 2.31$
		Bezug A_G <i>Based on</i> <i>A_G</i>	Bezug A_{Ap} <i>Based on</i> <i>A_{Ap}</i>
Konversionsfaktor basierend auf der direkten Bestrahlungsstärke <i>peak collector efficiency based on beam irradiance</i>	$\eta_{0,b}$ [-]	0.750	0.818
Einfallswinkel-Korrekturfaktor für diffuse Strahlung <i>incidence angle modifier for diffuse radiation</i>	K_d [-]	0.962	0.962
Wärmedurchgangskoeffizient <i>heat loss coefficient</i>	a_1 [W/(m²K)]	3.259	3.555
temperaturabhängiger Wärmedurchgangskoeffizient <i>temperature dependent heat loss coefficient</i>	a_2 [W/(m²K²)]	0.010	0.011
windabhängiger Wärmedurchgangskoeffizient <i>wind speed dependent heat loss coefficient</i>	a_3 [J/(m³K)]	0	0
Faktor zur Berechnung der von der Himmelstemperatur abhängigen Strahlungswärmeverluste <i>factor for calculation of sky temperature dependent radiative heat losses</i>	a_4 [-]	0	0
effektive spezifische Wärmekapazität <i>effective specific thermal capacity</i>	a_5 [J/(m²K)]	9197	10033
Koeffizient zur Berechnung der Windabhängigkeit des Konversionsfaktors <i>coefficient for calculation of wind dependence of zero loss efficiency</i>	a_6 [s/(m)]	0	0
Windabhängiger Strahlungsaustauschkoeffizient <i>wind speed dependence or IR radiation exchange</i>	a_7 [s/m]	0	0
Koeffizient zur Berechnung der Strahlungswärmeverluste <i>coefficient for radiation losses</i>	a_8 [W/m²K⁴]	0	0

Einfallswinkel-Korrekturfaktor der direkten Bestrahlungsstärke

Incidence angle modifier of the beam solar irradiance

Einfallswinkel θ <i>incident angle θ</i>	0	10	20	30	40	50	60	70	80	90
$K_b(\theta_L, 0)$:	1.00	1.00	1.00	1.00	1.00	0.96	0.88	0.58	0.29	0.00
$K_b(0, \theta_T)$:	1.00	1.00	1.00	1.00	1.00	0.96	0.88	0.58	0.29	0.00

Anhang D: Nomenklatur*Annex D: Symbols and Units*

A_G	[m ²]	Brutto-Kollektorfläche / <i>gross area of collector</i>
A_{Ap}	[m ²]	Aperturfläche / <i>aperture area of collector</i>
a	[(mbar h ²)/l ²]	Koeffizient zur Berechnung des Druckverlusts <i>coefficient for calculation of pressure loss</i>
b	[(mbar h)/l]	Koeffizient zur Berechnung des Druckverlusts <i>coefficient for calculation of pressure loss</i>
a₁	[W/(m ² K)]	Wärmedurchgangskoeffizient bei (ϑ _m - ϑ _a) = 0 <i>heat loss coefficient at (ϑ_m - ϑ_a) = 0</i>
a₂	[W/(m ² K ²)]	temperaturabhängiger Wärmedurchgangskoeffizient <i>temperature dependent heat loss coefficient</i>
a₃	J/(m ³ K)	windabhängiger Wärmedurchgangskoeffizient <i>wind speed dependent heat loss coefficient</i>
a₄	-	Faktor zur Berechnung der von der Himmelstemperatur abhängigen Strahlungswärmeverluste <i>factor for calculation of sky temperature dependent radiative heat losses</i>
a₅	[kJ/(m ² K)]	effektive spezifische Wärmekapazität des Kollektors <i>effective specific heat capacity of the collector</i>
a₆	s/m	Koeffizient zur Berechnung der Windabhängigkeit des Konversionsfaktors <i>coefficient for calculation of wind dependence in zero loss efficiency</i>
a₇	s/m	Windabhängiger Strahlungsaustauschkoeffizient <i>wind speed dependence or IR radiation exchange</i>
a₈	W/m ² K ⁴	Koeffizient zur Berechnung der Strahlungswärmeverluste <i>coefficient for radiation losses</i>
E_L	[W/m ²]	langwellige Strahlung (λ > 3 μm) / <i>long wave irradiance (λ > 3 μm)</i>
η_{0,b}	[-]	Konversionsfaktor basierend auf der direkten Bestrahlungsstärke G _b <i>peak collector efficiency based on beam irradiance G_b</i>
η_{0,hem}	[-]	Konversionsfaktor der hemisphärischen Bestrahlungsstärke G <i>conversion factor based on hemispherical irradiance G</i>
G	[W/m ²]	hemisphärische Bestrahlungsstärke / <i>hemispherical solar irradiance</i>
G_b	[W/m ²]	direkte Bestrahlungsstärke / <i>beam solar irradiance</i>
G_d	[W/m ²]	diffuse Bestrahlungsstärke / <i>diffuse solar irradiance</i>
K_b(θ_L, θ_T)	[-]	Einfallswinkelkorrekturfaktor der direkten Bestrahlungsstärke <i>incident angle modifier of beam solar irradiance</i>
K_b(θ_L, 0)	[-]	Einfallswinkelkorrekturfaktor der direkten Bestrahlungsstärke (longitudinal) <i>incident angle modifier of beam solar irradiance (longitudinal)</i>
K_b(0, θ_T)	[-]	Einfallswinkelkorrekturfaktor der direkten Bestrahlungsstärke (transversal) <i>incident angle modifier of beam solar irradiance (transversal)</i>
K_d	[-]	Einfallswinkelkorrekturfaktor der diffusen Bestrahlungsstärke <i>incident angle modifier of diffuse solar irradiance</i>
$\dot{m}$	[kg/h]	Massenstrom / <i>mass flow rate</i>
$\dot{Q}$	[W]	Kollektorleistung pro Modul / <i>power per collector unit</i>
Δp	[mbar]	Druckverlust / <i>pressure loss</i>
t	[s]	Zeit / <i>time</i>
T_a	[K]	Umgebungstemperatur / <i>ambient air temperature</i>
u	[m/s]	Windgeschwindigkeit / <i>surrounding air speed</i>
u'	[m/s]	Reduzierte Windgeschwindigkeit / <i>reduced surrounding air speed</i>
$\dot{V}$	[l/h]	Volumenstrom / <i>volume flow</i>
ϑ	[°C]	Temperatur / <i>temperature</i>
ϑ_a	[°C]	Umgebungstemperatur / <i>ambient air temperature</i>
ϑ_e	[°C]	Kollektoraustrittstemperatur / <i>collector outlet temperature</i>

ϑ_{in}	[°C]	Kollektoreintrittstemperatur / <i>collector inlet temperature</i>
ϑ_m	[°C]	mittlere Fluidtemperatur / <i>mean fluid temperature</i>
θ	[°]	Einfallswinkel der direkten Bestrahlungsstärke <i>incidence angle of beam solar irradiance</i>
σ	W/(m ² K ⁴)	Stefan-Boltzmann-Konstante $\sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{K}^4\text{)}$ <i>Stefan-Boltzmann-constant $\sigma = 5.67 \times 10^{-8} \text{ W/(m}^2\text{K}^4\text{)}$</i>



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Test Report Hot Water Store Determination of heat losses according to EN 12977-3:2018

Test Report No.: 21STO396OEM03

Stuttgart, November 3rd, 2021

Claimant: ECOFER OIKONOMOU Z. KOSTAS
Xanthippou 150
15669 Papagou Athens
Greece

Manufacturer: ECOFER OIKONOMOU Z. KOSTAS
Store Type: ECOFER SMARTECO 200
Construction Year: 2021

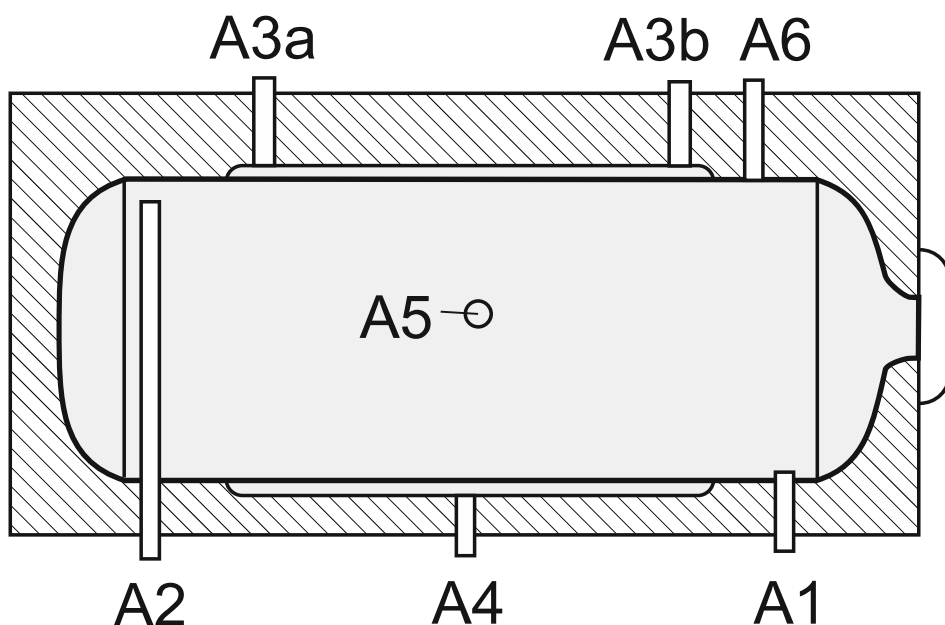
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1 Technical Data¹			
Manufacturer:		Type:	
ECOFER OIKONOMOU Z. KOSTAS		ECOFER SMARTECO 200	
Year:	Serial No.:	Nominal volume:	Design:
2021	not specified	200 liters	Horizontal thermosiphon solar domestic hot water store
Heat output or coefficient of performance:		Test acc. to DIN 4753	Weight (empty):
no reference		no reference	69.0 kg
Water volume:			
Corrosion protection:		Enamel Powder Coated,	
		Magnesium Anode	
Max operation pressure:		10 bar	
Max operation temperature:		95 °C	
Thermal insulation:		Polyurethane: 50 mm	
Mantle Heat exchanger			
Max operation pressure [bar]:		3.0	
Max operation temperature [°C]:		95	
Volume of heat exchanger [liters]:		6.5	
Area [m ²]:		0.96	

¹ as stated by the manufacturer

2 Schematic design²



Connections

	Type	Application
A1	AT 1/2"	Cold water
A2	AT 1/2"	Hot water
A3a	AT 1/2"	ventilation
A3b	AT 1/2"	ventilation
A4	AT 3/4"	Collector loop, return (outlet)
A5	AT 3/4"	Collector loop, flow (inlet)
A6	AT 1/2"	Ventilation / P/T valve connection

AT = outside thread

IT = inside thread

² as stated by the manufacturer

3 Test results

3.1 Geometrical Data			
Maximum lenght:	Max.diameter:	Height of water volume:	Diameter of water volume:
1.29 m	0.58 m	0.48 m	0.48 m
3.2 Volumes			
Domestic hot water volume:		Heat exchanger:	
195.5 liters		7.0 liters	
3.3 Thermal parameters			
Heat loss capacity rate (standby):	Standing loss power S ³ :		Thermal losses Q _{PR} ³
1.95 W/K	87.8 W		2.11 kWh/24h

Table 1: Equivalent Energy efficiency classes for a hot water store with a rated capacity of 200.0 l according to SASO 2884:2017

Equivalent energy efficiency class	Daily thermal losses limit value [kWh/24h]
A	0.76
B	1.05
C	1.30
D	2.05
E	2.57
F	3.35
G	> 3.35

³ at a temperature difference of 45 K

4 Test occurrences

No special incidents

5 General

The thermal testing of the store was performed according to EN 12977-3:2018 '*Thermal solar systems and components, Custom built systems, Part 3: Performance test methods for solar water heater stores*'.

The **bold** printed values were determined by means of parameter identification.

The determined results are only valid for the tested version of the test sample.

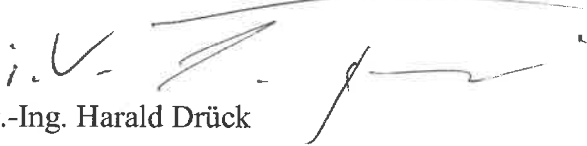
Water was used as heat transfer fluid.

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The nomenclature of SASO 2884:2017 and EN 12977-3:2018 was used.

Arrival of test sample:	04.05.2021
Testing period:	06.05. bis 10.05.2021
Test location:	Stuttgart, Pfaffenwaldring 10
Identification of test sample:	Adhesive label: 21STO396
Test engineer:	Dipl.-Ing. S. Bachmann

Stuttgart, November 3rd, 2021


Dr.-Ing. Harald Drück

- Head of test section solar -

Appendix A: Explanations

The following pages contain additional explanations and information related to the store test report. For a better understanding, some facts will be explained by examples and complex correlations will be shown in a simplified way.

Definition of terms

For the tested store the hot water is heated before draw off and then kept ready for use. According to DIN 4753 (water heaters and water heating installations for drinking water and service water) these stores or water heaters are named **store-water heaters**. For better readability of this text the term **store** is used in the following.

1 Schematic Design

Here the schematic design of the store as well as the positions of the connections and temperature sensors are shown according to the specifications of the manufacturer.

2 Test results

The *maximum lenght* and the *maximum diameter* have been measured at the test sample equipped with thermal insulation.

The *diameter of the water volume* was taken from the documentation.

The *height of the water volume* corresponds to the *diameter of the water volume*.

For the determination of all *thermal parameters* water was used as heat transfer fluid. Here the thermophysical properties for the density ($\rho = 992.42 \text{ kg/m}^3$) and the specific heat capacity ($c_p = 4.181 \text{ kJ/(kg}\cdot\text{K)}$), averaged over the common range of the operating temperature ($15^\circ\text{C} - 60^\circ\text{C}$) are assumed to be constant.

The *heat loss capacity rate* describes the heat losses from store to ambient per Kelvin temperature difference (between store and ambient). For this purpose, the hot water store was charged via connections A3a (inlet) and A4 (outlet) with a capacity of 2 kW and a volume flow of approx. 240 l/h until the outlet temperature reached 60°C . This was followed by a standby phase of 48 h. After this, the hot water store was discharged via connections A1 (inlet) and A2 (outlet) at a constant inlet temperature of 20°C and a volume flow of approx. 150 l/h.

The meaning of the heat loss capacity rate is illustrated in the following example for a solar domestic hot water system.

Example for the heat loss capacity rate of the store:

If the entire store has a uniform temperature of 60°C located in a room with a temperature of 20°C the relevant temperature difference between the water in the store and the ambient is 40 K. Furthermore assuming a heat loss capacity rate of 2,5 W/K the flow of heat loss $\dot{Q}_{\text{loss}}$ from the store to the ambient is calculated according to the following equation:

$$\dot{Q}_{\text{loss}} = 2,5 \text{ W/K} \cdot (60 - 20)\text{K} = 100 \text{ W}$$

100 W seems to be a marginal power compared to the power of the collector field which is about 2500 W (irradiation 800 W/m², collector area 5 m², $\eta = 80 \%$). However the heat losses occur for 24 hours a day, and so the store is losing 2,4 kWh each day. Compared with the daily hot water energy consumption of 8 kWh, (typical for a four person household), the energy loss is about 30 %!

As shown by this example, the heat loss capacity rate has an important influence on the performance of the system. Hence it should be as low as possible.



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Test Report Hot Water Store Determination of heat losses according to EN 12977-3:2018

Test Report No.: 21STO397OEM03

Stuttgart, November 3rd, 2021

Claimant:	ECOFER OIKONOMOU Z. KOSTAS Xanthippou 150 15669 Papagou Athens Greece
Manufacturer:	ECOFER OIKONOMOU Z. KOSTAS
Store Type:	ECOFER SMARTECO 300
Construction Year:	2021

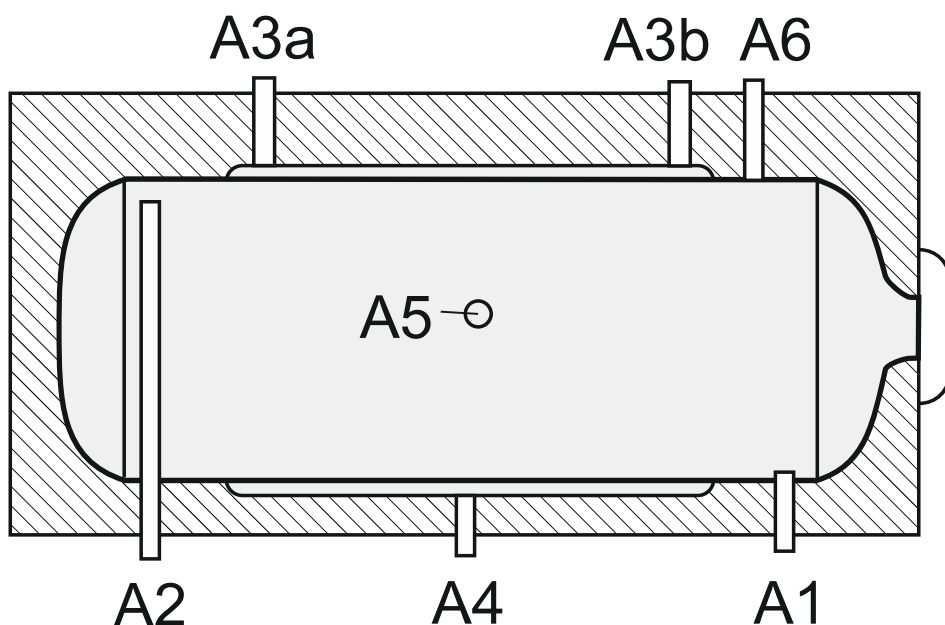
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1 Technical Data¹			
Manufacturer:		Type:	
ECOFER OIKONOMOU Z. KOSTAS		ECOFER SMARTECO 300	
Year:	Serial No.:	Nominal volume:	Design:
2021	not specified	300 liters	Horizontal thermosiphon solar domestic hot water store
Heat output or coefficient of performance:		Test acc. to DIN 4753	Weight (empty):
no reference		no reference	102.0 kg
Water volume:			
Corrosion protection:		Enamel Powder Coated, Magnesium Anode	
Max operation pressure:		10 bar	
Max operation temperature:		95 °C	
Thermal insulation:		Polyurethane: 50 mm	
Mantle Heat exchanger			
Max operation pressure [bar]:		3.0	
Max operation temperature [°C]:		95	
Volume of heat exchanger [liters]:		9.2	
Area [m ²]:		1.53	

¹ as stated by the manufacturer

2 Schematic design²



Connections

	Type	Application
A1	AT 1/2"	Cold water
A2	AT 1/2"	Hot water
A3a	AT 1/2"	ventilation
A3b	AT 1/2"	ventilation
A4	AT 3/4"	Collector loop, return (outlet)
A5	AT 3/4"	Collector loop, flow (inlet)
A6	AT 1/2"	Ventilation / P/T valve connection

AT = outside thread

IT = inside thread

² as stated by the manufacturer

3 Test results

3.1 Geometrical Data			
Maximum lenght:	Max.diameter:	Height of water volume:	Diameter of water volume:
1.84 m	0.58 m	0.48 m	0.48 m
3.2 Volumes			
Domestic hot water volume:		Heat exchanger:	
295.5 liters		10.0 liters	
3.3 Thermal parameters			
Heat loss capacity rate (standby):	Standing loss power S ³ :		Thermal losses Q _{PR} ³
2.45 W/K	110.3 W		2.65 kWh/24h

Table 1: Equivalent Energy efficiency classes for a hot water store with a rated capacity of 300.0 l according to SASO 2884:2017

Equivalent energy efficiency class	Daily thermal losses limit value [kWh/24h]
A	0.88
B	1.20
C	1.48
D	2.34
E	2.93
F	3.84
G	> 3.84

³ at a temperature difference of 45 K

4 Test occurrences

No special incidents

5 General

The thermal testing of the store was performed according to EN 12977-3:2018 *'Thermal solar systems and components, Custom built systems, Part 3: Performance test methods for solar water heater stores'*.

The **bold** printed values were determined by means of parameter identification.

The determined results are only valid for the tested version of the test sample.

Water was used as heat transfer fluid.

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The nomenclature of SASO 2884:2017 and EN 12977-3:2018 was used.

Arrival of test sample:	04.05.2021
Testing period:	11.05. bis 15.05.2021
Test location:	Stuttgart, Pfaffenwaldring 10
Identification of test sample:	Adhesive label: 21STO397
Test engineer:	Dipl.-Ing. S. Bachmann

Stuttgart, November 3rd, 2021



Dr.-Ing. Harald Drück

- Head of test section solar -

Appendix A: Explanations

The following pages contain additional explanations and information related to the store test report. For a better understanding, some facts will be explained by examples and complex correlations will be shown in a simplified way.

Definition of terms

For the tested store the hot water is heated before draw off and then kept ready for use. According to DIN 4753 (water heaters and water heating installations for drinking water and service water) these stores or water heaters are named **store-water heaters**. For better readability of this text the term **store** is used in the following.

1 Schematic Design

Here the schematic design of the store as well as the positions of the connections and temperature sensors are shown according to the specifications of the manufacturer.

2 Test results

The *maximum lenght* and the *maximum diameter* have been measured at the test sample equipped with thermal insulation.

The *diameter of the water volume* was taken from the documentation.

The *height of the water volume* corresponds to the *diameter of the water volume*.

For the determination of all *thermal parameters* water was used as heat transfer fluid. Here the thermophysical properties for the density ($\rho = 992.42 \text{ kg/m}^3$) and the specific heat capacity ($c_p = 4.181 \text{ kJ/(kg}\cdot\text{K)}$), averaged over the common range of the operating temperature ($15^\circ\text{C} - 60^\circ\text{C}$) are assumed to be constant.

The *heat loss capacity rate* describes the heat losses from store to ambient per Kelvin temperature difference (between store and ambient). For this purpose, the hot water store was charged via connections A3a (inlet) and A4 (outlet) with a capacity of 3 kW and a volume flow of approx. 360 l/h until the outlet temperature reached 60°C . This was followed by a standby phase of 60 h. After this, the hot water store was discharged via connections A1 (inlet) and A2 (outlet) at a constant inlet temperature of 20°C and a volume flow of approx. 150 l/h.

The meaning of the heat loss capacity rate is illustrated in the following example for a solar domestic hot water system.

Example for the heat loss capacity rate of the store:

If the entire store has a uniform temperature of 60°C located in a room with a temperature of 20°C the relevant temperature difference between the water in the store and the ambient is 40 K. Furthermore assuming a heat loss capacity rate of $2,5 \text{ W/K}$ the flow of heat loss $\dot{Q}_{\text{loss}}$ from the store to the ambient is calculated according to the following equation:

$$\dot{Q}_{\text{loss}} = 2,5 \text{ W/K} \cdot (60 - 20)\text{K} = 100 \text{ W}$$

100 W seems to be a marginal power compared to the power of the collector field which is about 2500 W (irradiation 800 W/m², collector area 5 m², $\eta = 80 \%$). However the heat losses occur for 24 hours a day, and so the store is losing 2,4 kWh each day. Compared with the daily hot water energy consumption of 8 kWh, (typical for a four person household), the energy loss is about 30 %!

As shown by this example, the heat loss capacity rate has an important influence on the performance of the system. Hence it should be as low as possible.



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Research and Testing Center for Thermal Solar
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University of Stuttgart



Test Report

Solar Water Heater

Determination of energy efficiency according to SASO 2884:2017

Test Report No.: 21SU128OEM03

Stuttgart, November 3rd, 2021

Claimant:	ECOFER OIKONOMOU Z. KOSTAS Xanthippou 150 15669 Papagou Athens Greece
Manufacturer:	ECOFER OIKONOMOU Z. KOSTAS
System:	ECOFER SMARTSOL 200.25
Store:	ECOFER SMARTECO 200
Collector:	ECOFER SMARTEVO 25
Construction Year:	2021

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1 Technical data of store¹

Manufacturer: ECOFER OIKONOMOU Z. KOSTAS			Product type: ECOFER SMARTECO 200
Model year: 2021	Serial No.: not specified	Rated capacity: 200 liters	Design: Horizontal thermosiphon solar domestic hot water store
Country of manufacture: Europe	Length ² : 1.29 m	Diameter ² : 0.58 m	Weight (empty): 69.0 kg
Water volume:			
Corrosion protection:		Enamel Powder Coated, Magnesium Anode	
Max operation pressure:		10 bar	
Max operation temperature:		95 °C	
Thermal insulation:		Polyurethane: 50 mm	
Mantle Heat exchanger			
Max operation pressure [bar]:		3.0	
Max operation temperature [°C]:		95	
Volume of heat exchanger [liters]:		6.5	
Area [m ²]:		0.96	

¹ as stated by the manufacturer

² with insulation

2 Technical data of collector³			
Manufacturer: ECOFER OIKONOMOU Z. KOSTAS			Type: ECOFER SMARTEVO 25
Year: 2021	Serial No.: not specified	Weight (empty): 35.0 kg	Design: Flat plate collector
Gross area			2.52 m ²
Absorber area			2.31 m ²
Length			2.006 m
Width			1.257 m
Height			0.085 m
Max. operating pressure			10 bar
Absorber volume			1.9 liters
Stagnation temperature ⁴			230 °C

³ as stated by the manufacturer

⁴ determined by test laboratory

3. Calculation of the water heating energy efficiency η_{WH}

The water heating energy efficiency η_{WH} of the solar water heater is determined according to SASO 2884:2017, chapter C3.2.

3.1 Parameters of the storage tank

Type:	ECOFER SMARTECO 200
Rated capacity:	200 l
Total store volume $V_{sto,tot}$:	202.5 l
Auxiliary store volume $V_{sto,bu}$:	101.3 l
Heat loss rate of the whole store $H_{sto,los,tot}$:	1.95 W/K
Rated thermal losses Q_{PR} :	2.11 kWh/24h
For further details see:	Test report: 21STO396OEM03, dated 03.11.2021 Test Institute: IGTE Universität Stuttgart

3.2 Parameters of the solar collector

Type:	ECOFER SMARTEVO 25
Gross area A_G :	2.52 m ²
Zero-loss efficiency η_0 :	0.746
First-order coefficient a_1 :	3.26
Second-order coefficient a_2 :	0.01
Incidence angle modifier $K_{hem}(50^\circ)$:	0.96
Number of collectors	1
For further details see:	Test report: 21COL1591OEM03, dated 03.11.2021 Test Institute: IGTE Universität Stuttgart

3.3 Further parameters

Daily hot water load (tapping profile) Q_{ref} : "M"	5.85 kWh
Conversion coefficient CC according to SASO 2884:2017:	1
Auxiliary electric consumption Q_{aux} (no controller):	0 kWh
Heat generator water heating energy efficiency $\eta_{WH,nonsol}$ (electric heating element):	1
Monthly average cold water temperature $\vartheta_{w,low}$ according to EN 15316-4-3:2014:	10 °C
Hot water temperature $\vartheta_{w,high}$ according to EN 15316-4-3:2014:	40 °C
Power collector loop pump $P_{sol;pmp}$ (no pump, thermosiphon system):	0 W
Correction coefficient for the orientation of the collector f_{col} : according to table A.9, EN 15316-4-3:2014	0.8
Type of system according to EN 15316-4-3:2014 (SOL_TYPE):	parallel
Efficiency factor of the collector loop η_{loop} according to EN 15316-4-3:2014, table A.11	0.9
Correction coefficient f_{app} according to EN 15316-4-3:2014, table A.18	1.08

Correlation factor a according to EN 15316-4-3:2017, table A.18	1.029
Correlation factor b according to EN 15316-4-3:2017, table A.18	-0.065
Correlation factor c according to EN 15316-4-3:2017, table A.18	-0.245
Correlation factor d according to EN 15316-4-3:2017, table A.18	0.0018
Correlation factor e according to EN 15316-4-3:2017, table A.18	0.0215
Correlation factor f according to EN 15316-4-3:2017, table A.18	0
Factor describing the effect of insulation of the auxiliary heating loop $f_{bu,ins}$ according to EN 15316-4-3:2017, table B.14	0.02
recoverable heat losses of the solar system $Q_{x,sol;ls;rbl,m}$ (without solar space heating system):	0 kWh
Annual operation time for solar loop pump t_{aux} according to EN 15316-4-3:2017, table B.13	2000 h
Annual global irradiation $I_{glob,ref}$ according to SASO 2884:2017, table B2	1848 kWh/m ²
Auxiliary energy consumption of the auxiliary heat generator $W_{x;bu;aux;nom,m}$:	0 kWh
Heat losses of the auxiliary heat generator $Q_{x;bu;ls;nom,m}$:	0 kWh

3.4 Results

Table 1: Monthly Contribution of the auxiliary heater to the heat demand $Q_{w;bu,out,m}$ [kWh]

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
111.8	82.6	65.3	43.6	31.8	24.3	21.1	21.8	39.5	66.0	98.3	121.9

The annual non-solar heat contribution $Q_{non,sol}$ is calculated according to equation 1:

$$Q_{non,sol} = \sum_{m=1}^{12} Q_{w,bu,out,m} = 728.0 \text{ kWh} \quad (1)$$

The annual energy consumption Q_{tota} is calculated according to equation 2:

$$Q_{tota} = \frac{Q_{non,sol}}{1.1 \times \eta_{WH,nonsol} - 0.1} + Q_{aux} \times CC = 728.0 \text{ kWh} \quad (2)$$

The water heating energy efficiency η_{WH} is calculated according to equation 3:

$$\eta_{WH} = \frac{220 \times Q_{ref}}{Q_{tota}} = 176.8 \% \quad (3)$$

Table 2: Energy efficiency classification for load profile “M” according to SASO 2884:2017:

Energy class	A	B	C	D	E	F	G
$\eta_{WH} [\%]$	210	140	93	87	80	73	65

4 Test occurrences

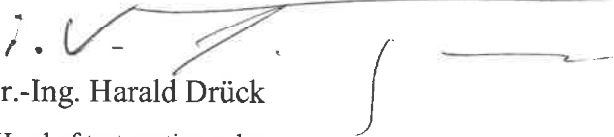
No special incidents

5 General

The determined results are only valid for the tested versions of the test samples.
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The nomenclature of SASO 2884:2017 and EN 15316-4-3:2014/2017 was used.

Arrival of test samples:	27.01.2021 (collector), 04.05.2021 (storage tank)
Testing period:	12.02. bis 10.05.2021
Test location:	Stuttgart, Pfaffenwaldring 10
Identification of test samples:	Adhesive label: 21STO396, 21COL1591
Test engineer:	Dipl.-Ing. S. Bachmann, F. Sansonnens

Stuttgart, November 3rd, 2021


Dr.-Ing. Harald Drück

- Head of test section solar -



**Institute for Building Energetics,
Thermotechnology and Energy Storage**
Research and Testing Center for Thermal Solar
Systems (TZS)
University of Stuttgart



Test Report

Solar Water Heater

Determination of energy efficiency according to SASO 2884:2017

Test Report No.: 21SU129OEM03

Stuttgart, November 3rd, 2021

Claimant:	ECOFER OIKONOMOU Z. KOSTAS Xanthippou 150 15669 Papagou Athens Greece
Manufacturer:	ECOFER OIKONOMOU Z. KOSTAS
System:	ECOFER SMARTSOL 300.40
Store:	ECOFER SMARTECO 300
Collector:	ECOFER SMARTEVO 20
Construction Year:	2021

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1 Technical data of store¹

Manufacturer: ECOFER OIKONOMOU Z. KOSTAS			Product type: ECOFER SMARTECO 300
Model year: 2021	Serial No.: not specified	Rated capacity: 300 liters	Design: Horizontal thermosiphon solar domestic hot water store
Country of manufacture: Europe	Length ² : 1.84 m	Diameter ² : 0.58 m	Weight (empty): 102.0 kg
Water volume:			
Corrosion protection:		Enamel Powder Coated, Magnesium Anode	
Max operation pressure:		10 bar	
Max operation temperature:		95 °C	
Thermal insulation:		Polyurethane: 50 mm	
Mantle Heat exchanger			
Max operation pressure [bar]:		3.0	
Max operation temperature [°C]:		95	
Volume of heat exchanger [liters]:		9.2	
Area [m ²]:		1.53	

¹ as stated by the manufacturer

² with insulation

2 Technical data of collector³

Manufacturer: ECOFER OIKONOMOU Z. KOSTAS			Type: ECOFER SMARTEVO 20
Year: 2021	Serial No.: not specified	Weight (empty): 27.0 kg	Design: Flat plate collector
Gross area			2.02 m ²
Absorber area			1.83 m ²
Length			2.006 m
Width			1.007 m
Height			0.085 m
Max. operating pressure			10 bar
Absorber volume			1.6 liters
Stagnation temperature ⁴			230 °C

³ as stated by the manufacturer

⁴ determined by test laboratory

3. Calculation of the water heating energy efficiency η_{WH}

The water heating energy efficiency η_{WH} of the solar water heater is determined according to SASO 2884:2017, chapter C3.2.

3.1 Parameters of the storage tank

Type:	ECOFER SMARTECO 300
Rated capacity:	300 l
Total store volume $V_{sto,tot}$:	305.5 l
Auxiliary store volume $V_{sto,bu}$:	152.8 l
Heat loss rate of the whole store $H_{sto,los,tot}$:	2.45 W/K
Rated thermal losses Q_{PR} :	2.65 kWh/24h
For further details see:	Test report: 21STO397OEM03, dated 03.11.2021 Test Institute: IGTE Universität Stuttgart

3.2 Parameters of the solar collector

Type:	ECOFER SMARTEVO 20
Gross area A_G :	2.02 m ²
Zero-loss efficiency η_0 :	0.737
First-order coefficient a_1 :	3.39
Second-order coefficient a_2 :	0.01
Incidence angle modifier $K_{hem}(50^\circ)$:	0.94
Number of collectors	2
For further details see:	Test report: 21COL1590OEM03, dated 03.11.2021 Test Institute: IGTE Universität Stuttgart

3.3 Further parameters

Daily hot water load (tapping profile) Q_{ref} : "M"	5.85 kWh
Conversion coefficient CC according to SASO 2884:2017:	1
Auxiliary electric consumption Q_{aux} (no controller):	0 kWh
Heat generator water heating energy efficiency $\eta_{WH,nonsol}$ (electric heating element):	1
Monthly average cold water temperature $\vartheta_{w,low}$ according to EN 15316-4-3:2014:	10 °C
Hot water temperature $\vartheta_{w,high}$ according to EN 15316-4-3:2014:	40 °C
Power collector loop pump $P_{sol;pmp}$ (no pump, thermosiphon system):	0 W
Correction coefficient for the orientation of the collector f_{col} : according to table A.9, EN 15316-4-3:2014	0.8
Type of system according to EN 15316-4-3:2014 (SOL_TYPE):	parallel
Efficiency factor of the collector loop η_{loop} according to EN 15316-4-3:2014, table A.11	0.9

Correction coefficient f_{app} according to EN 15316-4-3:2014, table A.18	1.08
Correlation factor a according to EN 15316-4-3:2017, table A.18	1.029
Correlation factor b according to EN 15316-4-3:2017, table A.18	-0.065
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Correlation factor e according to EN 15316-4-3:2017, table A.18	0.0215
Correlation factor f according to EN 15316-4-3:2017, table A.18	0
Factor describing the effect of insulation of the auxiliary heating loop $f_{bu;ins}$ according to EN 15316-4-3:2017, table B.14	0.02
recoverable heat losses of the solar system $Q_{x;sol;ls;rbl,m}$ (without solar space heating system):	0 kWh
Annual operation time for solar loop pump t_{aux} according to EN 15316-4-3:2017, table B.13	2000 h
Annual global irradiation $I_{glob,ref}$ according to SASO 2884:2017, table B2	1848 kWh/m ²
Auxiliary energy consumption of the auxiliary heat generator $W_{x;bu;aux;nom,m}$:	0 kWh
Heat losses of the auxiliary heat generator $Q_{x;bu;ls;nom,m}$:	0 kWh

3.4 Results

Table 1: Monthly Contribution of the auxiliary heater to the heat demand $Q_{w;bu;out,m}$ [kWh]

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
104.5	75.1	59.8	42.2	32.8	24.6	22.1	20.9	35.0	57.3	89.9	116.8

The annual non-solar heat contribution $Q_{non,sol}$ is calculated according to equation 1:

$$Q_{non,sol} = \sum_{m=1}^{12} Q_{w,bu,out,m} = 681.0 \text{ kWh} \quad (1)$$

The annual energy consumption Q_{tota} is calculated according to equation 2:

$$Q_{tota} = \frac{Q_{non,sol}}{1.1 \times \eta_{WH,non,sol} - 0.1} + Q_{aux} \times CC = 681.0 \text{ kWh} \quad (2)$$

The water heating energy efficiency η_{WH} is calculated according to equation 3:

$$\eta_{WH} = \frac{220 \times Q_{ref}}{Q_{tota}} = 189.0 \% \quad (3)$$

Table 2: Energy efficiency classification for load profile “M” according to SASO 2884:2017:

Energy class	A	B	C	D	E	F	G
η_{WH} [%]	210	140	93	87	80	73	65

4 Test occurrences

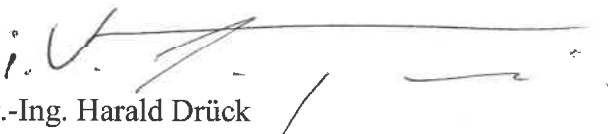
No special incidents

5 General

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Testing period:	10.02. bis 15.05.2021
Test location:	Stuttgart, Pfaffenwaldring 10
Identification of test samples:	Adhesive label: 21STO397, 21COL1590
Test engineer:	Dipl.-Ing. S. Bachmann, F. Sansonnens

Stuttgart, November 3rd, 2021


Dr.-Ing. Harald Drück
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