TASK 54

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Reference System, Germany

Solar Domestic Hot Water System for Single-Family House

INFO Sheet A08

Description:	*Definition of the reference solar domestic hot water (SDHW) system, Germany*
Date:	23.03.2018, revised 10.04.2018[1]
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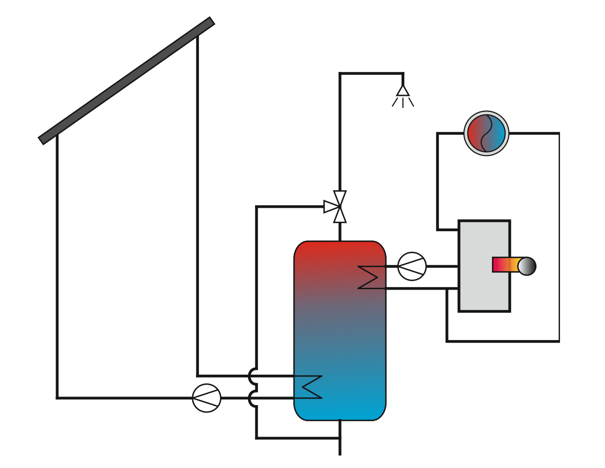
Download possible at:	http://task54.iea-shc.org/

Introduction

This document describes the reference solar domestic hot water (SDHW) system for domestic hot water preparation and space heating in Germany. The system is modelled with TRNSYS to calculate the fuel consumption and electric energy needed to provide the required domestic hot water and space heating as well as the substituted fuel provided by the SDHW system. Using this result the levelized costs of heating (LCoH) for the substituted fuel is calculated using eq. 1 and the reference costs for the investment of the system, installation costs, fuel and electricity costs.

Hydraulic Scheme of the System



Key data	
Collector area	5 m²
Heat store volume	300 l
Location	Germany, Würzburg
Hemispherical irradiance on horizontal surface	$\Sigma G_{hem,hor}$ =1118.8 kWh/(m^2 a)
Lifetime of system	20 years

Levelized Cost of Heat (LCoH)

LCoHs solar part without VAT	**0.141 €/kWh**
LCoHc conventional part without VAT	**0.116 €/kWh**
LCoHo complete system without VAT	**0.122 €/kWh**

Details of the system

Location	Germany, Würzburg
Type of system	Solar domestic hot water (SDHW) system
Weather data including - Hemispherical irradiance on horizontal surface - Beam irradiance on horizontal surface - Diffuse irradiance on horizontal surface - Ambient temperature in hourly values	test reference year (TRY Würzburg) $\Sigma G_{hem,hor}$ =1118.8 kWh/(m^2 a) $\Sigma G_{beam,hor}$ = 550.1 kWh/(m^2 a) $\Sigma G_{diff,hor}$ = 568.7 kWh/m^2 a) $T_{amb,av}$ = 9.0 °C
Collector orientation - Collector tilt angle to horizontal - South deviation of collector - Ground reflectance - Resulting hemispherical irradiance on tilted surface	 45 ° south = 0° 0.2 $\Sigma G_{hem,tilt}$ =1229.8 kWh/(m^2 a)
Load information including - Heat demand space heating - Tapping profile - Tapping temperature - Average inlet temperature of cold water - Cold water inlet temperature amplitude	 9090 kWh/a /1/ EU-tapping profile L (4254 kWh/a) /2/ 55°C according EU tapping profile 10°C 0 K
Collector information based on gross area	**TRNSYS-type 132**
Number of collectors	2
Collector area of one collector	2.5 m^2
Maximum collector efficiency	0.684
Incidence angle modifier for direct irradiance b_0	0.2
Incidence angle modifier for diffuse irradiance K_d	0.91
Linear heat loss coefficient a_1	3.51 W/(m^{2}K)
2nd order heat loss coefficient a_2	0.011 W/(m^{2}K^2)
Effective heat capacity c_{eff}	8.0 kJ/(m^{2}K)
Heat store parameters	**TRNSYS-type 340**
Heat store volume	300 l
Auxiliary volume for DHW preparation	150 l
Store inner diameter	0.6 m
Rel. height of solar inlet	0.4
Rel. height of solar outlet	0.04
Rel. height of auxiliary inlet	0.8
Rel. height of auxiliary outlet	0.5
Rel. height of sensor for collector loop	0.2
Rel. height of sensor for auxiliary heating	0.7
Set temperature for DHW	57.5 °C +- 2.5 K
Overall heat loss capacity rate of store	3.56 W/K
Effective vertical conductivity	1.2 W/(mK)

Heat transfer capacity rate of solar loop HX	$(kA)_{WT,Sol} = 102{,}7 \cdot \dot{m}^{0{,}226} \cdot \vartheta_m^{0{,}550}$ [W/K]
Heat transfer capacity rate of auxiliary loop HX	$(kA)_{WT,Aux} = 82{,}3 \cdot \dot{m}^{0{,}185} \cdot \vartheta_m^{0{,}482}$ [W/K]
Volume solar loop HX	10 l
Volume auxiliary loop HX	6 l
Maximum heat store temperature	90 °C
Ambient temperature of heat store	15 °C
Solar thermal controller and hydraulic piping	
Total pipe length of collector loop	20 m
Inner diameter of collector loop pipe	16 mm
Ambient temperature of heat store	15 °C
Mass flow collector loop	40 kg/(m^2h), constant
Temperature difference collector start-up	6 K
Temperature difference collector shut-off	4 K
Electric power of solar thermal controller	3 W
Operating hours of solar thermal controller per year	8760 h
Electric consumption of controller per year	26.3 kWh
Electric power of solar loop pump	40 W
Operating hours of solar loop pump	1277 h (L-profile), 929 h (M-profile)
Electric consumption of solar loop pump per year	51.1 kWh (L-profile), 37.2 kWh (M-profile)
Conventional back up system	
Type of auxiliary heating	Gas condensing boiler
Boiler capacity	19 kW
Mass flow	1090 kg/h (ΔT = 15 K)
Efficiency factor of boiler	0.9
Electric power of controller	3 W
Operating hours of controller per year	8760
Electric consumption of controller per year	26.3 kWh
Electric power of pump	55 W
Operating hours of pump (aux. heating + space heating)	3999 h
Electric consumption of pump per year	220 kWh
Investment costs solar thermal system	
Solar thermal collector, heat store, solar thermal controller solar thermal hydraulic components	3600 € /5/
Installation	1250 € /5/
Credit conventional heat store and share of installation	-1000 €
Overall investment costs solar thermal part I_0	3850 €
Operation costs conventional part per year	
Heat demand hot water	3002 kWh/a
Fuel demand hot water	3335 kWh/a
Heat demand space heating	9090 kWh/a /1/
Fuel demand space heating	10100 kWh/a

Fuel demand hot water + space heating E_t	13435 kWh/a
Cost per kWh fuel (gas)	0.066 € kWh/a /4/
Fuel costs	887 €/a
Electricity demand	246 kWh/a
Cost per kWh electric energy /4/	0.254 €
Electricity costs	63 €/a
Maintenance costs	200 €/a /3/
Gas meter	130 €/a /3/
Yearly operation and maintenance cost conventional part C_t	1279 €
Operation costs solar part per year	
Electricity demand	83 kWh/a
Cost per kWh electric energy /4/	0.254 €
Electricity costs	21 €/a
Maintenance costs (I_0 * 2%)	100 €/a
Yearly operation and maintenance cost solar part C_t	121 €/a
Fractional energy savings with credit for 150l-store, UA=2,05 W/K	40 %
Saved final energy (year t) E_t	2226 kWh
Type of incentives	None
Amount of incentives	0 €
Lifetime of system	20 year
Discount rate r	0 %
Inflation rate	0 %
Corporate tax rate TR	0 %
Asset depreciation (year t) DEP_t	0 €
Subsidies and incentives (year t) S_t (considered in I_0)	0 €
Residual value RV	0 €
Discount rate r	0 %
VAT rate	19 %

Calculation of levelized cost LCoH:

$$LCoH = \frac{I_0 - S_0 + \sum_{t=1}^{T} \frac{C_t(1-TR) - DEP_t \cdot TR}{(1+r)^t} - \frac{RV}{(1+r)^T}}{\sum_{t=1}^{T} \frac{E_t}{(1+r)^t}}$$

Where:

$LCoH$: levelized cost of heat in €/kWh
I_0: initial investment in €
S_0: subsidies and incentives in €
C_t: operation and maintenance costs (year t) in €
TR: corporate tax rate in %
DEP_t: asset depreciation (year t) in €
RV: residual value in €
E_t: saved final energy (year t) in kWh
r: discount rate in %
T: period of analysis in years

Annex: Comparison to figures published in Solar Heat Worldwide

To compare the above presented LCoHs based on the saved final energy with the $LCoH_{SHWW}$ presented in Solar Heat World Wide based on the collector yield the following table is presented

Collector yield (year t) E_t	2288 kWh
$LCoH_{SHWW}$ solar part without VAT	**0.105 €/kWh**

References

[1] EN 12977-2 (2012): "*Thermal solar systems and components – Custom built systems – Part 2: Test methods for solar water heaters and combisystems*".

[2] COMMISSION DELEGATED REGULATION (EU) No 812/2013, ANNEX VII.

[3] Hafner, B. (2016): "*E-Mail*". Dated 13.06.2016.

[4] Check24 (2016): "*Würzburg reference costs*". URL: www.check24.com (accessed in Sept. 2016).

[5] Mean values of evaluated invoices, supplied by Bafa.

[6] Louvet, Y., Fischer, S. et. al. (2017): "*IEA SHC Task 54 Info Sheet A1: Guideline for levelized cost of heat (LCoH) calculations for solar thermal applications*". URL: http://task54.iea-shc.org/.

[7] Louvet, Y., Fischer, S. et.al. (2017): "*Entwicklung einer Richtlinie für die Wirtschaftlichkeitsberechnung solarthermischer Anlagen: die LCoH Methode*". Symposium Thermische Solarenergie, Bad Staffelstein.

[1] To avoid confusion with the results of other works ([1], [8], [9]) also using the notion of LCoH for solar thermal systems, new acronyms were introduced in this Info Sheet. As previous studies have considered different assumptions for the definition of the terms of the LCoH equation, it does not make sense to compare the values they obtained with the LCoHs, LCoHc and LCoHo values defined here. A detailed explanation of the differences between the approaches chosen in the framework of IEA-SHC Task 54 and in the Solar Heat Worldwide report [9] can be found in Info Sheet A13 [10].