Reference System, Germany
Solar Combisystem for Multi-Family House

INFO Sheet A 10

Description:	*Definition of reference solar combi system for multifamily houses (MFH), Germany*
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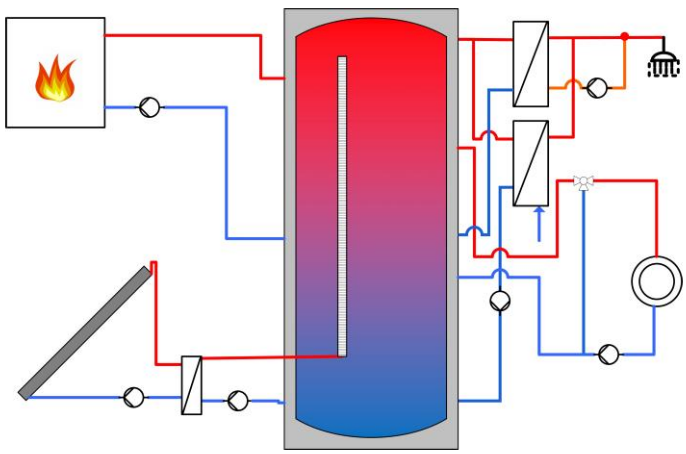
Download possible at:	http://task54.iea-shc.org/

Introduction

This document describes the reference solar combi system for domestic hot water preparation and space heating in multifamily houses (MFH) 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 combi system. Using these results the levelized cost of heat (LCOH) for the substituted fuel is calculated using eq. 1 and the reference costs for the investment of the system, installation, fuel and electricity costs. System model and cost assumptions are based on [1] and [2].

Hydraulic Scheme of the System



Key data	
Collector area	33 m²
Heat store volume	1500 l
Location/ weather data	Wuerzburg, Germany
Hemispherical irradiance on horizontal surface	$\Sigma G_{hem,hor}$ =1120 kWh/(m^2 a)
Lifetime of system	25 years

Levelized Cost of Heat (LCoH)

$LCoH_{sol,fin}$ solar part without VAT	**0.112 €**
$LCoH_{conv,fin}$ conventional part without VAT	**0.103 €**
$LCoH_{ov,fin}$ complete system without VAT	**0.105 €**

Details of the System

Location	Wuerzburg, Germany
Type of system	Combisystem
Weather data - hemispherical irradiance on horizontal surface - beam irradiance on horizontal surface - diffuse irradiance on horizontal surface - ambient temperature in hourly values	TRY $\Sigma G_{hem,hor}$ =1120 kWh/(m^2 a) $\Sigma G_{beam,hor}$ = 550 kWh/(m^2 a) $\Sigma G_{diff,hor}$ = 569 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 $\Sigma G_{hem,tilt}$ =1190 kWh/(m^2 a)
Load information [1; 2] - heat demand space heating - tapping profile: DHW demand and circulation - store heat losses - tapping temperature - average inlet temperature of cold water - cold water inlet temperature amplitude	 20890 kWh/a (40 kWh/m²/a) 11872 kWh/a (23 kWh/m²/a) --> (DHW: 6088 kWh/a; circulation: 5784 kWh/a) 2290 kWh/a 45°C (circulation temperature: 65°C) 10°C 0 K
Building specification [2] - construction information - number of flats and size - DHW circulation	**TRNSYS-type 56 with 53 thermal zones** built in 1968, refurbished according to EnEV 2016 8 flats with each 65 m² living area 24 h/d with 150 kg/h
Collector information (based on gross area)	**TRNSYS-type 832v500**
number of collectors	14
collector area of one collector	2.35 m²
Maximum collector efficiency	0.81
incidence angle modifier for direct irradiance	0.89 (50°)
incidence angle modifier for diffuse Irradiance	0.92
linear heat loss coefficient	3.76 W/(m²K)
2nd order heat loss coefficient	0.0147 W/(m²K²)
effective heat capacity	7.0 kJ/(m²K)
Heat store parameters	**TRNSYS-type 340**
heat store volume	1500 l
auxiliary volume for DHW preparation	400 l
Store inner diameter	0.79

Rel. height of solar inlet	stratified charging
Rel. height of solar outlet	0.0
Rel. height of auxiliary inlet	0.85
Rel. height of auxiliary outlet	0.37
Rel. height of space heating inlet	0.28
Rel. height of space heating outlet	0.56
Rel. height of cold water inlet	0.0
Rel. height of hot water outlet	1.0
Rel. height of sensor for aux. charging	0.9
Rel. height of sensor for collector loop	0.0
overall heat loss capacity rate of store	5.76 W/K
effective vertical conductivity	1.2 W/(mK)
maximum heat store temperature	95 °C
ambient temperature of heat store	15 °C
Solar thermal controller and hydraulic piping	
total pipe length of collector loop	53.5 m
inner diameter of collector loop pipe	20 mm
temperature difference collector start-up	7 K
temperature difference collector shut-off	2 K
electric power of solar loop pump	80 W
Operating hours of solar loop pump	1800 h
Electric consumption of solar loop pump	144 kWh
electric consumption of other el. components	-
Conventional system	
auxiliary heater	**TRNSYS-type 203**
Type of auxiliary heating	Gas condensing boiler
boiler capacity	23.9 kW
Mass flow	variable: 700 to 2000 l/h
Efficiency factor of boiler	0.96
electric power of pumps	different
Operating hours of pump (aux. heating + space heating + DHW circulation)	1500 h +5000 h + 8760 h
electric consumption of pumps per year	200 kWh
Investment costs conventional system I_0 [2]	13350 €
Investment costs solar thermal system [2]	
solar thermal collector, heat store, solar thermal controller solar thermal hydraulic components	15984 €
Installation	6737 €
Credit conventional heat store and share of installation	-1538 €

Overall investment costs solar thermal part I_0	21183 €
Operation costs conventional part per year [2]	
Fuel demand hot water	10770 kWh/a
Fuel demand space heating	18959 kWh/a
Fuel demand hot water + space heating E_t	29729 kWh/a
Cost per kWh fuel (gas)	0.066 € kWh/a
Fuel costs	1962 €/a
Electricity demand	235 kWh/a
cost per kWh electric energy	0.254 €
electricity costs	59.7 €/a
Maintenance costs	368 €/a
Gas meter	130 €/a
yearly operation and maintenance cost conventional part C_t	2520 € /a
Operation costs solar part per year [2]	
Electricity demand	179 kWh/a
cost per kWh electric energy	0.254 €
electricity costs	45.5 €/a
Maintenance costs (I_0 * 2%)	217 €/a
yearly operation and maintenance cost solar part C_t	263 €/a
fractional energy savings	31 %
Saved final energy (year t) E_t	9873 kWh
type of incentives	None
amount of incentives	0 €
lifetime of system	25 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	0 %

Calculation of levelized cost LCoH [3; 4]:

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

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: Fuel demand (year t) in kWh
r: discount rate in %
T: period of analysis in year

Annex: Comparison to Figures Published in Solar Heat Worldwide

To compare the calculation of the LCoH based on the saved final energy with the $LCoH_{SHWW}$ featured in Solar Heat World Wide based on the collector yield the following table is presented.

Collector yield (year t) E_t	11005 kWh
$LCOH_{SHWW}$ solar part without VAT	**0.100 €**

References

[1] O. Arnold, O. Mercker, J. Steinweg, G. Rockendorf. Efficiency Analysis of Solar Assisted Heat Supply Systems in Multi-Family Houses (2017). Proceedings EuroSun 2016, Palma de Mallorca (Spain), 11 – 14 October 2016.

[2] S. Helbig, D. Eggert, M. Adam (2017). Energetic and Economic Efficiency Evaluation of Solar Assisted Heating Systems for Multi-Family Houses. Proceedings ISES/SHC Conference, Abu Dhabi (UAE), 29th October - 2nd November 2017.

[3] Y. Louvet, S. Fischer et. al. (2017). IEA SHC Task 54 Info Sheet A. 01: Guideline for levelized cost of heat (LCOH) calculations for solar thermal applications“, March 2017. Download: http://task54.iea-shc.org/.

[4] Y. Louvet, S. Fischer et al. (2017). Entwicklung einer Richtlinie für die Wirtschaftlichkeitsberechnung solarthermischer Anlagen: die LCOH Methode. Proceedings Symposium Thermische Solarenergie, Bad Staffelstein (DE), 10th – 12nd May 2017.

[5] F. Mauthner, W. Weiss, M. Spörk-Dür (2017). Solar Heat Worldwide - Markets and Contribution to the Energy Supply 2016 - 2017 Edition. SHC/AEE Intec.