Structure of the Reference Buildings of Task 26

A Report of IEA SHC - Task 26

Solar Combisystems

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Wolfgang Streicher
Richard Heimrath

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by

Wolfgang Streicher* and Richard Heimrath*

A technical report of Subtask C

*Institute of Thermal Engineering
Graz University of Technology
Austria

Contents

1 Introduction

Three single-family houses (SFH) with the same geometry but different building physics data were defined in a way that the specific annual space heating demand for the Zurich (Switzerland) climate amounts to 30, 60 and 100 kWh/m^{2}a. Additionally, a multi-family house (MFH) with 5 apartments and a specific annual space heating demand for Zurich of 45 kWh/m^{2}a was defined. Chapter 3 shows the principal design of the buildings. In chapter 4 the internal gains by persons and others, the ventilation rate and the building physics data are given. Chapter 5 summarizes the technical data of the heat distribution system and the design space heating load for the reference buildings.

2 Requirements of building and users

Table 1 shows the reference space-heating load according to the ambient design temperature and the layout characteristics of the radiator heat distribution system.

Table 1 Reference data for single-family house with 140 m² gross area (Zurich conditions)

space heating demand $^{*)}$ [kWh/m² a]	**design temp. for heat distribution system [°C]**	**Δt heat distribution system [K]**	**name of *.bui-file**
100	60 (45$^{**)}$)	10(5$^{**)}$)	Refbu1oz.bui
60	40	5	Refbu6oz.bui
30	35	5	Refbu3oz.bui
45$^{***)}$	40	5	Refbumf.bui

$^{*)}$... gross area
$^{**)}$ ... recommended for the French solar floor system
$^{***)}$ ... multi-family house with flats - 100 m² gross area

Room temperature:
The controls of the heating system were set in a way, that the room temperature is kept around t_R = 20 ± 0.5 °C and never drops below 19.5 °C during heating season. For buildings with floor heating system which use the thermal mass of the floor as a heat storage, the room temperature was allowed to range from 19.5 to 24 °C. Temperatures above 24 °C were excluded for the analysis because solar combisystems for heating purposes and not the buildings (with their specific overheating characteristic) were to be compared. If the required room temperature range is not reached, a penalty function optionally adds extra auxiliary energy (ref. [1]).

Ventilation:
The air change rate of ventilation is assumed to be 0.4 h^{-1} based on the gross volume of the building. This rate is assumed in most European standards. No air heat recovery system was used.

Shading:
There was no internal or external shading device used, because only the heating period was analysed and shading is mainly used in times where overheating occurs and no space heating is needed.

3 Design of the reference houses

Figure 1 and Figure 2 show the principal design of the reference buildings of task 26.

Single-family house (SFH)

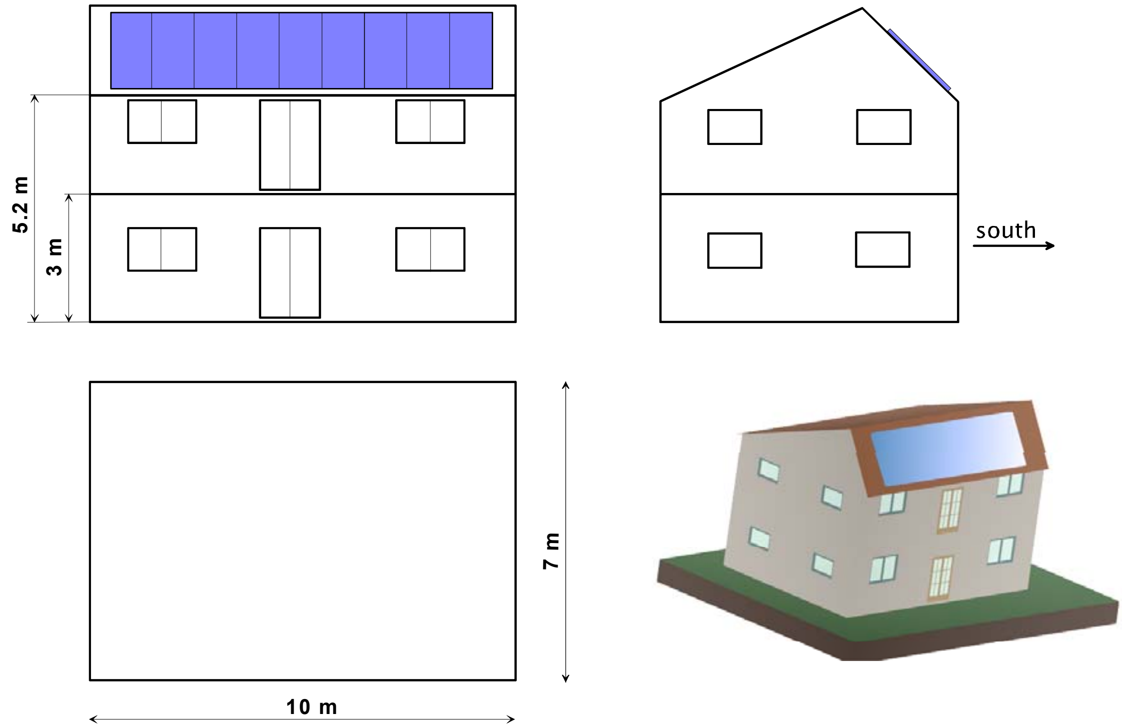

Figure 1: Sketch of the single-family house (SFH) used in Task 26

Multi-family house (MFH)

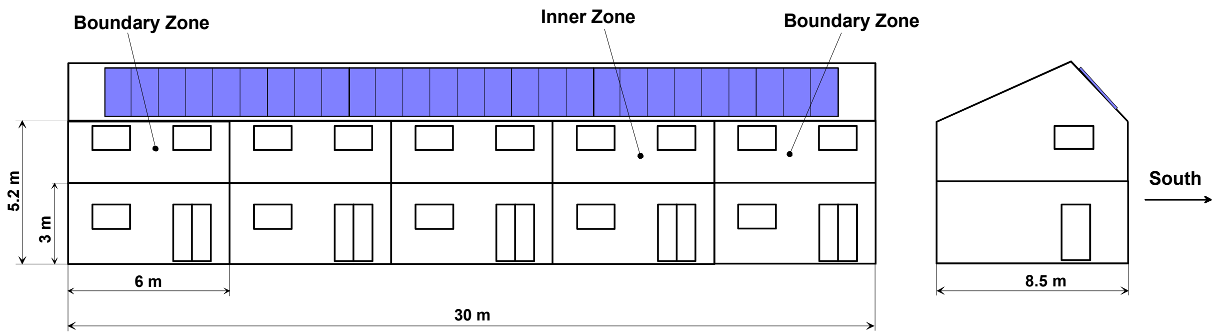

Figure 2: Sketch of the multi-family house (MFH) used in Task 26

4 Building physics data

30 kWh/m²a Single-family building (SFH)

The building is calculated with a single zone model. The window type was chosen with type 4002 (TRNSYS windows library) , u-value: 0.4 W/m²K, g-value: 0.408. Table 2 shows the chosen window areas and Table 3 the building physics data for the constructive elements of the 30 kWh/m²a single-family house (SFH). Additionally the internal heat gains and the ventilation rate are given below.

Table 2: Window areas in m² for the 30 kWh/m²a single-family house (SFH)

	East	West	North	South
Zone One	4	4	3	12

Internal Heat Gains

Zone One: 2 Persons 8 h seated at rest (ISO 7730 [3]), (100 W) and 1 Person 9,5 h seated eating (ISO 7730 [3]) (100 W)
Other gains: 700 kJ/h, constant (~195 W)

Table 3: Building physics data for the constructive elements of the 30 kWh/m²a single-family house (SFH)

Wall to external (from inside to outside), u-value: 0.135 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum/plate	0.013	0.76	1	900
Wood	0.015	0.54	1	100
Rockwool	0.280	0.144	0.8	80
Gypsum/plate	0.013	0.76	1	900
Plaster	0.020	5.04	1	2000

Roof (from inside to outside), u-value: 0.107 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum/plate	0.026	0.76	1	900
Wood	0.015	0.54	1	800
Rockwool	0.320	0.13	0.9	40
Wood	0.015	0.54	1	800

Ground-Floor (from inside to outside), u-value: 0.118 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Wood	0.015	0.47	1	600
Flooring	0.060	5.04	1	2000
Polyurethane	0.090	0.09	2.09	40
Polystyrene	0.160	0.13	1.25	25
Concrete	0.160	5.76	1	2000

Internal Wall (from inside to outside), u-value: 2.686 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Brick	0.200	3.56	1	1500

60 kWh/m²a Single-family building (SFH)

The building is calculated with a single zone model. The window type was chosen with type 2001 (TRNSYS windows library) , u-value: 1.4 W/m²K, g-value: 0.589. Table 4 shows the chosen window areas and Table 5 the building physics data for the constructive elements of the 60 kWh/m²a single-family house (SFH). Additionally the internal heat gains and the ventilation rate are given below.

Table 4 Window areas in m² for the 60 kWh/m²a single-family house (SFH)

	East	West	North	South
Zone One	4	4	3	12

Internal Heat Gains

Zone One: 2 Persons 8 h seated at rest (ISO 7730 [3]), (100 W) and 1 Person 9,5 h seated eating (ISO 7730 [3]) (100 W)
Other gains: 700 kJ/h, constant (~195 W)

Table 5: Building physics data for the constructive elements of the 60 kWh/m²a single-family house (SFH)

Wall to external (from inside to outside), u-value: 0.342 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum	0.01	1.26	1	1200
Brick	0.38	1.3	1	700
Polystyrene	0.06	0.13	1.25	25
Plaster	0.02	5.04	1	2000

Roof (from inside to outside), u-value: 0.227 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum/plate	0.02	0.76	1	900
Wood-Rockwool-comb.	0.24	0.216	1.12	144
Wood	0.02	0.54	1	800

Ground-Floor (from inside to outside), u-value: 0.196 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Wood	0.012	0.47	1	600
Flooring	0.06	5.04	1	2000
Polystyrene	0.18	0.14	1.25	30
Concrete	0.25	5.76	1	2000

Internal Wall (from inside to outside), u-value: 2.686 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Brick	0.2	3.56	1	1500

100 kWh/m²a Single-family building (SFH)

The building is calculated with a single zone model. The window type was chosen with type 1002 (TRNSYS windows library) , u-value: 2.8 W/m²K, g-value: 0.755. Table 6 shows the chosen window areas and Table 7 the building physics data for the constructive elements of the 100 kWh/m²a single-family house (SFH). Additionally the internal heat gains and the ventilation rate are given below.

Table 6 Window areas in m² for the 100 kWh/m²a single-family house (SFH)

	East	West	North	South
Zone One	4	4	3	12

Internal Heat Gains

Zone One: 2 Persons 8h seated at rest (ISO 7730 [3]) , (100 W) and 1 Person 9,5 h seated at rest (ISO 7730 [3])
Other gains: 700 kJ/h, constant

Table 7: Building physics data for the constructive elements of the 100 kWh/m²a single-family house (SFH)

Wall to external (from inside to outside), u-value: 0.508 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/hmK]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum	0.02	1.26	1	1200
Brick	0.38	1.3	1	700
Cork	0.03	0.16	1.8	100
Plaster	0.02	5.04	1	2000

Roof (from inside to outside), u-value: 0.494 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Concrete	0.20	5.04	1	2000
Wood-Rockwool-comb.	0.1	0.216	1.12	144
Wood	0.01	0.47	1.	600

Ground-Floor (from inside to outside), u-value: 0.546 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Wood	0.01	0.47	1	600
Flooring	0.06	5.04	1	2000
Polystyrene	0.05	0.13	1.25	25
Concrete	0.25	5.76	1.	2000

Internal Wall (from inside to outside), u-value: 2.686 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Brick	0.2	3.56	1	1500

45 kWh/m²a multi-family house (MFH)

The building is calculated with a two zone model (boundary zone for the two outer apartments, inner zone for the three inner apartments). The window type was chosen with type 2001 (TRNSYS windows library) , u-value: 1.4 W/m²K, g-value: 0.589. Table 8 shows the chosen window areas and Table 9 the building physics data for the constructive elements of the 45 kWh/m²a multi-family house (MFH). Additionally the internal heat gains and the ventilation rate are given below.

Table 8 Window areas in m² for the multi-family house (MFH)

	East	West	North	South
Boundary Zone	[3.5]	[3.5]	2	8
Inner Zone	0	0	2	8
Sum	3.5	3.5	10	40

Internal Heat Gains

Boundary Zone: 2 Persons 8 h seated at rest (ISO 7730 [3]), (100 W) and 1 Person 9,5 h seated at rest (ISO 7730 [3]) (100 W)
Other gains: 550 kJ/h, constant (~150 W)

Inner Zone: 2 Persons 8 h seated at rest (ISO 7730 [3]), (100 W) and 1 Person 9,5 h seated at rest (ISO 7730 [3]) (100 W)
Other gains: 550 kJ/h, constant (~150 W)

Table 9: Building physics data for the constructive elements of the 45 kWh/m²a multi-family house (MFH)

Wall to external (from inside to outside), u-value: 0.370 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum	0.01	1.26	1	1200
Brick	0.38	1.3	1	700
Polystyrene	0.05	0.13	1.25	25
Plaster	0.02	5.04	1	2000

Roof (from inside to outside), u-value: 0.222 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum/plate	0.02	0.76	1	900
Wood-Rockwoll-comb.	0.25	0.216	1.12	144
Wood	0.02	0.47	1	600

Ground-Floor (from inside to outside), u-value: 0.231 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Wood	0.012	0.47	1	600
Flooring	0.08	5.04	1	2000
Polystyrol	0.15	0.14	1.25	30
Concrete	0.25	5.76	1	2000

Celling between Zones (from inside to outside), u-value: 0.943 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Gypsum	0.01	1.26	1	1200
Brick	0.25	1.08	1	700
Gypsum	0.01	1.26	1	1200

Internal Wall (from inside to outside), u-value: 2.686 W/m²K

Type	Thickness [m]	Therm. cond. [kJ/(h m K)]	Therm. cap. [kJ/kgK]	Density [kg/m³]
Brick	0.2	3.56	1	1500

5 Space heating demand and heat distribution system

The space heating is performed with radiators (non-standard TRNSYS TYPE 162, radiator with thermal mass) and thermostatic valves adjusting the mass flow simulated with a PID controller (non-standard TRNSYS TYPE 120). Two systems used floor heating. They are calculated with non-standard TRNSYS TYPE 100 (floor heating, calculated with transfer functions), (ref. [1]).

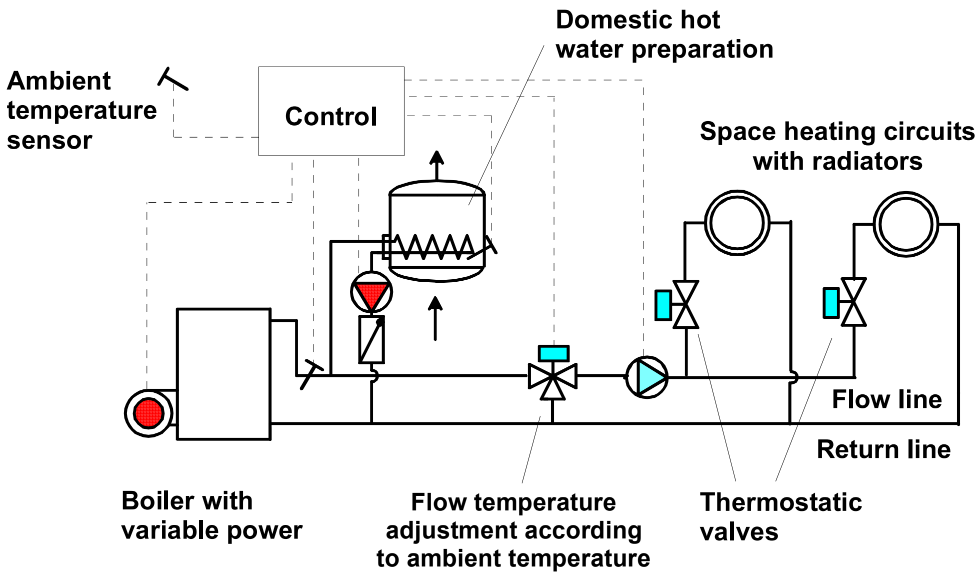

Figure 3: Schematic of the space-heating distribution system of the reference buildings

Figure 4 shows the control characteristics of the radiator heating system for a time period of 3 weeks in spring. In the first and third week, there is space heating demand, in the second week the room air temperature rises above 20.5 °C because of passive gains and the finite thermal mass of the building resulting in no additional heat demand. The outdoor temperature in the second week remains below 20 °C most of the day. Therefore the flow temperature to the radiators is kept above 20.5 °C. The flow temperature to the heating system is directly dependent on outdoor temperature. When the sun is shining during the day or other internal gains occur the room air temperature rises and the mass flow rate of the heating system is reduced by the thermostatic valves. These fluctuations of the mass flow rate can be clearly seen in Figure 4.

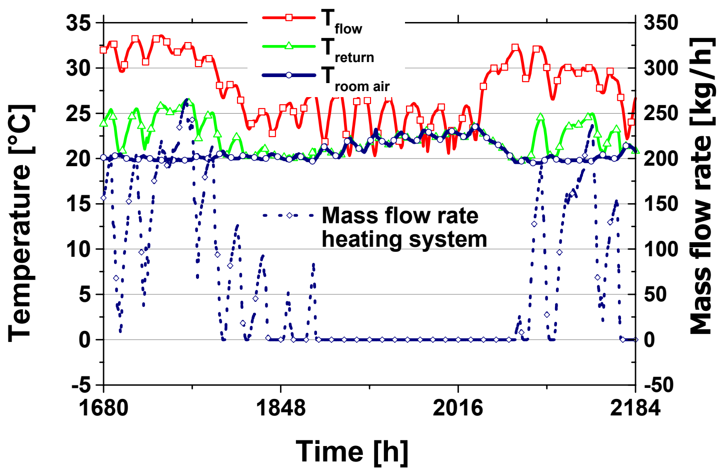

Figure 4: Space heating demand, mass flow rate and temperatures of reference space heating system for a time period of 3 weeks in spring, with radiators and PID controller (thermostatic valve), using DIN 4701 [4] space heating load for the reference SFH 60 in Zurich as the design heating rate

The space heating distribution system is defined as an ambient temperature controlled radiator system with thermostatic valves adjusting the mass flow according to variable inner heat loads. Table 10 lists the specifications of this system for the different buildings and climates.

The heat loads according to DIN 4701 [4] for the four building types in the various climates were calculated with the design temperature for each climate with TRNSYS (without gains and solar radiation).

The standard specific heating capacity of the radiators ($\dot{Q}_N = 1263\ W/m$) was derived from [2] for a two rows radiator with 0.6 m height. The actual specific heating capacity was recalculated by

equu. 1: $$\dot{Q} = \dot{Q}_N \cdot \left(\Delta T / \Delta T_N\right)^{radiater\ \exp}.$$

Table 10: Specifications of the heat distribution system – constant flow rate and radiator area

Zürich clima file

	standard						
	heat load DIN 4701 Q_{4701} [W]	heatcap. radiator q_N [W/m]	height radiator $h_{rad.}$ [m]	area radiator A_{R_N} [m²]	incoming temperature t_{in} [°C]	temperature difference Δt_{rad} [°C]	temp.-diff room-radia. Δt_N [°C]
Refbu30	2830	1263	0,6	1,34	35	5	60
Refbu60	4950	1263	0,6	2,35	40	5	60
Refbu100	7290	1263	0,6	3,46	60	10	60
RefbuMF	13970	1263	0,6	6,64	40	5	60
	real						
	temp.-diff room-radia. Δt [°C]	radiator-exponent n [-]	heatcap. radiator q_{real} [W/m]	area radiator A_{R_real} [m²]	flow rate constant m [kg/s]	m [kg/h]	length radiator A_{R_real} [m]
Refbu30	12,5	1,3	164,36	10,33	0,135	487,5	17,22
Refbu60	17,5	1,3	254,54	11,67	0,237	852,6	19,45
Refbu100	35	1,3	626,75	6,98	0,174	627,8	11,63
RefbuMF	17,5	1,3	254,54	32,93	0,668	2406,3	54,88

Carpentras clima file

	standard						
	heat load DIN 4701 Q_{4701} [W]	heatcap. radiator q_N [W/m]	height radiator $h_{rad.}$ [m]	area radiator A_{R_N} [m²]	incoming temperature t_{in} [°C]	temperature difference Δt_{rad} [°C]	temp.-diff room-radia. Δt_N [°C]
Refbu30	2460	1263	0,6	1,17	35	5	60
Refbu60	4260	1263	0,6	2,02	40	5	60
Refbu100	6320	1263	0,6	3,00	60	10	60
RefbuMF	12060	1263	0,6	5,73	40	5	60
	real						
	temp.-diff room-radia. Δt [°C]	radiator-exponent n [-]	heatcap. radiator q_{real} [W/m]	area radiator A_{R_real} [m²]	flow rate constant m [kg/s]	m [kg/h]	length radiator A_{R_real} [m]
Refbu30	12,5	1,3	164,36	8,98	0,118	423,7	14,97
Refbu60	17,5	1,3	254,54	10,04	0,204	733,8	16,74
Refbu100	35	1,3	626,75	6,05	0,151	544,3	10,08
RefbuMF	17,5	1,3	254,54	28,43	0,577	2077,3	47,38

Stockholm clima file

	standard						
	heat load DIN 4701 Q_{4701} [W]	heatcap. radiator q_N [W/m]	height radiator $h_{rad.}$ [m]	area radiator A_{R_N} [m²]	incoming temperature t_{in} [°C]	temperature difference Δt_{rad} [°C]	temp.-diff room-radia. Δt_N [°C]
Refbu30	3480	1263	0,6	1,65	35	5	60
Refbu60	6160	1263	0,6	2,93	40	5	60
Refbu100	9050	1263	0,6	4,30	60	10	60
RefbuMF	17350	1263	0,6	8,24	40	5	60
	real						
	temp.-diff room-radia. Δt [°C]	radiator-exponent n [-]	heatcap. radiator q_{real} [W/m]	area radiator A_{R_real} [m²]	flow rate constant m [kg/s]	m [kg/h]	length radiator A_{R_real} [m]
Refbu30	12,5	1,3	164,36	12,70	0,167	599,4	21,17
Refbu60	17,5	1,3	254,54	14,52	0,295	1061,1	24,20
Refbu100	35	1,3	626,75	8,66	0,217	779,4	14,44
RefbuMF	17,5	1,3	254,54	40,90	0,830	2988,5	68,16

6 References

[1] Weiss, W. (ed.), Solar Heated Houses - A Design Handbook for Solar Combisystems, James&James Science Publisher, 2003

[2] Recknagel, Sprenger, Taschenbuch für Heizung + Klimatechnik, Publ. Oldenbourg, 1992

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