SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

# Definition of Reference Solar Energy Buildings

*Part 1 of 2*

IEA SHC TASK 66 | SOLAR ENERGY BUILDINGS

Technology Collaboration Programme
by iea

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

# Definition of Reference Solar Energy Buildings

## *Part 1 of 2*

**This is a report from SHC Task 66: Solar Energy Buildings and work performed in Subtask A: Boundary conditions, KPIs, definitions and dissemination**

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Cover photo credit Jenni Energietechnik AG, 100% solar-heated multi-family building in Oberburg, Switzerland

## Solar Heating & Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

**Our mission** is *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

**IEA SHC** members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

**Our focus areas,** with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

**Our members**

| | | |
|---|---|---|
| Australia | European Copper Institute | SICREEE |
| Austria | France | Slovakia |
| Belgium | Germany | South Africa |
| Canada | International Solar Energy Society | Spain |
| CCREEE | Italy | Sweden |
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*For more information on the IEA SHC work, including many free publications, please visit [www.iea-shc.org](http://www.iea-shc.org).*

# Contents

# 1 Executive Summary

In subtask A of the SHC Task 66 “Solar Energy Buildings”, definitions for reference buildings, building blocks and/or communities shall be elaborated to enable

- a comparison of different energy supply concepts on the basis of clear and comprehensible boundary conditions,
- the elaboration of reasonable energy supply concepts for typical buildings, building blocks and/or communities in the participating countries based on representative samples,
- the validation and calibration of simulation models based on representative samples.

Each Task 66 participant may define one or more country-specific reference building(s) for each of the country-relevant building types (single family, multi family, block, community) and related heating system(s).

This document serves as a guideline, indicated as “Part 1”, and provides a spreadsheet file for the definition of the characteristics of the country-specific reference buildings, building blocks and/or communities. This spreadsheet is indicated as “Part 2”.

# 2 Introduction

The country-specific reference, example and country-representing buildings defined by Subtask A shall serve as basis for comparing different implementations of buildings of the same building type, e. g. single-family or multi-family houses, within and between countries participating in Task 66.
Explanations of the purpose and intention of using *country-specific* reference, example and *country-representing* buildings can be found in Annex A. In practice, different building types are represented by different shapes, sizes and energy performances.
The purpose of this document is to describe an evaluation method intended to enable comparisons between buildings, building blocks and/or communities (municipalities) consisting of the defined building types within and between the participating countries. The comparisons should focus on different variants of particular buildings, building blocks and/or communities that are documented by measurements, mimic by simulation or represented by a combination of both.
The evaluation and comparison aim on the thermal performances and thermal behavior of the buildings concerned and their energy supply systems. Wherever applicable, the comparison shall base on the Key Performance Indicators (KPIs) defined by Task 66, refer to document <<Task66_D.A2_KPIs for SEBs.pdf>>.

# 3 Definition of country-specific reference, example and country representing buildings

In compliance with the agreement among the task members on specifying *country-specific* reference, example and *country-representing* buildings, each country defines country-relevant building types like single-family and multi-family houses, building blocks and/or communities including their energy supply systems. The buildings might be defined alternatively,
a) derived by simulation (country specific reference buildings) or
b) based on measured entities (example buildings).
To increase the benefit of the evaluation, simultaneously focusing on *country-representing* buildings is advantageous. For comparisons by means of simulation in addition typical user behavior has to be specified. The template belonging to this document (Task66_D.A4_Definition of Reference SEBs_Part2of2.xlsx, see annex B and separate excel-file) lists characteristic properties and values regarding the thermal performance, e. g. characterized by U-values and the Solar Heat Gain Coefficients (SHGC-values) of windows as well as the kinds of energy supply and distribution systems.

# 4 Evaluation and comparison procedure to be applied by each country/participant

For evaluation and comparison of the energetic and ecological performances of different buildings and unlike building types within a country and between the participating countries, each country has to define and work out the following points and fill in the corresponding template.

1. Definition of country-specific buildings, building blocks and/or communities and/or other country-relevant building types, e. g. single-family buildings, multi-story residential buildings and building blocks. In most cases, one *country-representing* building per building type should be sufficient. However, the definition of additional entities is possible.
2. Definition of country-specific heating, cooling and any other kind of relevant HVAC (heating, ventilation and air conditioning) system for space heating and cooling and for domestic hot water preparation.
3. Definition of country-specific operating conditions like set points, threshold temperatures, gains and loads and relevant appliances.
4. Definition of country-specific climatic conditions. In most cases, one set of weather data should be sufficient. The statement of additional weather data is possible.
5. Definition and simulation of country-relevant variants of the defined buildings, e. g. with respect to changed U-values and/or SHGC-values and/or operating conditions. In addition, the impact of changes in energy supply, distribution and emission systems and energy-related features like solar thermal collectors or photovoltaic systems should be examined.

Evaluation and comparison on the basis of key performance indicators KPI defined by Task 66, refer to document << Task66_D. A2_KPIs for SEBs.pdf>>.

1. Calculation/simulation of the selected cases defined in item 1. to 5. on a yearly basis with a resolution of at least quarter-hourly time steps.
   Each participant chooses the calculation method or software used. The calculation method or software shall be capable to determine performance indicators to derive the defined KPIs.
2. Generation and documentation of calculated/simulated results in yearly and monthly resolution. Supplementary weekly and daily results are appreciated.
3. Relating the results from 1. and 2. to the number of inhabitants, useful and heated/cooled area and other references to calculate the defined KPIs.
4. Assessing of country-specific reference, example and country-representing buildings based on documented KPIs.

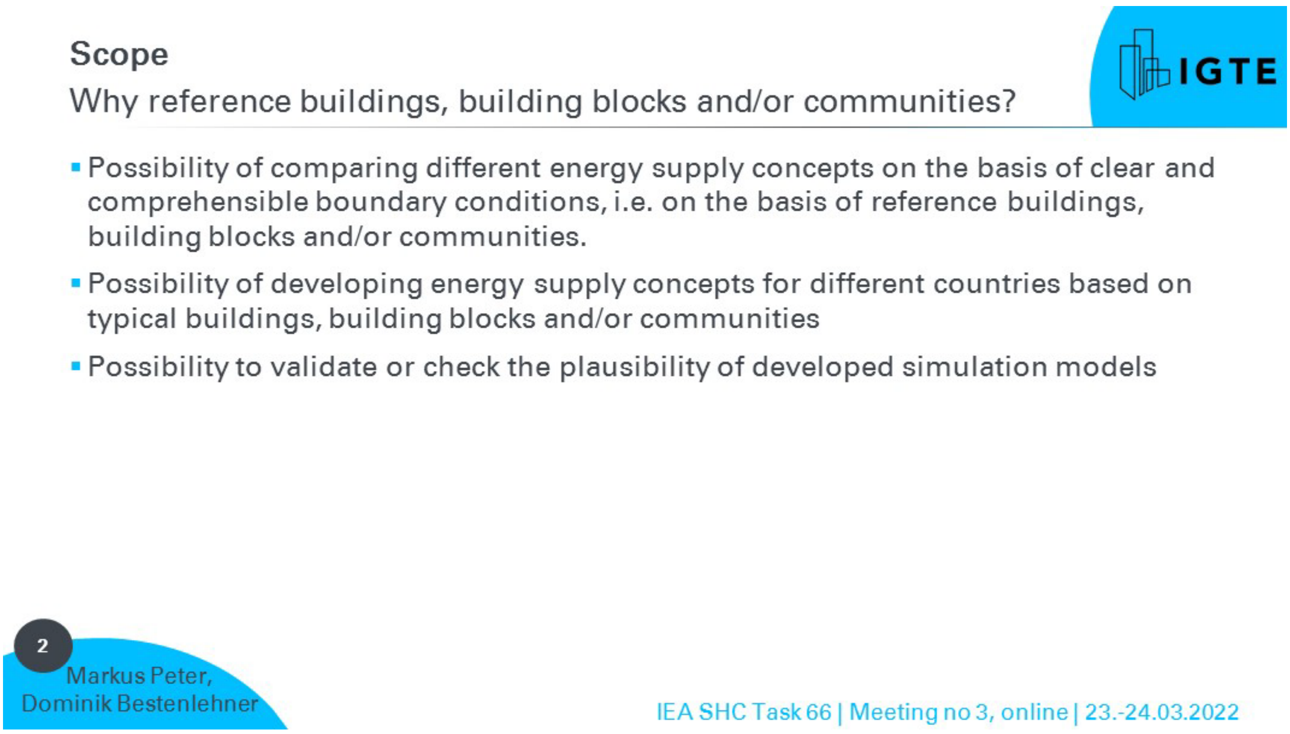
Finally, summarizing the results and defining “best practices” for each country.

# 5 Documentation of examined buildings by each country/participant

The documentation of country-specific reference, example and country-representing buildings is carried out in the template, file <<Task66_D.A4_Definition of Reference SEBs_Part2of2.xlsx>>.
The template is intended for both, buildings originated from measurements and buildings model by simulation.
The template serves for documentation of the examined buildings and relevant parameters but also summarizes important backgrounds and parameters necessary for simulation.
The content of the template might be adjusted, extended and/or changed regarding the work of Subtask B and Subtask C.

Each participant (country) should report measured and/or simulated results of all buildings and respective variants that have been examined.

# 6 Annex A: Presentation Task66A_M3_Def_Bui_Praes1.pdf

## Definition of reference buildings, building blocks and communities

Two approaches possible:

1. Definition of one or more country-specific reference building(s) for each of the country-relevant building types (single family, multi family, block, community) and related heating system(s) by each of the Task 66 participants.
   This results in **many different** but **country-specific** reference buildings valid only for a particular country.
2. Definition of one or more joint reference building(s) for each of the building types (single family, multi family, block, community) and related heating system(s) for all Task 66 participants.
   This results in a **very few** (max. four) different but **very general** reference buildings valid for all Task 66 participants.

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Dominik Bestenlehner

IEA SHC Task 66 | Meeting no 3, online | 23.-24.03.2022

## Definition of reference buildings, building blocks and communities

Subtask A propose that the Task 66 participants agree on country specific reference building(s), example building(s) and/or country representing building(s)

1. Definition of one or more country-specific reference building(s) for each of the country-relevant building types (single family, multi family, block, community) and related heating system(s) by each of the Task 66 participants.
   This results in **many different** but **country-specific** reference buildings valid only for a particular country.
2. Definition of one or more joint reference building(s) for each of the building types (single family, multi family, block, community) and related heating system(s) for all Task 66 participants.
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## Definition of reference buildings, building blocks and communities

### Country-specific reference building(s) and related heating system(s)

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Advantages:

- Every country/participant can define reference buildings and relevant heating, cooling and HVAC systems that take into account the specificities in the country.
- If applicable, building(s) can be defined and subsequently compared with those involved in measurement campaigns.
- With regard to reality, this approach seems to be most realistic.
- Consideration of country-specific standards and regulations.
- Consideration of country-specific building characteristics and building traditions.
- More precise consideration of country-specific climate conditions.
- Enhanced usability of the results within the respective countries.

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## Definition of reference buildings, building blocks and communities

### Country-specific reference building(s) and related heating system(s)

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Advantages:

- Independent work and workflow of the participants of each country after defining the relevant performance indicators and KPIs.
- Favourably, participants within one country arrange the country specific approach(es) amongst each other.
- Reflecting local conditions, country-specific buildings possibly can boost the local market more than findings and/or statements derived for joint reference building(s).
- Revealing differences in building and construction as well as heating, cooling and HVAC systems with and without the use of solar energy but also other environmentally relevant issues within the participating countries might be crucial for setting the direction towards an environmentally friendly market development in the respective countries.

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## Definition of reference buildings, building blocks and communities

Country-specific reference building(s) and related heating system(s)

Disadvantages:

- Different ways to define buildings, heating, cooling and HVAC systems can hinder the comparability.
- KPIs may not be uniformly applicable and thus might have to be adapted country-specifically.
- More complicate comparison of building performances, even if buildings belong to the same category (e.g. single-family house).
- Presumably, more effort (work) compared to joint reference building(s) and related heating, cooling and HVAC system(s).

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## Definition of reference buildings, building blocks and communities

Joint reference building(s) and related heating system(s)

Advantages:

- If it is possible to agree on joint reference building(s) and heating, cooling and HVAC system(s), similar calculation procedures generate more easy comparable results for/from each country.
- Similar derivation of many KPIs in all countries does enhance their comparability.

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## Definition of reference buildings, building blocks and communities

### Joint reference building(s) and related heating system(s)

Disadvantages:

- Defining joint reference building(s) with heating, cooling and HVAC system(s) seem to be very difficult.
- Defining joint reference building(s) with heating, cooling and HVAC system(s) accounting for all differences between the countries is virtually impossible.
- Agreed joint reference building(s) with heating, cooling and HVAC system(s) will presumably be quite unrealistic for several countries.
- Typical and energy-related country-specific characteristics of buildings must be neglected.
- In most cases, the joint reference building(s) will be not or only partly comparable with typical buildings within a country and/or with buildings involved in measurement campaigns, if applicable, refer to Subtask B.

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## Definition of reference buildings, building blocks and communities

### Criteria for choosing country-specific buildings and relevant variants

Participants are **free in choosing appropriate** (reference) buildings. The chosen building(s) should represent country-specific building characteristics, traditions and typical building sizes. Buildings can be new buildings, reconstructions/rehabilitation or existing buildings. The buildings should reflect country-specific regulations and building standards. For each building, at least five variants should be defined and processed. However, more variants are appreciated. The different variants should focus on, e.g.

- Thermal insulation, typically represented by U-values
- Heating, cooling and HVAC system(s) for space heating, space cooling and domestic hot water preparation, and altering of the technical equipment
- Building cubage
- Building and roof orientation including inclinations
- proportion of window area on the different orientations
- ....

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## Definition of reference buildings, building blocks and communities

### Criteria for choosing country-specific buildings and relevant variants

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Per building the different items should be varied within country-specific ranges.

The building(s) can either be generic, representing country-specific building characteristics, traditions and typical sizes or buildings for that particular knowledge is available, e. g. from measurements.

In cases participants choose a building or buildings that has/have been monitored or that are still under investigation, for instance in the context of a measurement campaign, the building(s) might be rather (an) "example building(s)" or (a) "country representing building(s)" than (a) typical reference building(s).

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## Definition of reference/example buildings and methodology for evaluation of buildings


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# 7 Annex B: Template "Task66_D.A4_Definition of Reference SEBs_Part2of2.xlsx"

## Definition of Reference Solar Energy Buildings_Part 2 of 2 (Template)

The listed buildings might originate from measured entities or building models for simulation

**The overall aim of the template is to obtain comparable documentations and results.**
**The examples shown, display characteristics and values of possible buildings. They may serve as examples and guideline for participating countries (participants).**
**By altering parameters like U-values and/or SHGC-values, variants of buildings, e. g. in the direction to "new", "existing" and "old" buildings, might be defined.**

**Note that the template on hand focus on building types like single-family or multi-family houses.**
**Unchanged the template will hardly fit to other building types and only little to non-residential buildings or building blocks.**
**To document particular house types the template might be adapted, changed or extended.**
**Values should be given in SI units.**

| Characteristic | | Description | Explanation | (Unit) | example building I<br>single-family house, Germany<br>proposal for a reference building | example building II<br>multy-family house, Germany<br>six housing units |
|---|---|---|---|---|---|---|
| **Building (general)** | Category | - country-specific reference building<br>- country-specific example building<br>- country-representing building<br>- .... | typology | - | country-specific reference building | country-specific example building |
| | Building type | - single-family house<br>- multi-family house (2-6 housing units)<br>- multi-story residential buildings (more than 6 housing units)<br>- building blocks<br>- .... | type of building | - | single familiy house | multi-family house |
| | Areas and volumes | number of storey proper | | - | 1,5 | 3 |
| | | Usefull area | | m² | 150 | 880 |
| | | Heated / cooled area | | m² | 125 / 0 | 740 / 0 |
| | | Total air volume | | m³ | 420 | 2500 |
| | | Heated / cooled air volume | | m³ | 350 / 0 | 2100 / 0 |
| | Thermal inertia | Overall thermal inertia of building | Sum of thermal inertias of building materials | MJ/K | 750 | 4500 |
| | Building standard | - year of construction<br>- old building<br>- building stock<br>- new building<br>- .... | Classification of building into the country-specific building stock | - | new building | building stock |
| | Energy consumption | - space heating (SH)<br>- space cooling (SC)<br>- domestic hot water (DHW)<br>- .... | demand/consumption of usefull energy | kWh/a | SH 7500<br>SC -<br>DHW 2700 | SH 105600<br>SC -<br>DHW 16000 |
| | | specific space heating / cooling demand | | kWh/(m²a) | 50 / 0 | 120 / 0 |
| | | additional (H)VAC* | | $kWh_{el}/a$ | 0 | 0 |
| | | electricity consumption household | household, without HVAC | $kWh_{el}/a$ | 3900 | 17500 |
| | | electricity consumption installation | Auxiliary electricity for HVAC, pumps, valves, controllers, .... | $kWh_{el}/a$ | 800 | 3500 |
| | Location (weather data) | Documentation of the location the building is sited and weather data (climate conditions) used for design and/or simulation | location of the building and weather data for calculation/simulation<br>- If applicable, e. g. weather data released by Meteonorm, Deutscher Wetterdienst (DWD) or the like<br>- Main figures of the climate/weather conditions should be summarized, refer to the end of this template. | - | Potsdam | Madrid |
| **Building (envelope)** | External walls | orientation, inclination, sizes | opaque external walls | - | east 90°, 50 m²; south 90°, 50 m²<br>west 90°, 50 m²; north 90°, 50 m² | east 90°, 200 m²; south 90°, 100 m²<br>west 90°, 200 m²; north 90°, 100 m² |
| | | average heat transfer coefficient (U-value) | average heat transfer coefficient of opaque external walls | W/(m² K) | 0,09 | 0,1 |
| | Roof | orientation, inclination, sizes | opaque roof area | - | east 0, 0 m²; south 45°, 30 m²<br>west 0, 0 m²; north 45°, 30 m² | east 15°, 120 m²; south 0, 0 m²<br>west 0, 0 m²; north 15°, 120 m² |
| | | average heat transfer coefficient (U-value) | average heat transfer coefficient of opaque roof area | W/(m² K) | 0,075 | 0,8 |
| | Windows | orientation, inclination, sizes | windows and translucent areas | - | east 90°, 6 m²; south 90°, 8 m²<br>west 90°, 5 m²; north 90°, 2 m² | east 90°, 105 m²; south 90°, 45 m²<br>west 90°, 90 m²; north 90°, 12 m² |
| | | average heat transfer coefficient (U-value) | average heat transfer coefficient of windows and translucent areas | W/(m² K) | 0,35 | 0,4 |
| | | average solar heat gain coefficient (SHGC-value) | average solar heat gain coefficient of windows and translucent areas | between 0 - 1 | 0,45 | 0,6 |
| | | shading yes / no / controlled shading | | - | no | controlled shading |
| | Air exchange rate | Ventilation through windows | | 1/h | 0,15 | 0,25 |
| | | Mechanical ventilation | | 1/h | 0,2 | 0,25 |
| | | Heat recovery | in combination with mechanical ventilation | % | 80 | 75 |
| | Air tightness | Infiltration | Caused by building and construction leakages | 1/h | 0,05 | 0,04 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **energy supply system** | Solar thermal | orientation, inclination, sizes, collector performance figures, tubing length inside and outside | performanve figures (ref. gross area)<br>- ηo in [-]<br>- a1 / c1 in [W/(m²K)]<br>- a2 / c2 in [W/(m²K²)] | - | south 45°, 6 m²<br>0.74 -, 3,54 W/(m²K), 0,015 W/(m²K²)<br>inside 30 m, outside 2 m | south 45°, 40 m²<br>0.74 -, 3,54 W/(m²K), 0,015 W/(m²K²)<br>inside 50, outside 10 m |
| | Thermal storage | Storage type, volume for space heating / domestic hot water | Store for domestic hot water or combistore for space heating and domestic hot water | - | domestic hot water store 350 l | combistore 3000 / 500 |
| | Photovoltaic | Orientation, inclination, peak power | peak power at<br>- ambient temperature 25 °C<br>- solar irradiation 1000 W/m²<br>- air mass 1,5 | - | south 45°, 4,0 kWp | south 15°, 20,0 kWp |
| | Battery | Type of battery, nominal capacity | E. g. lithium ion battery, lead-acid battery | - | lithium ion battery, 5 kWh | lithium ion battery, 20 kWh |
| | Other heat source | Type of heat source, e. g. heat pump, gas boiler, electric heating element | heat pump<br>- nominal power [kW]<br>- heat source<br>- inverter yes / no<br>- Coefficient of Performance (COP)<br>gas boiler<br>- nominal power [kW]<br>electric heating element<br>- power [kW] | - | heat pump, 11 kW, air, inverter (yes)<br>COP = 4,35 | gas boiler, 52 kW |
| | Cold production | Type of cold production, e. g. heat pump, other cooling unit | heat pump<br>- nominal power [kW]<br>- cooling source<br>- inverter yes / no<br>- Energy Efficiency Ratio (EER)<br>other cooling unit<br>- capacity [kW] | - | no cooling | no cooling |
| **heat and cold distribution and emission** | Heating | floor heating, radiator, convector heater | system and operating conditions | - | floor heating, 35/28 °C | radiators, 55/45 °C |
| | Cooling | floor cooling, cooling ceiling, thermo active building elements (concrete) | system and operating conditions | - | no cooling | no cooling |
| | Domestic hot water | heat source, central preparation, dezentral preparation | system and set temperature | - | central preparation | central preparation |
| **Operating conditions** | Space heating | Set point for room temperatur, night setback | - demanded temperatur<br>- time interval of night setback<br>- night setback | - | 20 °C, 22:00-06:00 o'clock, 3 K | 21 °C, 23:00-05:00 o'clock, 3 K |
| | Space cooling | temperatur to activate cooling | | °C | no cooling | no cooling |
| | Domestic hot water | Set temperatur (threshold temperature) of the domestic hot water store | | °C | 50 | 55 |
| | Tapping of domestic hot water | Temperature at the tap, DHW volume per day, tapping profile | | - | 45 °C / 150 l/d / see below | 45 °C / 900 l/d / see below |
| | Ventilation | time interval of ventilation<br>- through windows<br>- mechanical ventilation | | - | 00:00-24:00 o'clock<br>06:00-21:00 o'clock | 00:00-24:00 o'clock<br>05:00-23:00 o'clock |
| | others | particular<br>- appliances<br>- energy gains<br>- energy loads | list and/or description | - | greenhouse, electricity demand 2500 kWh/a | none |

*HVAC: heating, ventilation and air conditioning

| | | | |
|---|---|---|---|
| Tapping profile for domestic hot water | time interval, volume flow | 06:00-07:00 ==> 30 l/h<br>11:00-13:00 ==> 60 l/h<br>17:00-18:00 ==> 30 l/h | 06:00-07:00 ==> 150 l/h<br>11:00-13:00 ==> 250 l/h<br>17:00-18:00 ==> 250 l/h |

hint
13 o'clock ≙ 01:00 p.m.
17 o'clock ≙ 05:00 p.m.
18 o'clock ≙ 06:00 p.m.
21 o'clock ≙ 09:00 p.m.
23 o'clock ≙ 11:00 p.m.
24 o'clock ≙ 12:00 p.m.

## climate/weather conditions

**Climate/weather conditions should be documented by listing monthly and annual mean values of the ambient temperature and the monthly and annual integral of beam and diffuse solar irradiance on a horizontal plane. If relevant, e. g. for simulation, in addition monthly and annual mean values of the wind speed and relative humidity should be given.**

| | Ambient temperature [°C] | Beam (direct) solar irradiation [kWh/m²] | Diffuse solar irradiation [kWh/m²] | wind speed [m/s] | relative humidity [%] |
|---|---|---|---|---|---|
| January | 0,8 | 7,8 | 12,4 | 3,2 | 80,8 |
| February | 1,8 | 11,9 | 23,3 | 3,2 | 80,2 |
| March | 4,7 | 25,8 | 47,1 | 3,1 | 73,9 |
| April | 9,9 | 59,2 | 60,4 | 2,9 | 67,0 |
| May | 14,8 | 74,2 | 80,7 | 2,8 | 66,3 |
| June | 17,1 | 87,5 | 77,1 | 2,8 | 67,0 |
| July | 19,2 | 78,4 | 85,0 | 2,7 | 66,9 |
| August | 18,8 | 70,8 | 68,0 | 2,6 | 69,3 |
| September | 14,4 | 37,0 | 56,1 | 2,8 | 74,2 |
| October | 9,8 | 24,5 | 30,8 | 2,9 | 80,3 |
| November | 5,2 | 8,2 | 15,0 | 3 | 85,2 |
| December | 1,4 | 4,2 | 10,5 | 3,1 | 84,7 |
| **Year** | **9,9** | **489,4** | **566,4** | 2,9 | 74,6 |