Typology Approach
for Building Stock
Energy Assessment

# TABULA Calculation Method – Energy Use for Heating and Domestic Hot Water –

## Reference Calculation and Adaptation to the Typical Level of Measured Consumption

– TABULA Documentation –

TABULA Project Team

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## Contents

# 1 The TABULA Calculation Procedure

## 1.1 Principles

The methodology presented in this report has been developed in the course of the Intelligent Energy Europe project TABULA. It was primarily designed to collect and compare data of example buildings which represent different building sizes and construction year classes of the respective national building stocks. The method consists of

− a harmonised data structure which is the foundation of a building data base;
− a standard reference calculation procedure for determining the heat need and the delivered energy demand;
− a scheme for assessing the calculated energy wares in terms of primary energy, carbon dioxide emissions and heating costs;
− a scheme for adapting the calculated energy use to the level of energy consumption which is typical for the respective building types and energy performance levels of the different countries.

The method is focused on the energy use for space heating and domestic hot water of residential buildings. Cooling, air conditioning, lighting, electric appliances are until now not considered in the concept but can of course later be supplemented.

The TABULA maxim is to image the relevant parameters determining the energy consumption of a building in a realistic way and to keep at the same time the method as simple as possible. In consequence, averages are used when applicable, which of course can be determined by more detailed methods.

The objective of simplification is to ensure transparency of the calculation, so that the procedure can be easily understood by experts in each country. It is also the precondition for a traceable online calculation, implemented in form of the [TABULA WebTool], and for an easy handling of the calculation of large numbers of building datasets by realising a row by row Excel spreadsheet.

The common approach was implemented by use of an Excel workbook "TABULA.xls" which consists of two tables for the calculation of the building and supply system balance and about 60 referenced tables with constant and variable input data (e.g. construction element types by construction year classes including U-values, heat generator types including energy expenditure factors, …). A simplified version "tabula-calculator.xls" which abstains from referenced tables and can therefore easily be used by third parties is available at the website [TABULA Spreadsheets]. In parallel to the Excel workbook a webtool was developed which enables an online calculation according to the TABULA method [TABULA WebTool]. In all mentioned tools both can be traced at the same time: the formulas and the current values of the selected building / system combination.

The calculation procedure is defined in accordance with the relevant CEN standards and takes into account standard values for the utilisation as well as national or regional climatic data. The details are documented in the next chapters.

## 1.2 Methodical Basis of the Reference Calculation Procedure

The energy need for space heating is calculated by applying the seasonal method according to EN ISO 13790 on the basis of a one-zone model. The external boundary conditions (air temperature, external temperature / solar radiation) are defined by each partner for his own country for a standard base temperature. In case of significant climatic differences between regions of a country several climate datasets are supposed to be provided. Standard values are used for the utilisation conditions (room temperature, air exchange rate, internal heat sources) and for the solar radiation reduction factors (shading).[1]

The basis of the envelope area calculation is the buildings' external dimension, as already established as a harmonised approach in the framework of the Intelligent Energy Europe project DATAMINE [DATAMINE FR]. As regards the thermal transfer coefficient tables are available for all participating countries with U-values of typical construction elements, differentiated by construction period, supplemented by explanations in national language and in English. A detailed description of the input data and formulas for calculating the energy need for space heating can be found in chapter 2.

The energy performance of the supply system is calculated by use of tabled values for the different subsystems (approach according to EN 15316, Level B). The respective energy expenditure factors of typical heat generators and floor area related distribution and storage heat losses as well as auxiliary electricity demands were determined distinguishing between heating and DHW systems. This has been done by the TABULA experts for their countries by use of the respective national energy performance certificate methods. The details of the supply system calculation and energy carrier assessment are described in chapter 3.

## 1.3 Relation to Measured Consumption

Physical models should usually be verified and calibrated by measurements. Due to lack of information about the real utilisation conditions (indoor temperatures, air exchange rates) and the exact thermal properties of existing buildings (construction elements, supply system elements) it is difficult to calibrate all these input values to realistic levels, even for the average of building types. In consequence, systematic deviations of the calculated energy use from the typical level of measured consumption can be expected.

Nevertheless, it is necessary to provide realistic numbers for the possible savings of delivered and primary energy, energy costs, and carbon dioxide emissions. As a starting point information about the typically measured energy consumption of existing buildings of different types and energy performance levels is needed for all countries. By setting these consumption benchmarks in relation to the calculated energy use adaptation factors can be determined which enable a calibration of the theoretical to empirical values. Thus, the TABULA method provides – apart from the standard reference calculation – a second type of calculation result: the typical level of measured consumption. This type of energy performance indicator can also be seen as "expectation values of the measured consumption".

In the long run it will of course be useful to also provide realistic numbers of the different calculation input parameters in order to make assessments of single saving measures as realistic as possible. In the best case the empirical calibration factors will converge towards the value 1.0.

## 1.4 Relation to National Calculation Procedures

The specific relation of the TABULA method to the results of the respective national calculation procedure should be determined in an empirical way for each country: Both calculation procedures are applied for a number of buildings with different energy related properties. The ratio of the calculated energy use of both methods are documented in the national scientific reports of the TABULA partners [TABULA NSR].

[1] However, the Excel workbook "TABULA.xls" also enables a change of input parameters in the context of national applications which do not imply a comparison with other countries.

# 2 Calculation of the Energy Need for Space Heating

## 2.1 Energy Need for Heating

The calculation of the energy need for space heating is based on the seasonal method of the standard EN 13790 "Energy performance of buildings - Calculation of energy use for space heating and cooling".

The building energy need for space heating, $Q_{H,nd}$ is calculated as given by equation (1):

$$Q_{H,nd} = Q_{ht} - \eta_{h,gn}\, Q_{H,gn} \qquad \text{[kWh/a]} \qquad (1)$$

where

| | | |
|---|---|---|
| $Q_{H,nd}$ | is the building energy need for heating, assumed to be greater than or equal to 0 | [kWh/a] |
| $Q_{ht}$ | is the total heat transfer for the heating mode, determined in accordance with equation (2) | [kWh/a] |
| $Q_{H,gn}$ | gives the total heat gains for the heating mode, determined in accordance with equation (7) | [kWh/a] |
| $\eta_{h,gn}$ | is the dimensionless gain utilization factor, determined in accordance with equation (10) | [ - ] |

The total heat transfer $Q_{ht}$ for the heating mode is given by equation (2):

$$Q_{ht} = Q_{ht,tr} + Q_{ht,ve} = 0.024 \frac{kh}{d} \left(H_{tr} + H_{ve}\right) F_{nu} \left(\vartheta_{\text{int}} - \vartheta_{e}\right) d_{hs} \qquad \text{[kWh/a]} \qquad (2)$$

where

| | | |
|---|---|---|
| $Q_{ht,tr}$ | is the total heat transfer by transmission during the heating season | [kWh/a] |
| $Q_{ht,ve}$ | is the total heat transfer by ventilation during the heat-ing season | [kWh/a] |
| $H_{tr}$ | is the overall heat transfer coefficient by transmission, determined in accordance with equation (2) | [W/K] |
| $H_{ve}$ | is the total heat transfer by ventilation, determined in accordance with equation (5) | [W/K] |
| $F_{nu}$ | is the dimensionless correction factor for non-uniform heating, taking into account systematic deviations of the set-point temperature and the actual average tempera-ture (time average over night and day as well as space average over living areas and reduced or indirectly heated spaces), see chapter equation (14) | [ - ] |
| $\vartheta_{int}$ | is the internal temperature (set-point temperature for space heating)<br>TABULA standard value $\vartheta_{\text{int}}$ = 20° C | [°C] |

| | | |
|---|---|---|
| $\overline{\vartheta_{e,hs}}$ | is the temperature of the external environment (average value during heating season) determined in accordance with equation (28) | [°C] |
| $d_{hs}$ | is the length of the heating season expressed in days, determined in accordance with equation (27) | [d/a] |

**Table 1: Boundary conditions – TABULA standard values**

| Quantity | Description | | TABULA standard values* | |
|---|---|---|---|---|
| | | | Single-unit housing | Multi-unit housing |
| $\vartheta_{int}$ | internal temperature | [°C] | 20 | |
| $F_{nu}$ | reduction factor, considering non-uniform heating (effect of night setback and unheated space) for two values of the floor area related heat transfer coefficient by trans-mission, linear interpolation is applied between them (see chapter 2.6):<br>• $h_{tr}$ = 1 W/(m²K) (high thermal quality)<br>• $h_{tr}$ = 4 W/(m²K) (low thermal quality) | [°C] | <br>0.90<br>0.80 | <br>0.95<br>0.85 |
| $n_{air,use}$ | average air change rate, related to the utilisation of the building | [1/h] | 0.4 | |
| $h_{room,ve\ ref}$ | ventilation reference room height | [m] | 2.5 | |
| $\varphi_{int}$ | average internal heat sources per m² reference area | [W/m²] | 3 | |
| $F_{sh}$ | reduction factor external shading,<br>• horizontal orientation<br>• vertical orientations | [ - ] | <br>0.8<br>0.6 | |
| $F_F$ | frame area fraction of a window | [ - ] | 0.3 | |
| $F_W$ | reduction factor, considering radiation non-perpendicular to the glazing | [ - ] | 0.9 | |
| $c_m$ | internal heat capacity per m² reference area | [Wh/(m²K)] | 45 | |
| $q_{w,nd}$ | net energy need domestic hot water | [kWh/(m²a)] | 10 | 15 |

* to be used in case of cross-country comparisons

## 2.2 Transmission Heat Losses

In accordance with equation (2) the annual transmission heat losses are:

$$Q_{ht,tr} = 0.024 \frac{kh}{d} H_{tr} F_{nu} (\vartheta_{int} - \vartheta_e) d_{hs}$$ [kWh/a] (3)

The overall heat transfer coefficient by transmission $H_{tr}$ is calculated as given by equation (4):

$$H_{tr} = \sum_i b_{tr,i} A_{env,i} U_{eff,i} + \left( \sum_i A_{env,i} \right) \Delta U_{tbr}$$ [W/K] (4)

where

| | | |
|---|---|---|
| $b_{tr}$ | is the adjustment factor soil<br>for TABULA standard values see Table 2 | [ - ] |
| $A_{env,i}$ | is the area of envelope element i,<br>determined in accordance with chapter 2.2.1 | [m²] |
| $U_{eff,i}$ | is the effective U-value,<br>determined in accordance with chapter 2.2.2 | [W/(m²K)] |
| $\Delta U_{tbr}$ | is the surcharge on all U-values, taking into account the additional loses caused by thermal bridging determined in accordance with chapter 2.2.3 | [W/(m²K)] |

**Table 2: Classification of construction borders**

| **TABULA code of the construction border situation** | **Description of the construction border situation** | **TABULA standard values** | |
|---|---|---|---|
| | | **Additional thermal resistance due to unheated space bordering at the construction element** $R_{add}$ | **Adjustment factor soil** $b_{tr}$ |
| | | [m²K/W] | |
| **Ext** | construction bordering on external air | 0 | 1 |
| **Unh** | construction bordering on unheated rooms (e.g. unheated attic) | 0.3 | 1 |
| **Cellar** | construction bordering on unheated cellar | 0.3 | 0.5 |
| **Soil** | construction bordering on soil | 0 | 0.5 |

### 2.2.1 Thermal envelope area

The thermal envelope area $A_{env}$ consisting of the elements $A_{env,i}$ completely encloses the whole conditioned volume of the building. In principle, the determination of the surface area of a building can be based on different types of length elevations: starting from the inner or from the outer edges, but also from the centre of the construction element junctions.[2] These definitions are different from country to country. In case of the TABULA method the convention is to determine the thermal envelope area on the basis of the external dimensions of the building. For countries where – according to the national standards – envelope areas are calculated by other rules the envelope surface areas cannot be directly entered into the TABULA database but must be adequately corrected before.

In case variants of a building are calculated by considering insulation measures applied at the outside of the elements the envelope area of the unrefurbished building can be used without modification, in order to simplify the procedure.

In case of unheated rooms the thermal envelope is to be considered as positioned at the construction element of the lowest thermal transmittance (highest thermal resistance). In consequence, the surface

a) separating heated rooms and unheated rooms, or

b) separating unheated rooms and external air

can alternatively be selected as the relevant boundary plane. For existing buildings the very envelope plane should be selected where insulation measures would preferably be installed in case of refurbishment.

The area and U-value of the selected envelope plane are considered as intake quantities in the energy balance calculation. In accordance with EN ISO 6946 additional thermal resistances are applied to consider the respective unheated spaces. The resulting temperature and area related transmission losses, the "effective U-values", are defined in the following clause. TABULA standard values of $R_{add}$ can be found in Table 2.

### 2.2.2 Effective U-value

As a simplified approach additional thermal resistances of unheated rooms and additionally applied refurbishment measures are taken into account by modifying the respective U-values. The resulting effective U-value $U_{eff,i}$ of an envelope element i is determined as follows:

$$U_{eff,i} = \frac{1}{R_{eff,i}} = \frac{1}{R_{0,i} + R_{measure,i} + R_{add,i}} = \frac{1}{\frac{1}{U_{0,i}} + \frac{d_{ins,i}}{\lambda_{ins,i}} + R_{add,i}} \quad \text{[W/(m}^2\text{K)]} \quad (5)$$

where

| | | |
|---|---|---|
| $U_{eff,i}$ $R_{eff,i}$ | are the effective U-value and the effective thermal resistance of the envelope element i | [W/(m²K)] [m²K/W] |

[2] The different definitions are in principle equivalent – as far as the thermal losses at the element junctions are assessed in an adequate way. Thermally homogenous elements bordering at each other will for example result in positive surcharges on the non-distorted U-values in case of internal dimensions, and in negative surcharges in case of external dimensions.

| | | |
|---|---|---|
| $U_{0,i}$ $R_{0,i}$ | are the U-value and the thermal resistance of the envelope element i in the original state, calculated according to EN ISO 6946 | [W/(m²K)] [m²K/W] |
| $R_{measure,i}$ | is the (additional) thermal resistance of a thermal refurbishment measure applied to the element i<br>in case of a simple insulation measure (additional layer of insulation) $R_{measure,i}$ is calculated by a quotient of the insulation thickness $d_{ins,i}$ and the thermal conductivity $\lambda_{ins,i}$; in other cases (e.g. in case of insulation between rafters) the thermal resistance is calculated by the rules of EN ISO 6946 | [m²K/W] |
| $R_{add,i}$ | is the additional thermal resistance due to unheated space bordering at the construction element i<br>for TABULA standard values see Table 2 | [m²K/W] |

When values for $U_{0,i}$ are determined for elements bordering at soil or cellar the heat transfer through soil must not be taken into account. The relevant outside surface for the calculation of U-values $U_{0,i}$ is the bottom surface of the element. The TABULA method considers cellar rooms in the effective U-value $U_{eff,i}$ by an additional thermal resistance $R_{add,i}$, the decrease of heat flow through soil is considered in the balance equation by the supplemental reduction factor $b_{tr}$.

For countries where – according to the national standards – U-values of elements bordering at cellar or soil are calculated including the thermal resistance of cellar or soil the respective U-values of these elements can not be directly entered to the TABULA database but must be adequately corrected before.

### 2.2.3 Thermal bridging

Since according to the TABULA method the thermal envelope area of a building is calculated on the basis of external dimensions (see clause 2.2.1) the thermal losses are in general slightly overestimated at the linkages of construction elements made of homogeneous material (e.g. at the edges of masonry). Therefore only constructive thermal bridging is taken into account by the categories of thermal bridging surcharge.

Three categories (low / medium / high) of thermal bridging are defined depending on the effect of constructional thermal bridging. The assessment takes into account the amount of penetration of the thermal envelope by punctual or linear construction elements with significantly higher thermal conductivity not considered in the U-values. The respective additional losses are incorporated in the calculation procedure in the form of an addend on the heat transfer coefficient by transmission (see equation (4)).

**Table 3: Classification of thermal bridging**

| TABULA code for classifica-tion of thermal bridging | Thermal bridging classification | Description | TABULA standard values<br>Additional losses of the thermal envelope caused by thermal bridging (surcharge on all U-values)<br>$\Delta U_{tbr}$ |
|---|---|---|---|
| | | | [W/(m²K)] |
| **Minimal** | no relevant effect of constructional thermal bridging | thermally relevant layers of the envelope are not penetrated by elements with higher thermal conduc-tivity; indication: additional transmission losses <= 0 W/K per m² envelope; examples: masonry building with wood beam ceilings, insulated building with thermally optimised junctions | 0 |
| **Low** | low effect of con-structional ther-mal bridging | only small parts of the envelope are penetrated by elements with higher thermal conductivity; indication: additional transmission losses <= 0,05 W/K per m² envelope; examples: existing buildings which do not have concrete ceilings penetrating the outer walls, buildings with later applied insulation and relevant thermal bridging only at the junction of cellar ceiling and outer wall | 0.05 |
| **Medium** | medium effect of constructional thermal bridging | parts of the envelope are penetrated by elements with higher thermal conductivity; indication: additional transmission losses > 0,05 and <= 0,15 W/K per m² envelope; example: inside thermal insulation of walls in buildings with wood beam ceilings | 0.1 |
| **High** | high effect of constructional thermal bridging | relevant parts of the envelope are penetrated by ele-ments with relative high thermal conductivity; indica-tion: additional transmission losses > 0,15 W/K per m² envelope; example: concrete ceilings are penetrating insulation | 0.15 |

## 2.3 Ventilation Heat Losses

In accordance with equation (2) the annual ventilation heat losses are:

$$Q_{ht,ve} = 0.024\frac{kh}{d}\, H_{ve}\; F_{nu}\; \left(\vartheta_{\text{int}} - \vartheta_e\right) d_{hs} \qquad \text{[kWh/a]} \qquad (6)$$

The overall heat transfer coefficient by ventilation $H_{ve}$ is calculated as given by equation (7):

$$H_{ve} = c_{p,air}\; \left(n_{air,use} + n_{air,infiltr}\right) A_{C,ref}\; h_{room,ve\ ref} \qquad \text{[W/K]} \qquad (7)$$

where

| | | |
|---|---|---|
| $c_{p,air}$ | is the volume-specific heat capacity of air<br>*standard value 0.34 Wh/(m³K)* | [Wh/(m³K)] |
| $n_{air,use}$ | average air change rate during heating season, related to the utilisation of the building<br>*TABULA Standard value:*<br>$n_{air,use}$ *= 0.4 1/h (see Table 1)* | [1/h] |
| $n_{air,infiltr}$ | air change rate by infiltration<br>*TABULA standard values: see Table 4* | [1/h] |
| $A_{C,ref}$ | is the reference area of the building, determined in accordance with chapter 7 | [m²] |
| $h_{room,ve\ ref}$ | ventilation reference room height<br>*TABULA standard value:*<br>$h_{room}$ *= 2.50 m* | [m] |

Since the average air change rate by utilisation of the building does in principle not depend on the room height, $h_{room,ve\ ref}$ is only a calculation value and does not reflect the actual room heights of the buildings.[3]

The reduction of the ventilation heat losses attained by heat recovery units of ventilation systems is considered in the heating system section of the energy balance (chapter 3.2). The overall heat transfer coefficient by ventilation defined by Equation (7) is thus valid for the difference between the temperature of the air exhausted from the rooms and the external air introduced into the building.

**Table 4: Classification of building air-tightness**

| **TABULA code for classification of airtightness** | **Air tightness classification** | **Description** | **TABULA standard values**<br>**Additional air exchange rate, caused by infiltration (surcharge on air exchange rate)**<br>$n_{air,infiltr}$ |
|---|---|---|---|
| | | | [1/h] |
| **Minimal** | minimal air infiltration, very tight building | indication: blower door result n_50 <= 0.6 1/h | 0.05 |
| **Low** | low effect of air infiltration | indication: blower door result n_50 <= 1.0 1/h | 0.1 |
| **Medium** | medium effect of air infiltration | indication: blower door result n_50 <= 3.0 1/h | 0.2 |
| **High** | high effect of air infiltration | indication: blower door result n_50 > 3.0 1/h | 0.4 |

[3] The appropriate definition of the air exchange rate induced by the building usage would be an air volume flow related to the building's reference area in m³/(m²h), if a standard value for the number of persons per reference area is considered. Since this quantity is not very illustrative, the air exchange rate is related to a standard volume, defined by the product of reference floor area and standard room height ("reference ventilation room height").

## 2.4 Internal and Solar Heat Gains

The total heat gains during the heating season $Q_{H,gn}$ is calculated as follows:

$$Q_{H,gn} = Q_{Sol} + Q_{\text{int}}$$ [kWh/a] (8)

The internal heat gains during the heating season $Q_{int}$ is calculated as given by equation (9):

$$Q_{int} = 0.024 \frac{\text{kh}}{\text{d}} \; \varphi_{int} \; d_{hs} \; A_{C,ref}$$ [kWh/a] (9)

where

| | | |
|---|---|---|
| $\varphi_{int}$ | is the average thermal output of internal heat sources<br>*TABULA standard value: 3 W/m² (see Table 1)* | [W/m²] |
| $d_{hs}$ | is the length of the heating season expressed in days, determined in accordance with equation (27) | [d/a] |
| $A_{C,ref}$ | is the reference area of the building, determined in accordance with chapter 7 | [m²] |

The solar heat load during the heating season, $Q_{Sol}$ is calculated as given by equation (10):

$$Q_{sol} = F_{sh} \left(1 - F_F\right) F_W \; g_{gl,n} \sum_j A_{window,j} \; I_{sol,j}$$ [kWh/(m²a)] (10)

where

| | | |
|---|---|---|
| $F_{sh}$ | is the reduction factor external shading<br>*TABULA standard values: 0,6 for vertical / 0,8 for horizontal windows (see Table 1)* | [ - ] |
| $F_F$ | is the frame are fraction of the windows<br>*TABULA standard value: 0,3 (see Table 1)* | [ - ] |
| $F_W$ | is a reduction factor, considering radiation non-perpendicular to the glazing<br>*TABULA standard value: 0,9 (see Table 1)* | [ - ] |
| $g_{gl,n}$ | is the total solar energy transmittance for radiation perpendicular to the glazing | [ - ] |
| $A_{window,j}$ | is the area of all windows with orientation j | [m²] |
| $I_{Sol,j}$ | average global irradiation on surfaces with orientation j during the heating season, determined in accordance with chapter 6 | [m²] |

## 2.5 Gain Utilisation Factor for Heating

The gain utilisation factor for heating $\eta_{h,gn}$ is calculated as given by equation (11):

$$\eta_{h,gn} = \frac{1-\gamma^{a_H}}{1-\gamma^{a_H+1}}$$ [kWh/a] (11)

where the heat balance ratio for the heating mode $\gamma_{h,gn}$ and the parameter $a_H$ are defined as follows:

$$\gamma_{h,gn} = \frac{Q_{H,gn}}{Q_{ht}}$$ [kWh/a] (12)

$$a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$$ [ - ] (13)

where

| | | |
|---|---|---|
| $Q_{ht}$ | is the total heat transfer for the heating mode, determined in accordance with equation (2) | [kWh/a] |
| $Q_{H,gn}$ | gives the total heat gains for the heating mode, determined in accordance with equation (7) | [kWh/a] |
| $\tau$ | is the time constant of the building (see below) | [h] |
| $a_{H,0}$ | is a constant parameter<br>*standard value* for the seasonal method*:*<br>$a_{H,0}$ *= 0.8 (according to EN 13790)* | [ - ] |
| $\tau_{H,0}$ | is a constant parameter<br>*standard value* for the seasonal method*:*<br>$\tau_{H,0}$ *= 30 h (according to EN 13790)* | [h] |

The time constant of a building $\tau$ is calculated as given by equation (14):

$$\tau = \frac{c_m \ A_{C,ref}}{H_{tr} + H_{ve}}$$ [kWh/a] (14)

where

| | | |
|---|---|---|
| $c_m$ | is the internal heat capacity per m² reference area<br>*Standard TABULA value:* $c_m$ *= 45 Wh/(m²K) (see Table 1)* | [Wh/m²K] |
| $H_{tr}$ | is the overall heat transfer coefficient by transmission, deter-mined in accordance with (4) | [W/K] |
| $H_{ve}$ | is the total heat transfer by ventilation, determined in accor-dance with (7) | [W/K] |

| | | |
|---|---|---|
| $a_{H,0}$ | is a constant parameter<br>*standard value* for the seasonal method*:*<br>*$a_{H,0}$ = 0.8 (according to EN 13790)* | [ - ] |
| $\tau_{H,0}$ | is a constant parameter<br>*standard value* for the seasonal method*:*<br>*$\tau_{H,0}$ = 30 h (according to EN 13790)* | [h] |
| $A_{C,ref}$ | is the reference area of the building, determined in accordance with $$ | [m²] |

## 2.6 Non-Uniform Heating

The thermal losses of a building are calculated by considering the difference between the internal temperature $\vartheta_{\text{int}}$ (set-point temperature) and the external temperature $\overline{\vartheta_{e,hs}}$ averaged over the heating season. However, a reduced internal temperature will occur during the times of intermittent heating (night-time and/or weekend reduced set-point or switch-off) and in spaces of the building where a reduced set-point temperature is applied or where no heat emission system is installed (but which are nevertheless located inside the thermal envelope of the building).

The effects of non-uniform heating can be calculated by use of detailed methods by considering the time constants of the building and the thermal resistance of the not directly heated spaces.

Usually the effect of non-uniform heating is significant in buildings with poor insulation standards. In contrast, the effect is smaller in well insulated buildings and can be neglected in passive houses.

In case of the TABULA calculation procedure a simplified linear approach is followed: A linear interpolation is made starting from two base values of the heat transfer coefficient by transmission:

$$F_{nu}(h_{tr}) = F_{nu,A} \quad \text{for } h_{tr} \le h_A$$

$$F_{nu}(h_{tr}) = F_{nu,A} + (F_{nu,B} - F_{nu,A})\frac{h_{tr} - h_A}{h_B - h_A} \quad \text{for } h_A < h_{tr} < h_B \qquad [\text{ - }] \qquad (15)$$

$$F_{nu}(h_{tr}) = F_{nu,B} \quad \text{for } h_{tr} \ge h_B$$

where

| | | |
|---|---|---|
| $h_{tr}$ | is the heat transfer coefficient by transmission<br>per m² reference floor area $= \frac{H_{tr}}{A_{C,ref}}$ | [W/(m²K)] |
| $h_A$ , $h_B$ | are constants, depending on the building type<br>*TABULA standard values: see Table 1* | [W/(m²K)] |

# 3 Calculation of the Delivered Energy

The energy performance of the supply system is calculated on the basis of tabled values for different subsystems (EN 15316, Level B). In the case of heat generators energy expenditure coefficients are used which are defined as the ratio of delivered energy use to produced heat. As already agreed in the DATAMINE project, values for the delivered energy are always based on the gross calorific value. In case of heat storage and heat distribution, values for the annual losses in kWh/(m²a) are listed in the respective tables. The auxiliary energy is considered by values representing the annual electric consumption in kWh/(m²a). The above mentioned tables are created for both: space heating systems and dhw systems. The tabled values were determined for typical supply systems according to the respective national standards.

## 3.1 Domestic Hot Water (DHW) System

The energy use for DHW heat generator i is determined as follows:

$$q_{del,w,i} = \alpha_{nd,w,i}\, q_{g,w,out}\, e_{g,w,i}$$ [kWh/(m²a)] (16)

where

| | | |
|---|---|---|
| $\alpha_{nd,w,i}$ | fraction of heat generator i | [ - ] |
| $q_{g,w,out}$ | heat output of heat generator i | [kWh/(m²a)] |
| $e_{g,w,i}$ | heat generation expenditure factor of heat generator i | [ - ] |

The heat output of all heat generators $q_{g,w,out}$ is the DHW energy need plus the heat losses for storage and distribution:

$$q_{g,w,out} = q_{nd,w} + q_{d,w} + q_{s,w}$$ [kWh/(m²a)] (17)

where

| | | |
|---|---|---|
| $q_{nd,w}$ | is the annual energy need for domestic hot water (useful heat) per m² reference floor area | [kWh/(m²a)] |
| $q_{d,w}$ | is the annual heat loss of the DHW distribution system per m² reference floor area<br>*(national tabled values)* | [kWh/(m²a)] |
| $q_{s,w}$ | is the annual heat loss of the DHW storage per m² reference floor area<br>*(national tabled values)* | [kWh/(m²a)] |

The part $q_{w,h}$ of the heat losses which is produced inside the thermal envelope during the heating season is recoverable:

$$q_{w,h} = q_{g,w,h} + q_{s,w,h} + q_{d,w,h}$$ [kWh/(m²a)] (18)

where

| | | |
|---|---|---|
| $q_{g,w,h}$ | is the recoverable heat loss of the heat generators per m² reference floor area<br>*TABULA standard value = 0 kWh/(m²a) (simplification)* | [kWh/(m²a)] |
| $q_{s,w,h}$ | is the recoverable heat loss of the storages per m² reference floor area<br>*(national tabled values)* | [kWh/(m²a)] |
| $q_{d,w,h}$ | is the recoverable heat loss of the heat distribution system per m² reference floor area<br>*(national tabled values)* | [kWh/(m²a)] |

## 3.2 Heating System

The energy use for heat generator i of the heating system is determined as follows:

$$q_{del,h,i} = \alpha_{nd,h,i}\, q_{g,h,out} e_{g,h,i}$$ [kWh/(m²a)] (19)

where

| | | |
|---|---|---|
| $\alpha_{nd,h,i}$ | fraction of heat generator i | [ - ] |
| $q_{g,h,out}$ | heat output of heat generator i | [kWh/(m²a)] |
| $e_{g,h,i}$ | heat generation expenditure factor of heat generator i | [ - ] |

The heat output of all heat generators $q_{g,h,out}$ is the energy need for heating plus the effective heat losses for distribution and storage (in case a heat storage is installed):

$$q_{g,h,out} = q_{nd,h} - \eta_{h,gn}\left(q_{w,h} + q_{ve,h,rec}\right) + q_{d,h} + q_{s,h}$$ [kWh/(m²a)] (20)

where

| | | |
|---|---|---|
| $q_{nd,h}$ | is the annual energy need for heating (useful heat) per m² reference floor area | [kWh/(m²a)] |
| $\eta_{h,gn}$ | is the dimensionless gain utilization factor, for simplification use of value determined by equation (10) in the context of the energy need for heating | [ - ] |
| $q_{w,h}$ | is the recoverable heat loss of the DHW system per m² reference floor area, determined in accordance with equation (8) | [kWh/(m²a)] |
| $q_{ve,h,rec}$ | is the space heating contribution of the ventilation heat | [kWh/(m²a)] |

| | | |
|---|---|---|
| | recovery unit per m² reference floor area, determined in accordance with equation (21) | |
| $q_{d,h}$ | is the annual effective heat loss of the space heating distribution system per m² reference floor area *(national tabled values)* | [kWh/(m²a)] |
| $q_{s,h}$ | is the annual effective heat loss of the heating system storage per m² reference floor area *(national tabled values)* | [kWh/(m²a)] |

The "effective heat losses" only take into account the fraction of losses which are not reducing the annual energy need for heating. They are calculated by summing up the heat losses of the respective system components caused by the relevant temperature differences during the heating season and then reducing it by the part of heat losses inside the thermal envelope multiplied with the relevant gain utilisation factor.

The space heating contribution of the ventilation heat recovery unit $q_{ve,h,rec}$ is determined as follows:

$$q_{ve,h,rec} = \eta_{ve,rec} \ q_{ht,ve}$$ [kWh/(m²a)] (21)

where

| | | |
|---|---|---|
| $\eta_{ve,rec}$ | is the efficiency of ventilation heat recovery (weighted average during heating season) *(national tabled values)* | [ - ] |
| $q_{ht,ve}$ | is the annual heat transfer by ventilation per m² reference floor area, determined in accordance with equation (6) | [kWh/(m²a)] |

# 4 Assessment of Energywares

## 4.1 Non-Renewable and Total Primary Energy

The annual non-renewable primary energy demand for heating and hot water is calculated:

$$q_{p,nonren,h} = \sum_i f_{p,nonren,h,i}\ q_{del,h,i} + f_{p,nonren,aux}\ q_{del,h,aux} \qquad [\text{kWh/(m}^2\text{a)}]$$
$$q_{p,nonren,w} = \sum_j f_{p,nonren,w,j}\ q_{del,w,j} + f_{p,nonren,aux}\ q_{del,w,aux} \qquad [\text{kWh/(m}^2\text{a)}] \qquad (22)$$

where

| | | |
|---|---|---|
| $f_{p,nonren,h,i}$ <br> $f_{p,nonren,w,j}$ | are the non-renewable primary energy factors of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system <br> *European standard values (EN 15603 Annex E) or national values* | [ - ] |
| $f_{p,nonren,aux}$ | is the non-renewable primary energy factor of electricity used for auxiliary devices <br> *European standard values (EN 15603 Annex E) or national values* | [ - ] |
| $q_{del,h,i}$ <br> $q_{del,w,j}$ | is the annual energy use (delivered energy) of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area | [kWh/(m²a)] |
| $q_{del,h,aux}$ <br> $q_{del,w,aux}$ | is the annual auxiliary energy use of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area | [kWh/(m²a)] |

The total primary energy demand also includes the energy amount resulting from renewable energy sources (for example in the case of firewood it includes the combustion energy):

$$q_{p,total,h} = \sum_i f_{p,total,h,i}\ q_{del,h,i} + f_{p,total,aux}\ q_{del,h,aux} \qquad [\text{kWh/(m}^2\text{a)}]$$
$$q_{p,total,w} = \sum_j f_{p,total,w,j}\ q_{del,w,j} + f_{p,total,aux}\ q_{del,w,aux} \qquad [\text{kWh/(m}^2\text{a)}] \qquad (23)$$

where

| | | |
|---|---|---|
| $f_{p,total,h,i}$ <br> $f_{p,total,w,j}$ | are the total primary energy factors of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system <br> *European standard values (EN 15603 Annex E) or national values* | [ - ] |
| $f_{p,total,aux}$ | is the total primary energy factor of electricity used for auxiliary devices <br> *European standard values (EN 15603 Annex E) or national values* | [ - ] |

## 4.2 Carbon Dioxide Emissions

The annual carbon dioxide emissions for space heating and domestic hot water are determined as follows:

$$m_{co2,h} = 0.001 \left( \sum_i f_{co2,h,i} \; q_{del,h,i} + f_{co2,aux} \; q_{del,h,aux} \right) \quad \text{[kg/(m²a)]}$$

$$m_{co2,w} = 0.001 \left( \sum_j f_{co2,w,j} \; q_{del,w,j} + f_{co2,aux} \; q_{del,w,aux} \right) \quad \text{[kg/(m²a)]} \qquad (24)$$

where

| | | |
|---|---|---|
| $f_{co2,h,i}$<br>$f_{co2,w,j}$ | are the carbon dioxide emission factors of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system<br>*European standard values (EN 15603 Annex E) or national values* | [g/kWh] |
| $f_{co2,aux}$ | is the carbon dioxide emission factor of electricity used for auxiliary devices<br>*European standard values (EN 15603 Annex E) or national values* | [g/kWh] |

## 4.3 Energy Costs

The annual energy costs for space heating and domestic hot water are determined as follows:

$$c_h = \sum_i p_{h,i} \; q_{del,h,i} + p_{aux} \; q_{del,h,aux} \quad \text{[€/(m²a)]}$$

$$c_w = \sum_j p_{w,j} \; q_{del,w,j} + p_{aux} \; q_{del,w,aux} \quad \text{[€/(m²a)]} \qquad (25)$$

where

| | | |
|---|---|---|
| $p_{h,i}$<br>$p_{w,j}$ | are the prices of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system<br>*national values* | [€/kWh] |
| $p_{aux}$ | is the price of electricity used for auxiliary devices<br>*national values* | [€/kWh] |

# 5 Adaptation Method

Due to a number of reasons systematic discrepancies between the calculated and measured energy consumption can be found in practice: There are always uncertainties regarding the actual transmission losses, since the construction materials of an existing building are usually not known in detail and may also be inhomogeneous. In addition, the heat transfer at external and internal surfaces may vary depending on different influences (neighbouring buildings, greened facades, wind protection, furniture near the walls, …) which are difficult to determine. Further uncertainties result from unknown details of the supply system (length, insulation and average temperature of heat pipes, …).

Apart from technical properties of the building envelope and the supply system a further cause for discrepancies of calculated and measured consumption is the user behaviour. An indicator for this influence is the broad spread of consumption values which can be observed in thermally similar buildings and which is the result of different thermal comfort levels.

Systematic dependencies of average indoor conditions can be found in practice: The average winter indoor temperature will typically decrease with rising living space per person (higher probability of unused rooms), with increasing envelope area per living space and with increasing U-values. Apart from a lower temperature also the demand for fresh air would typically be smaller if fewer people were living on the same space. In consequence, it can be expected to find significantly different average indoor conditions for specific building types of a national building typology.

In practice also the type of heating system can influence systematically the average relation between actual and calculated consumption. In dwellings heated by wood or coal stoves a lower average temperature than in centrally heated buildings is experienced as the effort to heat the rooms is much higher (buy and carry the fuel, start a fire) and there is no automatic and continuous system to hold a given indoor temperature. A dependency on the heat or fuel price can be expected: The higher the price of the produced heat the lower the comfort level – of course depending on the income level of the inhabitants. In addition, it can be assumed that the comfort traditions are different from country to country.

It is difficult to include all these aspects in the energy assessment of buildings and in the calculation of the possible energy savings. Therefore the energy performance is usually calculated by making certain simplifications regarding the technical building properties and by determining standard boundary conditions. This helps to keep the effort for data acquisition acceptable. The use of standard values for indoor conditions can also be justified by the need for comparability. The energy performance and heating costs of different buildings should be compared by assuming the same thermal comfort.

One of the main objectives of the creation of national building typologies is to project the actual energy consumption of the building stock and to develop and evaluate strategies for possible reductions. In consequence, the actual consumption of the buildings has to be taken into account – it is the overall target quantity. Information is needed regarding the typical relationship of asset to operational rating – for all national methods as well as for the common calculation method. This knowledge constitutes an important precondition for a reliable determination of energy savings (reduction of energy costs and carbon dioxide emissions), in case of energy advice (typically achievable savings) and in case of building stock modelling (total or average energy savings).

In consequence the TABULA calculation method consists of two different types of energy performance indicators:

1. "standard calculation":
   values determined by the standard reference calculation procedure
2. "typical level of measured consumption":
   calculated values adapted to the typical level of measured consumption

As a simple approach to determine the typical level of measured consumption an adaptation factor is used which depends on the calculated energyware use. The expectation value of the measured consumption is:

$$q_{del,h,adapt,i} = f_{adapt,k}(q_{del})\, q_{del,h,i} \quad \text{[kWh/(m}^2\text{a)]}$$

$$q_{del,w,adapt,j} = f_{adapt,k}(q_{del})\, q_{del,w,j} \quad \text{[kWh/(m}^2\text{a)]} \qquad (26)$$

$$q_{del} = \sum_i q_{del,h,i} + \sum_j q_{del,w,j} \quad \text{[kWh/(m}^2\text{a)]}$$

where

| | | |
|---|---|---|
| $q_{del,h,adapt,i}$<br>$q_{del,w,adapt,j}$ | is the annual energy use of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area, adapted to the typical level of measured consumption | [kWh/(m²a)] |
| $f_{adapt,k}(q_{del})$ | is the adaptation factor of type k, as a function of the delivered energy $q_{del}$ (sum of energywares without auxiliary electricity) determined by standard calculation method; according to the TABULA method the adaptation function is given in form of tabled values for 6 nodes of $q_{del}$: 0, 100, 200, 300, 400 and 500 kWh/(m²a), interim values should be interpolated; different types k of adaptation factors may be used, depending on the type of energyware and supply system | [ - ] |
| $q_{del,h,i}$<br>$q_{del,w,j}$ | is the annual energy use of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area, calculated by applying the standard boundary conditions | [kWh/(m²a)] |

The empirical calibration factor describes a typical ratio of the energy uses determined by measurements for a large number of buildings and by the TABULA method for the given value of the TABULA method. Information about this correlation may be available from different kinds of sources. It is of course desirable to rely on statistically accurate determinations (representative samples, census). Nevertheless, not in all countries such investigations have been performed so far – and in none of the countries information is available for all types of supply systems. Therefore an indicator for the accuracy of the adaptation functions is introduced, which can assume the following levels:

accuracy level A: determined for the whole building stock or a representative sample;

accuracy level B: determined by a large number of example buildings;

accuracy level C: estimated (e.g. on the basis of few example buildings)

# 6 Climatic Data

## 6.1 General Approach

The length of the heating season $d_{hs}$ (number of "heating days" ) of a year is defined as follows:

$$d_{hs} = \sum_{i=1}^{365} d_i \quad for\, \overline{\vartheta_{e,i}} \leq \vartheta_{e,b} \qquad [d/a] \qquad (27)$$

where

| | | |
|---|---|---|
| $i$ | is the index of the days of a year | [ - ] |
| $d_i$ | duration of day $i$ = 1 d | [d] |
| $\overline{\vartheta_{e,i}}$ | temperature of the external environment, average value for the respective day $i$ | [°C] |
| $\vartheta_{e,b}$ | is the heating base temperature; *standard TABULA value:* $\vartheta_{e,b}$ *= 12°C* | [°C] |
| $d_{hs}$ | length of the heating season, expressed in days | [h/a] |

For simplification reasons the heating base temperature is set to a constant value for all types and energy performance levels of buildings and for all climates. [4]

[4] The *physical model* would of course be more precise if the heating season balance was determined by use of a variable base temperature or if a monthly method was implemented. However, the simplification was chosen due to the following reasons:

- Only one climatic dataset is necessary for each country or region. It only contains 7 quantities and is therefore easy to understand and to compare.
- An implementation of the calculation of large numbers of buildings or variants in spreadsheets is much easier.
- A constant base temperature also enables a simple handling of heat supply system losses (distribution and storage, see chapter 3).
- The correct balance (and correct base temperature) much depends on the solar and internal gains for which in practice a strong variation can be observed and which cannot be determined for a large number of buildings sufficiently exact. A detailed method with a large uncertainty of input parameters does not necessarily produce results which are more realistic.
- The systematic deviations of the seasonal method from the monthly method have been determined in [Loga 2003]: They are – considering the other uncertainties of the calculation of large building portfolios – not significant.
- In theory old buildings would be expected to show a higher base temperature than well insulated buildings, due to the lower loss/gain ratio. But this is only true if the indoor temperatures are the same. In practice, the average winterly room temperature of old buildings is typically much lower (“prebound effect” see [Sunikka-Blank/Galvin 2012]), caused by the influence of night setback and not directly heated spaces as well as by considerably higher costs per degree of temperature increase. This effect counteracts the higher base temperature to a certain extent, because it is only the difference of room and base temperature which depends on the thermal building quality.
- Since the TABULA concept includes an adaptation to the typical level of measured consumption a possible systematic deviation would be neutralised, anyway.

The average temperature during the heating season $\overline{\vartheta_{e,hs}}$ is given by equation (28):

$$\overline{\vartheta_{e,hs}} = \frac{\sum_{i=1}^{365} \overline{\vartheta_{e,i}}}{d_{HS}} \quad for \ \overline{\vartheta_{e,i}} \leq \vartheta_b$$ [d/a] (28)

where

| | | |
|---|---|---|
| $i$ | is the index of the days of a year | [ - ] |
| $\overline{\vartheta_{e,i}}$ | temperature of the external environment,<br>average value for the respective day $i$ | [°C] |
| $d_{hs}$ | length of the heating season, expressed in days | [d] |
| $\vartheta_b$ | is the heating base temperature;<br>*standard TABULA value:* $\vartheta_b$ *= 12°C* | [°C] |

The global solar radiation on a surface of orientation $k$ during the heating season $I_{sol,k,hs}$ is given by equation (29):

$$I_{sol,k,hs} = \frac{\sum_{i=1}^{365} I_{sol,k,i}}{d_{HS}} \quad for \ \overline{\vartheta_{e,i}} \leq \vartheta_b$$ [d/a] (29)

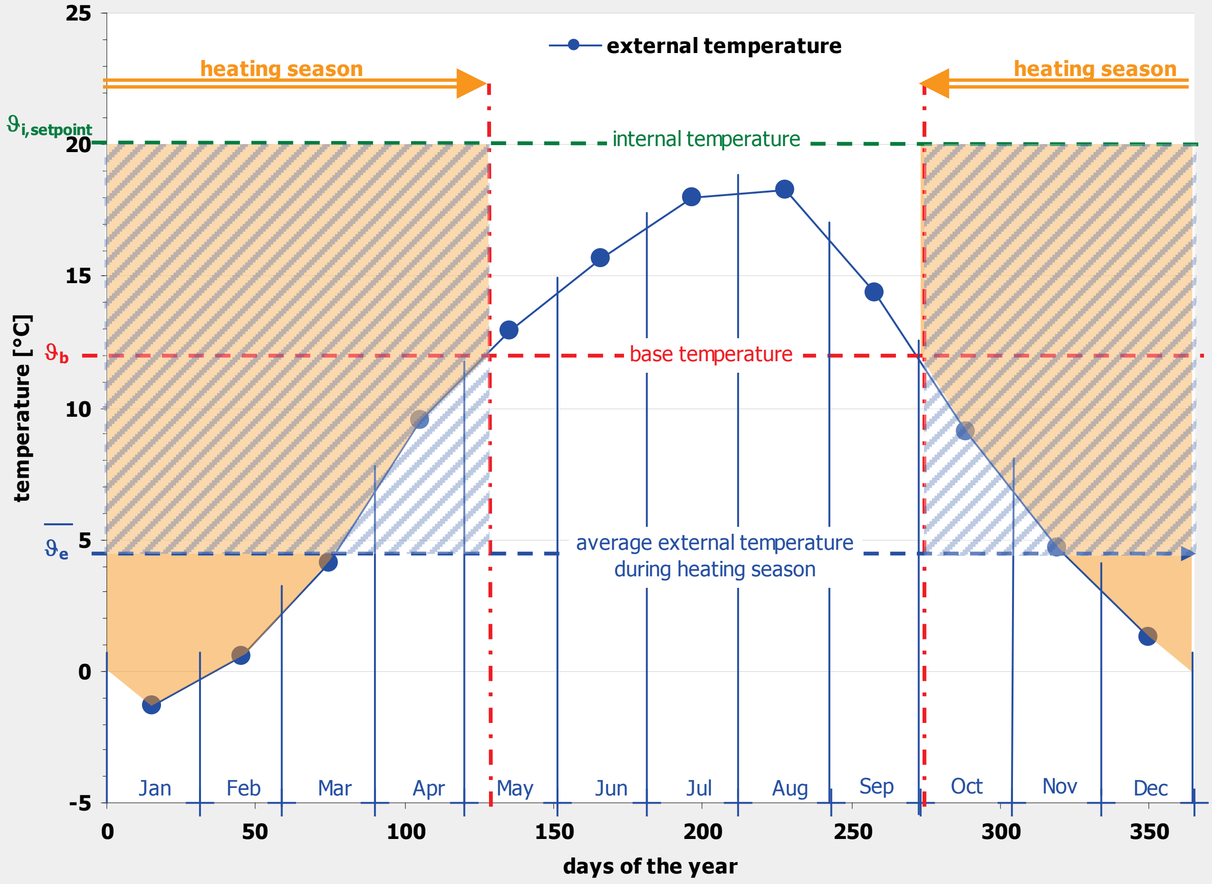
where

| | | |
|---|---|---|
| $i$ | is the index of the days of a year | [ - ] |
| $k$ | is the orientation of the respective surface | [ - ] |
| $I_{sol,k,hs}$ | global solar radiation on 1 m² surface of orientation $k$ during the heating season | [kWh/(m²a)] |
| $I_{sol,k,i}$ | global solar radiation on 1 m² surface of orientation $k$ during day i | [kWh/(m²d)] |
| $d_{hs}$ | length of the heating season, expressed in days | [d] |
| $\vartheta_b$ | is the heating base temperature;<br>*standard TABULA value:* $\vartheta_b$ *= 12°C* | [°C] |

## 6.2 Simplified Determination of Seasonal Climate by Use of Monthly Average Data

The above mentioned climatic data for the heating season will usually be determined on the basis of average daily data. In case that daily averages of the external temperature and the solar radiation are not available for a region or country they can be estimated by use of monthly data. For this purpose the daily values are determined by linear interpolation between the monthly averages as sketched in Fig. 1. In a similar manner the global solar radiation during the heating season is determined on the basis of monthly values. [5]

**Fig. 1: Determination of seasonal climatic data on the basis of monthly averages**




[5] The formulas for this approximation can be found in the calculation sheet "tabula-calculator.xls" at: http://www.building-typology.eu/ .

# 7 Common Reference Area

In order to compare different buildings it is convenient to relate the energy consumption to a quantity representing the size of the building, usually the conditioned floor area or volume of the building. However, different types of reference areas or volumes are being used in different countries and there is no type which is available for all countries. Therefore a common reference area is needed which is used for the purpose of cross-country comparison and which is derived from the available reference quantities.

In general those sections of a building are considered which are supposed to provide thermal conditions different from the external climate. In the context of this method referring to the energy service "space heating", the conditioned area includes all zones which are heated directly or indirectly during the heating season.

The definition of reference areas is based on the DATAMINE data structure. It contains the following types of floor areas (see [DATAMINE FR]):

**Table 5: Definition of different reference quantities according to the DATAMINE data structure [DATAMINE FR]**

| Quantity | symbol | | Description |
|---|---|---|---|
| **conditioned gross floor area** | $A_{C,extdim}$ | m² | conditioned floor area determined on the basis of external dimensions (measured from edges at the outside surface of external walls). |
| **conditioned floor area** | $A_{C,intdim}$ | m² | conditioned floor area calculated on the basis of internal dimensions (measured from edges at the inside surface of external walls).<br>*The floor area may be the gross internal area (= total building area measured inside external walls) or the net internal area (= total building area measured inside external and internal walls) - since the difference is small we don't distinguish between both.* |
| **conditioned useful floor area** | $A_{C,use}$ | m² | section of the conditioned net floor area primarily dedicated to the utilisation of the building, excluding functional and circulation areas (excluding e.g. stair cases in all buildings, corridors in non-residential buildings).<br>*In office buildings the conditioned useful floor area is equivalent to the net lettable area.* |
| **conditioned living area** | $A_{C,living}$ | m² | section of the conditioned net floor area inside of the apartments of the building (only relevant for buildings which are completely or at least partly used as residential buildings) |
| **conditioned building volume** | $V_C$ | m³ | conditioned volume of the building (external dimensions) |

The common reference area used in the DATAMINE concept is the conditioned floor area based on internal dimensions. The reason for this choice is that the values are typically in the middle of the variation range (between $A_{C,extdim}$ and $A_{C,use}$ or $A_{C,living}$). In consequence the area related energy performance indicators are closer to those which are known in the different countries and can therefore be more easily compared with well-known values without converting.

If this area is available for a building the reference area $A_{C,ref}$ will be derived directly from $A_{C,intdim}$. If it is not available, $A_{C,ref}$ is estimated by use of the available reference quantities using the following adaptation factors (and the given sequence of queries):

**Table 6: Conversion factors for the determination of the common reference area $A_{C,ref}$ used for cross-country comparisons** [DATAMINE FR]

| Available quantity | $A_{C,ref}$ [m²] |
|---|---|
| conditioned floor area based on internal dimensions | = $A_{C,intdim}$ |
| conditioned floor area based on external dimensions | = 0,85 · $A_{C,extdim}$ |
| conditioned living area | = 1,1 · $A_{C,living}$ |
| conditioned useful floor area | = 1,4 · $A_{C,use}$ |
| conditioned building volume | = 0.85/3.0 [1/m] · $V_C$ = 0,283 [1/m] · $V_C$ |

# 8 Appendix

## 8.1 References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*Download of the long version of this publication (in German language):*
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[TABULA NSR] National scientific reports of the TABULA partners, download from TABULA website
www.building-typology.eu/tabulapublications.html

[TABULA Spreadsheets] TABULA workbook "tabula-calculator.xls" consisting of spreadsheets for the row-by-row calculation, including datasets of all example buildings of the national residential building typologies (elaborated in the framework of the IEE project TABULA, simplified version of the Excel workbook "TABULA.xls"). Download at www.building-typology.eu/tabulapublications.html .

[TABULA WebTool] TABULA WebTool;
a) standard version for online calculation of predefined building/system combinations; b) expert version for arbitrary building/system combinations, data access and online comparison of calculation results; the webtool was elaborated in the framework of the IEE project TABULA (online version of the Excel workbook "TABULA.xls").
Online access and user guide: www.webtool.building-typology.eu .

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http://www.building-typology.eu/downloads/public/docs/report/TABULA_FinalReport_AppendixVolume.pdf

## 8.2 Used Quantities

| Quantity | Explanation | Unit | Chapter |
|---|---|---|---|
| $a_{H,0}$ | constant parameter<br>standard value for the seasonal method:<br>$a_{H,0}$ = 0.8 (according to EN 13790) | [ - ] | 2.5 |
| $\alpha_{nd,h,i}$ | fraction of heat generator i used for space heating | [ - ] | 3.2 |
| $\alpha_{nd,w,i}$ | fraction of DHW heat generator i | [ - ] | 3.1 |
| $\Delta U_{tbr}$ | surcharge on all U-values, taking into account the additional loses caused by thermal bridging | [W/(m²K)] | 2.2 |
| $\eta_{h,gn}$ | dimensionless gain utilization factor | [ - ] | 2.1 |
| $\varphi_{int}$ | average thermal output of internal heat sources | [W/m²] | 2.4 |
| $\eta_{h,gn}$ | dimensionless gain utilization factor, | [ - ] | 3.2 |
| $\eta_{ve,rec}$ | efficiency of ventilation heat recovery (weighted average during heating season) | [ - ] | 3.2 |
| $\vartheta_{e,b}$ | heating base temperature | [°C] | 6 |
| $\overline{\vartheta_{e,hs}}$ | temperature of the external environment (average value during heating season) | [°C] | 2.1 |
| $\overline{\vartheta_{e,i}}$ | temperature of the external environment, average value for the respective day $i$ | [°C] | 6 |
| $\vartheta_{int}$ | internal temperature (set-point temperature for space heating) | [°C] | 2.1 |
| $\tau$ | time constant of the building (see below) | [h] | 2.5 |
| $\tau_{H,0}$ | is a constant parameter<br>standard value for the seasonal method:<br>$\tau_{H,0}$ = 30 h (according to EN 13790) | [h] | 2.5 |
| $\tau_{H,0}$ | is a constant parameter<br>standard value for the seasonal method:<br>$\tau_{H,0}$ = 30 h (according to EN 13790) | [h] | 2.5 |
| $A_{C,extdim}$ | conditioned floor area based on external dimensions | [m²] | 7 |
| $A_{C,intdim}$ | conditioned floor area based on internal dimensions | [m²] | 7 |
| $A_{C,living}$ | conditioned living area | [m²] | 7 |
| $A_{C,ref}$ | reference area of the building | [m²] | 2.3, 2.4, 7 |
| $A_{C,use}$ | conditioned useful floor area | [m²] | 7 |
| $A_{window,j}$ | area of all windows with orientation j | [m²] | 2.4 |
| $b_{tr}$ | adjustment factor soil | [ - ] | 2.2 |

| | | | |
|---|---|---|---|
| $c_h$ $c_w$ | annual energy costs for space heating and domestic hot water | [€/(m²a)] | 4.3 |
| $c_m$ | internal heat capacity per m² reference area | [Wh/m²K] | 2.5 |
| $c_{p,air}$ | volume-specific heat capacity of air | [Wh/(m³K)] | 2.3 |
| $d_{hs}$ | length of the heating season expressed in days | [d/a] | 2.1, 2.4, 6 |
| $d_i$ | duration of day i = 1 d<br>i index of the days of a year | [d] | 6 |
| $e_{g,h,i}$ | heat generation expenditure factor of heat generator i used for space heating | [ - ] | 3.2 |
| $e_{g,w,i}$ | heat generation expenditure factor of DHW heat generator i | [ - ] | 3.1 |
| $A_{env,i}$ | area of envelope element i | [m²] | 2.2 |
| $f_{adapt,k}(q_{del})$ | adaptation factor of type k, as a function of the delivered energy $q_{del}$ (sum of energywares without auxiliary electricity) determined by standard calculation method | [ - ] | 5 |
| $f_{co2,aux}$ | carbon dioxide emission factor of electricity used for auxiliary devices | [g/kWh] | 4.2 |
| $f_{co2,h,i}$<br>$f_{co2,w,j}$ | carbon dioxide emission factors of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system | [g/kWh] | 4.2 |
| $F_F$ | frame are fraction of the windows | [ - ] | 2.4 |
| $F_{nu}$ | dimensionless correction factor for non-uniform heating, taking into account systematic deviations of the set-point temperature and the actual average temperature (time average over night and day as well as space average over living areas and reduced or indirectly heated spaces) | [ - ] | 2.1 |
| $f_{p,nonren,aux}$ | non-renewable primary energy factor of electricity used for auxiliary devices | [ - ] | 4 |
| $f_{p,nonren,h,i}$<br>$f_{p,nonren,w,j}$ | non-renewable primary energy factors of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system | [ - ] | 4.1 |
| $f_{p,total,aux}$ | total primary energy factor of electricity used for auxiliary devices | [ - ] | 4.1 |
| $f_{p,total,h,i}$<br>$f_{p,total,w,j}$ | total primary energy factors of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system | [ - ] | 4.1 |
| $F_{sh}$ | reduction factor external shading | [ - ] | 2.4 |
| $F_W$ | is a reduction factor, considering radiation non-perpendicular to the glazing | [ - ] | 2.4 |
| $g_{gl,n}$ | total solar energy transmittance for radiation perpendicular to the glazing | [ - ] | 2.4 |

| | | | |
|---|---|---|---|
| $h_{room,ve\ ref}$ | ventilation reference room height | [m] | 2.3 |
| $H_{tr}$ | overall heat transfer coefficient by transmission | [W/K] | 2.1, 2.5 |
| $h_{tr}$ | heat transfer coefficient by transmission per m² reference floor area | [W/(m²K)] | 2.6 |
| $h_A$ , $h_B$ | are constants, depending on the building type | [W/(m²K)] | 2.6 |
| $H_{ve}$ | total heat transfer by ventilation | [W/K] | 2.5, 2.1 |
| $I_{Sol,j}$ | average global irradiation on surfaces with orientation j during the heating season | [m²] | 2.4 |
| $I_{sol,k,hs}$ | global solar radiation on 1 m² surface of orientation k during the heating season | [kWh/(m²a)] | 6 |
| $I_{sol,k,i}$ | global solar radiation on 1 m² surface of orientation k during day i | [kWh/(m²d)] | 6 |
| $k$ | orientation of a transparent surface | [ - ] | 6 |
| $m_{co2,h}$ $m_{co2,w}$ | annual carbon dioxide emissions for space heating and domestic hot water | [kg/a] | 4.2 |
| $n_{air,infiltr}$ | air change rate by infiltration | [1/h] | 2.3 |
| $n_{air,use}$ | average air change rate during heating season, related to the utilisation of the building | [1/h] | 2.3 |
| $p_{aux}$ | price of electricity used for auxiliary devices | [€/kWh] | 4.3 |
| $p_{h,i}$ $p_{w,j}$ | prices of the energyware used by heat generator i of the heating system and by heat generator j of the hot water system | [€/kWh] | 4.3 |
| $q_{del,h,adapt,i}$ $q_{del,w,adapt,j}$ | expectation value of the measured consumption for space heating and DHW | [kWh/(m²a)] | 5 |
| $q_{del,h,adapt,i}$ $q_{del,w,adapt,j}$ | annual energy use of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area, adapted to the typical level of measured consumption | [kWh/(m²a)] | 5 |
| $q_{del,h,aux}$ $q_{del,w,aux}$ | annual auxiliary energy use of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area | [kWh/(m²a)] | 4 |
| $q_{del,h,i}$ $q_{del,w,j}$ | annual energy use (delivered energy) of heat generator i of the heating system and of heat generator j of the hot water system per m² reference floor area, calculated by applying the standard boundary conditions | [kWh/(m²a)] | 4, 5 |
| $q_{d,h}$ | annual effective heat loss of the space heating distribution system per m² reference floor area | [kWh/(m²a)] | 3.2 |
| $q_{d,w}$ | annual heat loss of the DHW distribution system per m² reference floor area | [kWh/(m²a)] | 3.1 |
| $q_{d,w,h}$ | recoverable heat loss of the DHW distribution system per m² reference floor area | [kWh/(m²a)] | 3.1 |

| | | | |
|---|---|---|---|
| $q_{g,h,out}$ | heat output of heat generator i used for space heating | [kWh/(m²a)] | 3.2 |
| $q_{g,w,h}$ | recoverable heat loss of the DHW heat generators per m² reference floor area | [kWh/(m²a)] | 3.1 |
| $q_{g,w,out}$ | heat output of DHW heat generator i | [kWh/(m²a)] | 3.1 |
| $Q_{H,gn}$ | total heat gains for the heating mode | [kWh/a] | 2.1, 2.4 |
| $Q_{H,nd}$ | building energy need for heating,<br>assumed to be greater than or equal to 0 | [kWh/a] | 2.1 |
| $Q_{ht}$ | total heat transfer for the heating mode | [kWh/a] | 2.1, 2.4 |
| $Q_{ht,tr}$ | total heat transfer by transmission during the heating season | [kWh/a] | 2.1 |
| $Q_{ht,ve}$ | total heat transfer by ventilation during the heating season | [kWh/a] | 2.1 |
| $q_{ht,ve}$ | annual heat transfer by ventilation<br>per m² reference floor area | [kWh/(m²a)] | 3.2 |
| $q_{nd,h}$ | annual energy need for heating (useful heat) per m² reference floor area | [kWh/(m²a)] | 3.2 |
| $q_{nd,w}$ | annual energy need for domestic hot water (useful heat) per m² reference floor area | [kWh/(m²a)] | 3.1 |
| $q_{p,nonren,h}$<br>$q_{p,nonren,w}$ | non-renewable primary energy demand for heating and hot water | | 4.1 |
| $q_{p,total,h}$<br>$q_{p,total,w}$ | total primary energy demand for heating and hot water | [kWh/(m²a)] | 4.1 |
| $q_{s,h}$ | annual effective heat loss of the heating system storage per m² reference floor area | [kWh/(m²a)] | 3.2 |
| $q_{s,w}$ | annual heat loss of the DHW storages per m² reference floor area | [kWh/(m²a)] | 3.1 |
| $q_{s,w,h}$ | recoverable heat loss of the DHW storages per m² reference floor area | [kWh/(m²a)] | 3.1 |
| $q_{w,h}$ | recoverable heat loss of the DHW system per m² reference floor area | [kWh/(m²a)] | 3.2 |
| $q_{ve,h,rec}$ | space heating contribution of the ventilation heat recovery unit per m² reference floor area | [kWh/(m²a)] | 3.2 |
| $R_{0,i}$ | thermal resistance of the envelope element i in the original state, calculated according to EN ISO 6946 | [m²K/W] | 2.2 |
| $R_{add,i}$ | additional thermal resistance<br>due to unheated space bordering<br>at the construction element i | [m²K/W] | 2.2 |
| $R_{eff,i}$ | effective thermal resistance of the envelope element i | [m²K/W] | 2.2 |
| $R_{measure,i}$ | (additional) thermal resistance of a thermal refurbishment measure applied to the element i<br>in case of a simple insulation measure (additional layer of | [m²K/W] | 2.2 |

| | | | |
|---|---|---|---|
| | insulation) $R_{measure,i}$ is calculated by a quotient of the insulation thickness $d_{ins,i}$ and the thermal conductivity $\lambda_{ins,i}$; in other cases (e.g. in case of insulation between rafters) the thermal resistance is calculated by the rules of EN ISO 6946 | | |
| $U_{0,i}$ | U-value of the envelope element i in the original state, calculated according to EN ISO 6946 | [W/(m²K)] | 2.2 |
| $U_{eff,i}$ | effective U-value of the envelope element i | [W/(m²K)] | 2.2 |
| $V_C$ | conditioned building volume | [m³] | 7 |

## 8.3 Exemplary Climatic Data

The following climatic data were compiled during the TABULA project. The current version of this table is available at: [TABULA Spreadsheets].

**Table 7: Exemplary climatic data**

| TABULA Code | Climate Region | National Name | Remarks | $\vartheta_{e,b}$ | $d_{hs}$ | $\vartheta_{e,b}$ | $I_{Sol,H}$ | $I_{Sol,E}$ | $I_{Sol,S}$ | $I_{Sol,W}$ | $I_{Sol,N}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | °C | d | °C | kWh/a | kWh/a | kWh/a | kWh/a | kWh/a |
| **AT.N** | national / whole country | Standard Österreich | Source: ÖNORM B 8110-5 | 12 | 212 | 3,9 | 403 | 246 | 401 | 246 | 148 |
| **AT.mountain** | Central Alps | Zentralalpen | Source: ÖNORM B 8110-5 | 12 | 260 | 2,8 | 657 | 436 | 261 | 436 | 993 |
| **BE.N** | national / whole country | Belgie - Ukkel | Ukkel | 12 | 210 | 6,2 | 336 | 202 | 340 | 202 | 110 |
| **CZ.N** | Czech Republic | Česka Republi-ka | | 12 | 217 | 3,8 | 374 | 225 | 396 | 225 | 99 |
| **CZ.NW** | North West. Liberec - Usti Nad Labem - Karlovy Varzy | | | 12 | 221 | 4,0 | 385 | 231 | 407 | 234 | 104 |
| **CZ.SW** | South West. Prague - Plzen - České Budejovice | | | 12 | 215 | 3,8 | 369 | 223 | 382 | 220 | 96 |
| **CZ.NC** | North Center. Hradec Kralove - Pardubice | | | 12 | 217 | 3,8 | 372 | 226 | 399 | 227 | 100 |
| **CZ.SC** | South Center. Jihlava | | | 12 | 226 | 3,4 | 416 | 249 | 398 | 248 | 111 |
| **CZ.NE** | North East. Olomouc - Ostrava | | | 12 | 212 | 3,5 | 355 | 212 | 390 | 213 | 94 |
| **CZ.SE** | South East. Brno - Zlin | | | 12 | 208 | 3,6 | 354 | 211 | 385 | 212 | 94 |
| **DE.N** | Germany | Standard Deutschland | Source: DIN V 18599 | 12 | 222 | 4,4 | 403 | 271 | 392 | 271 | 160 |
| **DK.N** | national / whole country | Danmark | Be06 klimadata | 12 | 246 | 4,2 | 447 | 313 | 524 | 313 | 150 |
| **ES.B3** | zone B3 | Alicante | | 18 | 34 | 11,7 | 112 | 52 | 115 | 45 | 24 |
| **ES.B4** | zone B4 | Valencia | | 17 | 84 | 10,9 | 211 | 141 | 285 | 116 | 66 |
| **FR.N** | National | N | National | 12 | 209 | 7,1 | 419 | 265 | 423 | 265 | 160 |
| **FR.H1** | ZoneH1 | H1 | ZoneH1 | 12 | 229 | 6,4 | 422 | 265 | 396 | 265 | 172 |
| **FR.H2** | ZoneH2 | H2 | ZoneH2 | 12 | 216 | 7,6 | 407 | 252 | 371 | 252 | 167 |
| **FR.H3** | ZoneH3 | H3 | ZoneH3 | 12 | 181 | 9,5 | 301 | 161 | 358 | 192 | 108 |
| **GR.A** | zone A | | KENAK 2009 | 12 | 57 | 11,3 | 139 | 88 | 165 | 88 | 40 |
| **GR.B** | zone B | | KENAK 2009 | 12 | 104 | 10,0 | 244 | 160 | 301 | 160 | 73 |
| **GR.C** | zone C | | KENAK 2009 | 12 | 150 | 7,5 | 351 | 232 | 424 | 232 | 106 |
| **GR.D** | zone D | | KENAK 2009 | 12 | 168 | 6,0 | 420 | 278 | 497 | 278 | 127 |
| **IE.N** | national / whole country | Ireland | Souce: DEAP | 12 | 243 | 7,6 | 475 | 306 | 485 | 306 | 185 |
| **IT.MidClim** | Climatic Middle Zone (Italian Climatic Zone E) | Zona Climatica Media (Zona E) | Source: UNI 10349 | 12 | 174 | 5,2 | 378 | 290 | 496 | 290 | 122 |
| **PL.N** | country | Poland | | 12 | 242 | 2,8 | 647 | 462 | 560 | 448 | 391 |
| **RS.N** | national / whole country | Srbija | | 12 | 185 | 5,6 | 398 | 310 | 455 | 310 | 145 |
| **SE.Zone3** | Zone III | Klimatzon 3 | Sourse: BBR (Building Regulations, BBR ) | 12 | 261 | 2,2 | 450 | 328 | 496 | 328 | 138 |
| **SE.Zone2** | Zone II | Klimatzon 2 | Sourse: BBR (Building Regulations, BBR ) | 12 | 286 | 0,3 | 492 | 372 | 524 | 372 | 161 |
| **SE.Zone1** | Zone I | Klimatzon 1 | Sourse: BBR (Building Regulations, BBR ) | 12 | 365 | -1,2 | 711 | 628 | 725 | 628 | 309 |
| **SI.N** | national / whole country | Slovenija | | 12 | 206 | 4,3 | 375 | 241 | 292 | 218 | 98 |

## 8.4 TABULA Supply System Codes

In order to identify different types of heat supply components and energy carriers in a uniform way codes have been defined. The basic set of codes was developed in the framework of the Intelligent Energy Europe project DATAMINE [DATAMINE FR]. Further definitions have been supplemented for the purposes of the TABULA project.

**Table 8: Heating System: Heat Generator Types**

| Code_Type_SysHG | Name_Type_SysHG | Description_Type_SysHG |
|---|---|---|
| code of the heat generator type (heating system) | name of the heat generator type (heating system) | description of the heat generator type (heating system) |
| **B** | boiler | boiler (type unknown) |
| **B_NC** | boiler, non-condensing | non-condensing boiler (further details unknown) |
| **B_NC_CT** | boiler, non-condensing, constant temperature | constant temperature non-condensing boiler |
| **B_NC_LT** | boiler, non-condensing, low temperature | low temperature non-condensing boiler |
| **B_C** | boiler, condensing | condensing boiler |
| **B_WP** | wood-pellets boiler | boiler for combustion of wood pellets |
| **G_IWH** | gas-fired instantaneous water heater | instantaneous water heater, fired by gas (tankless) |
| **G_IWH_NC** | gas-fired instantaneous water heater, non-condensing | instantaneous water heater, fired by gas (tankless) |
| **G_IWH_C** | gas-fired instantaneous water heater, condensing | instantaneous water heater, fired by gas (tankless), condensing |
| **G_SH** | gas-fired space heater | gas-fired space heater |
| **E** | direct electric heat generator | direct electric, not specified: any device which uses electricity for direct heat generation, e.g. electric stoves (no heat pumps which use also heat from the environment) |
| **E_Immersion** | electric immersion heater | electric heating rod or coil, immersed in a water storage |
| **E_Storage** | electrical night storage space heater | electrical night storage space heater (off-peak storage heating), heat emission by convection |
| **E_UnderFloor** | electrical underfloor heating | electrical underfloor heating |
| **E_SH** | electrical space heater | electrical space heater: radiative heater or (forced) convection heater |
| **HP** | heat pump | heat pump (type unknown), remark: also reversible engines that work as a cold generator in summer are to be considered here or (if heat source is known) below |
| **HP_Air** | heat pump, heat source external air | air source heat pump: heat pump, using the external air as the heat source |
| **HP_Ground** | heat pump, heat source ground | ground source heat pump (or geothermal heat pump): heat pump, using the ground as the heat source |
| **HP_ExhAir** | heat pump, heat source exhaust air | heat pump, using exhaust air of a ventilation system as the heat source |
| **HP_Water** | heat pump, heat source ground water | heat pump, using ground water or a water stream as the heat source |
| **HP_Other** | heat pump, other heat sources | heat pump, using more than one or other heat sources (e.g. industrial exhaust heat, low-temperature district heat) |
| **Stove** | stove | stove, fuel fired |
| **Stove_L** | stove for liquid fuels | stove for liquid fuels, especially oil stove |
| **Stove_S** | stove for solid fuels | stove for solid fuels, especially wood and coal |
| **OpenFire** | open fire | open fire (fireplace, mantle) |
| **TS** | district heating transfer station | heat exchanger (heat transfer station, heat substation) of a district heating system |
| **CHP** | combined heat and power generation | cogeneration system: combined heat and (electric) power generation |
| **Solar** | thermal solar plant | thermal solar plant |
| **Steam** | steam generator | steam generator (any type) |
| **Other** | other | other generator type |

### Table 9: DHW System: Heat Generator Types

| Code_Type_SysWG | Name_Type_SysWG | Description_Type_SysWG |
|---|---|---|
| code of the heat generator type (domestic hot water system) | name of the heat generator type (domestic hot water system) | description of the heat generator type (domestic hot water system) |
| **B** | boiler | boiler (type unknown) |
| **B_NC** | boiler, non-condensing | non-condensing boiler (further details unknown) |
| **B_NC_CT** | boiler, non-condensing, constant temperature | constant temperature non-condensing boiler |
| **B_NC_LT** | boiler, non-condensing, low temperature | low temperature non-condensing boiler |
| **B_C** | boiler, condensing | condensing boiler |
| **B_WP** | wood-pellets boiler | boiler for combustion of wood pellets |
| **G_IWH** | gas-fired instantaneous water heater | instantaneous water heater, fired by gas (tank-less) |
| **G_IWH_NC** | gas-fired instantaneous water heater, non-condensing | instantaneous water heater, fired by gas (tank-less) |
| **G_IWH_C** | gas-fired instantaneous water heater, condens-ing | instantaneous water heater, fired by gas (tank-less), condensing |
| **G_Tank** | gas burner for directly heated DHW tank | gas burner as a heating element of a domestic hot water tank (separately from space heating sys-tem) |
| **E** | direct electric heat generator, not specified | direct electric, not specified: any device which uses electricity for direct heat generation, e.g. electric heating element in water storage, instan-taneous water heater |
| **E_Immersion** | electric immersion heater | electric heating rod or coil, immersed in a water storage |
| **E_IWH** | electric instantaneous water heater | electric instantaneous water heater (tankless) |
| **HP** | heat pump | heat pump (type unknown), remark: also reversi-ble engines that work as a cold generator in sum-mer are to be considered here or (if heat source is known) below |
| **HP_Air** | heat pump, heat source external air | air source heat pump: heat pump, using the external air as the heat source |
| **HP_Ground** | heat pump, heat source ground | ground source heat pump (or geothermal heat pump): heat pump, using the ground as the heat source |
| **HP_ExhAir** | heat pump, heat source exhaust air | heat pump, using exhaust air of a ventilation system as the heat source |
| **HP_Water** | heat pump, heat source ground water | heat pump, using ground water or a water stream as the heat source |
| **HP_Cellar** | heat pump, heat source: cellar air | heat pump, using cellar air as heat source |
| **HP_Other** | heat pump, other heat sources | heat pump, using more than one or other heat sources (e.g. industrial exhaust heat, low-temperature district heat) |
| **TS** | district heating transfer station | heat exchanger (heat transfer station, heat sub-station) of a district heating system |
| **CHP** | combined heat and power generation | cogeneration system: combined heat and (elec-tric) power generation |
| **Solar** | thermal solar plant | thermal solar plant |
| **Steam** | steam generator | steam generator (any type) |
| **Other** | other | other generator type |

### Table 10: Energyware Types

| Code_EnergyCarrier | Name_EnergyCarrier | Description_EnergyCarrier |
|---|---|---|
| identification of the energy carrier | name of the energy carrier | detailed description of the energy carrier |
| **Gas** | **natural gas** | **natural gas, type unknown** |
| **Gas_E** | natural gas E | natural gas E |
| **Gas_LL** | natural gas LL | natural gas LL |
| **Gas_Liquid** | **liquid gas** | **liquid gas** |
| **Oil** | **heating oil** | **heating oil** |
| **Coal** | **coal** | **coal, type unknown** |
| **Coal_Hard** | hard coal | hard coal |
| **Coal_Lignite** | lignite coal | lignite coal |
| **Bio** | **biomass** | **biomass, type unknown** |
| **Bio_FW** | firewood | firewood |
| **Bio_WP** | wood pellets | wood pellets |
| **Bio_WC** | wood chips | wood chips |
| **Bio_Other** | other biomass | biomass, if different from firewood or wood pellets |
| **El** | **electricity** | **electricity** |
| **El_OP** | off-peak electricity | off-peak electricity |
| **El_Prod** | electricity production | electricity production by combined heat-power generation |
| **DH** | **district heating** | **district heating, type unknown** |
| **DH_Gas_NoCHP** | district heating gas without chp | district heating, fuel gas, heat generation without combined heat and power (chp) |
| **DH_Gas_CHP33** | district heating gas with 33% chp | district heating, fuel gas, heat generation with combined heat and power (chp) fraction 33% |
| **DH_Gas_CHP67** | district heating gas with 67% chp | district heating, fuel gas, heat generation with combined heat and power (chp) fraction 67% |
| **DH_Gas_CHP100** | district heating gas with 100% chp | district heating, fuel gas, heat generation with combined heat and power (chp) fraction 100% |
| **DH_Oil_NoCHP** | district heating oil without chp | district heating, fuel oil, heat generation without combined heat and power (chp) |
| **DH_Oil_CHP33** | district heating oil with 33% chp | district heating, fuel oil, heat generation with combined heat and power (chp) fraction 33% |
| **DH_Oil_CHP67** | district heating oil with 67% chp | district heating, fuel oil, heat generation with combined heat and power (chp) fraction 67% |
| **DH_Oil_CHP100** | district heating oil with 100% chp | district heating, fuel oil, heat generation with combined heat and power (chp) fraction 100% |
| **DH_Coal_NoCHP** | district heating coal without chp | district heating, fuel coal, heat generation without combined heat and power (chp) |
| **DH_Coal_CHP33** | district heating coal with 33% chp | district heating, fuel coal, heat generation with combined heat and power (chp) fraction 33% |
| **DH_Coal_CHP67** | district heating coal with 67% chp | district heating, fuel coal, heat generation with combined heat and power (chp) fraction 67% |
| **DH_Coal_CHP100** | district heating coal with 100% chp | district heating, fuel coal, heat generation with combined heat and power (chp) fraction 100% |
| **DH_Bio_NoCHP** | district heating biomass without chp | district heating, fuel biomass, heat generation without combined heat and power (chp) |
| **DH_Bio_CHP33** | district heating biomass with 33% chp | district heating, fuel biomass, heat generation with com-bined heat and power (chp) fraction 33% |
| **DH_Bio_CHP67** | district heating biomass with 67% chp | district heating, fuel biomass, heat generation with com-bined heat and power (chp) fraction 67% |
| **DH_Bio_CHP100** | district heating biomass with 100% chp | district heating, fuel biomass, heat generation with com-bined heat and power (chp) fraction 100% |
| **Other** | **other** | **other energy carriers** |
| **-** | **not existent** | **not existent or no energyware (e.g. solar heat pro-duced in the building)** |

## 8.5 Default Values for Heat Supply Components

During the TABULA project data for heat generators, storages and distribution of space heating and DHW systems were elaborated by the partners for their countries. Since these data refer to the same definitions it was possible to make comparisons and create averages. The details of this evaluation are described in [TABULA DataEval 2012].

The following tables are listing the averaged national values for each supply system component. Such "default values" might be helpful in case national values do not yet exist. The averages may also contribute to the elaboration of transnational building stock models.

**Table 11: Heat generation of heating systems / derived default values (simplified common values)**

| **TABULA Code** | **Description** | **heat generation expenditure factor (heating systems)** | | | **electricity generation expenditure factor (heating systems)** | | |
|---|---|---|---|---|---|---|---|
| | | delivered energy demand ($H_S$) devided by produced heat | | | electricity demand devided by produced heat | | |
| | | $e_{g,h}$ | | | $e_{g,el,h}$ | | |
| | | [ - ] | | | [ - ] | | |
| | **energy efficiency** | **poor** | **medium** | **high** | **poor** | **medium** | **high** |
| B_NC | boiler, non-condensing | 1,92 | 1,36 | 1,13 | - | - | - |
| B_C | boiler, condensing | 1,31 | 1,13 | 1,06 | - | - | - |
| B_WP | wood-pellets boiler | 2,12 | 1,52 | 1,31 | - | - | - |
| G_IWH_NC | gas-fired instantaneous water heater, non-condensing | 1,27 | 1,24 | 1,20 | - | - | - |
| G_IWH_C | gas-fired instantaneous water heater, condensing | 1,17 | 1,13 | 1,10 | - | - | - |
| G_SH | gas-fired space heater | 1,50 | 1,41 | 1,29 | - | - | - |
| E_Immersion | electric immersion heater | 1,08 | 1,03 | 1,00 | - | - | - |
| E | direct electric heat generator | 1,25 | 1,02 | 1,00 | - | - | - |
| HP_Air | heat pump, heat source external air | 0,50 | 0,37 | 0,30 | - | - | - |
| HP_Ground | heat pump, heat source ground | 0,52 | 0,31 | 0,21 | - | - | - |
| HP_ExhAir | heat pump, heat source exhaust air | 0,36 | 0,33 | 0,31 | - | - | - |
| Stove | stove | 2,96 | 1,92 | 1,40 | - | - | - |
| OpenFire | open fire | 4,44 | 3,39 | 2,44 | - | - | - |
| TS | district heating transfer station | 1,34 | 1,13 | 1,06 | - | - | - |
| CHP | combined heat and power generation | 1,67 | 1,67 | 1,67 | 3,33 | 3,33 | 3,33 |
| Solar | thermal solar plant | 0,00 | 0,00 | 0,00 | - | - | - |

**Table 12: Annual heat loss of the space heating storage / derived default values (simplified common values)**

| TABULA code | description | heat loss of the space heating storage | | |
|---|---|---|---|---|
| | | annual heat losses during heating season per m² reference area | | |
| | | $q_{s,h}$ | | |
| | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** |
| - | no heat storage | 0,0 | 0,0 | 0,0 |
| BS | buffer storage | 15,9 | 6,5 | 2,2 |

**Table 13: Annual heat loss of the space heating distribution / derived default values (simplified common values)**

| TABULA code | description | heat loss of the space heating distribution | | |
|---|---|---|---|---|
| | | annual heat losses during heating season per m² reference area | | |
| | | $q_{d,h}$ | | |
| | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** |
| D | decentral system | 0,0 | 0,0 | 0,0 |
| C_Int | central heating, all pipes inside of thermal envelope | 21,4 | 6,5 | 1,7 |
| C_Ext | central heating, fraction of pipeline outside of thermal envelope | 39,0 | 13,0 | 3,1 |

**Table 14: Annual auxiliary electricity demand of space heating systems / derived default values (simplified common values)**

| TABULA code | description | auxiliary energy demand (electricity) of heating systems | | |
|---|---|---|---|---|
| | | annual values in kWh per m² reference area for heat generation (blower, control), storage (pump), distribution (pump) and heat emission (fan), as far as available | | |
| | | $q_{del,h,aux}$ | | |
| | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** |
| D | decentral system, no distribution ducts available | 0,0 | 0,0 | 0,0 |
| C | central heating, distribution by pipeline | 8,9 | 3,6 | 0,9 |

**Table 15: Heat generation of dhw systems / derived default values (simplified common values)**

| TABULA Code | Description | heat generation expenditure factor (dhw systems) | | | electricity generation expenditure factor (dhw systems) | | |
|---|---|---|---|---|---|---|---|
| | | delivered energy demand ($H_S$) devided by produced heat | | | electricity demand devided by produced heat | | |
| | | $e_{g,w}$ | | | $e_{g,el,w}$ | | |
| | | [ - ] | | | [ - ] | | |
| | **energy efficiency** | **poor** | **medium** | **high** | **poor** | **medium** | **high** |
| B_NC | boiler, non-condensing | 2,49 | 1,41 | 1,14 | - | - | - |
| B_C | boiler, condensing | 1,56 | 1,19 | 1,08 | - | - | - |
| B_WP | wood-pellets boiler | 1,76 | 1,40 | 1,24 | - | - | - |
| G_IWH_NC | gas-fired instantaneous water heater, non-condensing | 1,96 | 1,34 | 1,23 | - | - | - |
| G_IWH_C | gas-fired instantaneous water heater, condensing | 1,27 | 1,22 | 1,17 | - | - | - |
| G_Tank | gas burner for directly heated DHW tank | 1,28 | 1,23 | 1,11 | - | - | - |
| E_Immersion | electric immersion heater | 1,52 | 1,10 | 1,03 | - | - | - |
| E | direct electric heat generator, not specified | 1,19 | 1,04 | 1,02 | - | - | - |
| HP_Air | heat pump, heat source external air | 0,65 | 0,44 | 0,38 | - | - | - |
| HP_Ground | heat pump, heat source ground | 0,35 | 0,30 | 0,26 | - | - | - |
| HP_ExhAir | heat pump, heat source exhaust air | 0,32 | 0,31 | 0,30 | - | - | - |
| HP_Cellar | heat pump, heat source: cellar air | 0,37 | 0,34 | 0,31 | - | - | - |
| TS | district heating transfer station | 1,81 | 1,22 | 1,10 | - | - | - |
| CHP | combined heat and power generation | 1,54 | 1,39 | 1,28 | 3,33 | 3,33 | 3,33 |
| Solar | thermal solar plant | 0,00 | 0,00 | 0,00 | - | - | - |

**Table 16: Annual heat loss of the dhw heat storage / derived default values (simplified common values)**

| TABULA code | description | heat loss of the dhw distribution | | | thereof recoverable portion | | |
|---|---|---|---|---|---|---|---|
| | | annual heat losses per m² reference area | | | contribution to space heating per m² reference area | | |
| | | $q_{d,w}$ | | | $q_{d,w,h}$ | | |
| | | [kWh/(m²a)] | | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** | **poor** | **medium** | **high** |
| S_D | decentral electric hot water storage | 6,7 | 3,1 | 1,3 | 2,8 | 1,6 | 1,6 |
| S_C_Int | central hot water storage, inside of thermal envelope | 31,2 | 5,8 | 0,9 | 24,5 | 2,8 | 2,8 |
| S_C_Ext | central hot water storage, outside of thermal envelope | 10,2 | 4,3 | 0,9 | 0,0 | 0,0 | 0,0 |
| S_Gas | directly gas heated hot water storage | 18,4 | 14,2 | 8,2 | 0,0 | 0,0 | 0,0 |

**Table 17: Annual heat losses of the dhw distribution / derived default values (simplified common values)**

| TABULA code | description | heat loss of the dhw distribution | | | thereof recoverable portion | | |
|---|---|---|---|---|---|---|---|
| | | annual heat losses per m² reference area | | | contribution to space heating per m² reference area | | |
| | | $q_{d,w}$ | | | $q_{d,w,h}$ | | |
| | | [kWh/(m²a)] | | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** | **poor** | **medium** | **high** |
| D | decentral DHW system | 4,5 | 3,1 | 1,6 | 2,0 | 1,1 | 1,1 |
| C_NoCirc_Int | central DHW distribution, all pipes inside of thermal envelope, no circulation | 9,7 | 4,4 | 2,1 | 2,4 | 1,1 | 1,1 |
| C_NoCirc_Ext | central DHW distribution, fraction of pipeline outside of thermal envelope, no circulation | 12,7 | 7,8 | 3,3 | 3,6 | 1,7 | 1,7 |
| C_Circ_Int | central DHW distribution with circulation, all pipes inside of thermal envelope | 20,3 | 7,3 | 2,1 | 3,6 | 1,4 | 1,4 |
| C_Circ_Ext | central DHW distribution with circulation, fraction of pipeline outside of thermal envelope | 35,0 | 15,7 | 5,7 | 7,9 | 2,5 | 2,5 |

**Table 18: Annual auxiliary electricity demand of DHW systems / derived default values (simplified common values)**

| TABULA code | description | auxiliary energy demand (electricity) of dhw systems | | |
|---|---|---|---|---|
| | | annual values in kWh per m² reference area for heat generation (blower, control), storage (pump), distribution (pump), as far as available | | |
| | | $q_{del,w,aux}$ | | |
| | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** |
| D | decentral DHW system | 0,0 | 0,0 | 0,0 |
| C_NoCirc | central DHW system, no circulation | 1,9 | 0,4 | 0,1 |
| C_Circ | central DHW system with circulation | 3,2 | 1,4 | 0,7 |
| C_NoCirc_Sol | central DHW system with solar thermal system, no circulation | 1,9 | 1,1 | 0,7 |
| C_Circ_Sol | central DHW system with solar thermal system and circulation | 3,9 | 2,4 | 1,3 |

**Table 19: Performance of ventilation systems / derived default values (simplified common values)**

| TABULA code | description | heat recovery by ventilation systems | | | auxiliary energy demand (electricity) of ventilation systems | | |
|---|---|---|---|---|---|---|---|
| | | overall performance ratio of heat recovery by the heat exchanger | | | annual values in kWh per m² reference area | | |
| | | $\eta_{ve,rec}$ | | | $q_{del,ve,aux}$ | | |
| | | [ - ] | | | [kWh/(m²a)] | | |
| | **energy efficiency** | **poor** | **medium** | **high** | **poor** | **medium** | **high** |
| Exh | exhaust air system | 0,00 | 0,00 | 0,00 | 1,7 | 1,3 | 1,2 |
| Bal | balanced ventilation system | 0,00 | 0,00 | 0,00 | 3,3 | 2,2 | 1,5 |
| Bal_Rec | balanced ventilation system with heat recovery | 0,62 | 0,73 | 0,83 | 5,3 | 2,6 | 2,0 |
| Bal_GroundRec | balanced ventilation system, preheated by ground heat exchanger + heat recovery | 0,90 | 0,90 | 0,90 | 2,6 | 2,6 | 2,6 |

## 8.6 Calculation Sheets and Examples

On the following pages illustrative calculations are shown for an exemplary building considering three states of the energy performance. The pages can be reproduced for this and for other example buildings by use of the Excel workbook "tabula-calculator.xls" [TABULA Spreadsheets] and of the [TABULA WebTool].

### Description of the calculation sheets

- **Sheet „Thermal Insulation Measures“:**
  **Determination of the effective U-values used in the energy balance calculation**

  Consideration of additional thermal resistances for the U-values of construction elements:
  - for unheated spaces, if available (here: unheated attic and cellar);
  - for thermal protection measues (measure package 1 and 2).

- **Sheet „Energy Balance Calculation – Building Performance“:**
  **Calculation of the energy need for space heating**

  Balance according to the TABULA reference calculation procedure / standard boundary conditions and national climate.

- **Sheet „Energy Balance Calculation – System Performance“:**
  **Calculation of the delivered energy by energyware**

  Balance according to the TABULA reference calculation procedure / standard boundary conditions.

- **Sheet „Energy Balance Calculation – Energy Carriers“:**
  **Assessment of energywares / realistic level of energy consumption**

  Determination of the primary energy demand, of the carbon dioxide emissions and of the heating costs on the basis of the delivered energy.

  Determination of the adaptation factor for calibrating the calculated energy demand to the typical level of measured energy consumption.

## Example Building – Existing State

### Thermal Insulation Measures — U-values

Building code DE.N.MFH.05.Gen.ReEx.001

| | | Roof 1 | Roof 2 | Wall 1 | Wall 2 | Wall 3 | Floor 1 | Floor 2 | Window 1 | Window 2 | Door 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| envelope area | $A_{env,i}$ | 0 | 971 | 2039 | 0 | 0 | 971 | 0 | 507 | 0 | 2 | m² |
| **Construction Element** | | | | | | | | | | | | |
| Code | | | DE.Ceiling.ReEx.06.01 | DE.Wall.ReEx.04.01 | | | DE.Floor.ReEx.05.01 | | DE.Window.ReEx.06.03 | | DE.Door.ReEx.01.01 | |
| U-value original state | $U_{original,i}$ | | 0,60 | 1,20 | | | 1,60 | | 3,50 | | 3,00 | W/(m²K) |
| included insulation thickness | $d_{insulation,i}$ | | 5,0 | 0,0 | | | 1,0 | | | | | cm |
| border type | | | Unh | Ext | | | Cellar | | | | | |
| additional thermal resistance | $R_{add,i}$ | | 0,30 | 0,00 | | | 0,30 | | | | | m²K/W |
| **Refurbishment Measure** | | | | | | | | | | | | |
| Code | | | | | | | | | | | | |
| thermal resistance of refurbishment measure | $R_{measure,i}$ | | 0,00 | 0,00 | | | 0,00 | | 0,00 | | 0,00 | m²K/W |
| **Result** | | | | | | | | | | | | |
| type of refurbishment | | | | | | | | | | | | |
| thermal resistance before measures | $R_{before,i}$ | | 1,97 | 0,83 | | | 0,93 | | 0,29 | | 0,33 | m²K/W |
| | $R_{actual,i}$ | | 1,97 | 0,83 | | | 0,93 | | 0,29 | | 0,33 | m²K/W |
| | $U_{actual,i}$ | | 0,51 | 1,20 | | | 1,08 | | 3,50 | | 3,00 | W/(m²K) |

## Energy Balance Calculation — Building Performance

Standard Reference Calculation - based on: EN ISO 13790 / seasonal method

| | | | |
|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001 (1958...1968) | reference area $A_{C,ref}$ | 3129,1 m² |
| Climate | DE.N (Germany) | (conditioned floor area) | |

| code construction element | original U-value $U_{original,i}$ W/(m²K) | measure type | applied refurbishment measure | actual U-value $U_{actual,i}$ W/(m²K) | | area (basis: external dimensions) $A_{env,i}$ m² | | adjustment factor soil $b_{tr,i}$ | | $H_{tr,i}$ W/K | annual heat loss related to $A_{C,Ref}$ kWh/(m²a) | heat transfer coefficients related to $A_{C,Ref}$ W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roof 1 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Roof 2 | 0,60 | | | 0,51 | x | 971,1 | x | 1,00 | = | 493,8 | 12,1 | 0,16 |
| Wall 1 | 1,20 | | | 1,20 | x | 2039,0 | x | 1,00 | = | 2446,8 | 60,0 | 0,78 |
| Wall 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Wall 3 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Floor 1 | 1,60 | | | 1,08 | x | 971,1 | x | 0,50 | = | 524,9 | 12,9 | 0,17 |
| Floor 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Window 1 | 3,50 | | | 3,50 | x | 507,5 | x | 1,00 | = | 1776,2 | 43,5 | 0,57 |
| Window 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Door 1 | 3,00 | | | 3,00 | x | 2,0 | x | 1,00 | = | 6,0 | 0,1 | 0,00 |
| thermal bridging: surcharge on the U-values | | | | $\Delta U_{tb}$ 0,10 | × | $\Sigma A_{envelope,i}$ 4490,7 | × | 1,00 | = | $H_{tr,tb}$ 449,1 | 11,0 | 0,14 |

**Heat transfer coefficient by transmission $H_{tr}$** — sum **5697** W/K — 139,6 kWh/(m²a) — 1,82 W/(m²K)

**Heat transfer coefficient by ventilation $H_{ve}$**

| volume-specific heat capacity air $c_{p,air}$ Wh/(m³K) | | air change rate by use $n_{air,use}$ 1/h | | by infiltration $n_{air,infiltration}$ 1/h | | $A_{C,ref}$ m³ | | room height (standard value) $h_{room}$ m | | W/K | kWh/(m²a) | W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,34 | x ( | 0,40 | + | 0,20 | ) × | 3129,1 | × | 2,50 | = | **1596** | 39,1 | 0,51 |

accumulated differences between internal and external temperature

| | internal temp. $\vartheta_i$ °C | | external temp. $\vartheta_e$ °C | | heating days $d_{hs}$ d/a | | Kd/a |
|---|---|---|---|---|---|---|---|
| ( | 20,0 | − | 4,4 | ) × | 222 | = | 3463 |

**Total heat transfer $Q_{ht}$**

| | $H_{tr}$ W/K | | $H_{ve}$ W/K | | temperature reduction factor $F_{red}$ ($h_{tr}$ = 1,82 W/(m²K)) | | x 0,024 kKh/a | | kWh/a | kWh/(m²a) | W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ( | 5697 | + | 1596 | ) × | 0,92 | × | 83,1 | = | **559250** | 178,7 | 2,33 |

| Window Orientation | reduction factors: external shading $F_{sh}$ | | frame area fraction $F_F$ | | non-perpendicular $F_W$ | | solar energy transmittance $g_{gl,n}$ | | window area $A_{window,i}$ m² | | solar global radiation $I_{sol,i}$ kWh/(m²a) | | kWh/a | kWh/(m²a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Horizontal | 0,80 | × (1 - | 0,30 | ) × | 0,90 | × | 0,75 | × | | × | 403 | = | | 0,0 |
| 2. East | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,75 | × | 22,2 | × | 271 | = | 1709 | 0,5 |
| 3. South | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,75 | × | 243,2 | × | 392 | = | 27032 | 8,6 |
| 4. West | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,75 | × | 22,2 | × | 271 | = | 1709 | 0,5 |
| 5. North | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,75 | × | 219,8 | × | 160 | = | 9968 | 3,2 |

**Solar heat load during heating season $Q_{sol}$** — sum **40418** kWh/a — 12,9 kWh/(m²a)

**Internal heat sources $Q_{int}$**

| kh/d | | internal heat sources $\varphi_i$ W/m² | | heating days $d_{hs}$ d/a | | $A_{C,ref}$ m² | | kWh/a | kWh/(m²a) |
|---|---|---|---|---|---|---|---|---|---|
| 0,024 | × | 3,00 | × | 222 | × | 3129,1 | = | **50015** | 16,0 |

internal heat capacity per m² $A_{C,ref}$ — $c_m$ = 45 Wh/(m²K)

time constant of the building — $\tau = \frac{c_m \cdot A_{C,ref}}{H_{tr} + H_{ve}}$ = 19 h

parameter — $a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$ = 1,44

heat balance ratio for the heating mode — $\gamma_{h,gn} = \frac{Q_{sol} + Q_{int}}{Q_L}$ = 0,162

**gain utilisation factor for heating** — $\eta_{h,gn} = \frac{1 - \gamma^{a_H}}{1 - \gamma^{a_H + 1}}$ = 0,94

**Energy need for heating $Q_{H,nd}$** — $Q_{ht} - \eta_{h,gn} \times (Q_{sol} + Q_{int})$ = **474344** kWh/a — 151,6 kWh/(m²a)

# Energy Balance Calculation — System Performance

| | code | | A_C_ref | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001.001 | conditioned floor area | 3129,1 | m² |
| System | DE.<Oil.B_NC_LT.MUH.01>.<El.E_IWH.Gen.01>.<-.Gen.01>.<Gen> | | | |

## Domestic Hot Water System

System (code): DE.El.E_IWH.Gen.01

| | code | | value | thereof recoverable for space heating: | value |
|---|---|---|---|---|---|
| energy need hot water | | $q_{nd,w}$ | 15,0 | | |
| + losses distrib. | DE.D.Gen.2 | $q_{d,w}$ | 1,4 | $q_{d,w,h}$ | 0,8 |
| + losses storage | | $q_{s,w}$ | 0,0 | $q_{s,w,h}$ | 0,0 |
| | | $q_{g,w,out} = q_{nd,w} + q_{d,w} + q_{s,w}$ | 16,4 | $q_{w,h} = q_{d,w,h} + q_{s,w,h}$ | 0,8 |
| | | | kWh/(m²a) | | kWh/(m²a) |

**energyware for domestic hot water**

| | code | heat generator code | $\alpha_{nd,w,i}$ | | heat generator output $q_{g,w,out}$ | | expenditure factor $e_{g,w,i}$ | | delivered energy $q_{del,w,i}$ | combined heat and power: expenditure factor electricity generation $e_{g,el,w,i}$ | | electricity production $q_{prod,el,w,i}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | El | DE.E_IWH.Gen.01 | 100% | x | 16,4 | x | 1,00 | = | 16,4 | 0,00 | = | 0,0 |
| 2 | | | 0% | x | | x | 0,00 | = | 0,0 | 0,00 | = | 0,0 |
| 3 | | | 0% | x | | x | 0,00 | = | 0,0 | 0,00 | = | 0,0 |
| | | | | | kWh/(m²a) | | | | kWh/(m²a) | | | |

**auxiliary energy**

| | | code | $q_{del,w,aux}$ |
|---|---|---|---|
| aux | el | DE.D.Gen.1 | 0,0 |
| | | | kWh/(m²a) |

## Heating System

System (code): DE.Oil.B_NC_LT.MUH.01

| | code | | value | unit | gain utilisation factor for heating $\eta_{h,gn}$ | | ventilation heat recovery $\eta_{ve,rec}$ | | $q_{ht,ve}$ |
|---|---|---|---|---|---|---|---|---|---|
| energy need space heating | | $q_{nd,h}$ | 151,6 | kWh/(m²a) | | | | | |
| – usable contribution of hot water system | | $q_{w,h}$ | 0,8 | kWh/(m²a) | 94% | x | | | |
| – usable contribution of ventilation heat recovery | | $q_{ve,h,rec}$ | 0,0 | kWh/(m²a) | 94% | x | 0% | x | 39,1 |
| + losses distribution and heat emission | DE.C_Ext.MUH.03 | $q_{d,h}$ | 15,1 | kWh/(m²a) | | | | | kWh/(m²a) |
| + losses storage | | $q_{s,h}$ | 0,0 | kWh/(m²a) | | | | | |
| | | $q_{g,h,out} = q_{nd,h} - q_{w,h} - q_{ve,h,rec} + q_{d,h} + q_{s,h}$ | 165,9 | kWh/(m²a) | | | | | |

**energyware for space heating**

| | code | heat generator code | $\alpha_{nd,h,i}$ | | heat generator output $q_{g,h,out}$ | | expenditure factor $e_{g,h,i}$ | | delivered energy $q_{del,h,i}$ | combined heat and power: expenditure factor electricity generation $e_{g,el,h,i}$ | | electricity production $q_{prod,el,h,i}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Oil | DE.B_NC_LT.SUH.03 | 100% | x | 165,9 | x | 1,23 | = | 204,1 | 0,00 | = | 0,0 |
| 2 | | | 0% | x | | x | 0,00 | = | 0,0 | 0,00 | = | 0,0 |
| 3 | | | 0% | x | | x | 0,00 | = | 0,0 | 0,00 | = | 0,0 |
| | | | | | kWh/(m²a) | | | | kWh/(m²a) | | | |

**auxiliary energy**

| | | | code | | value |
|---|---|---|---|---|---|
| heating system | aux | el | DE.C.MUH.1 | $q_{del,h,aux}$ | 1,8 |
| ventilation system | aux | el | DE.-.Gen.01 | $q_{del,ve,aux}$ | 0,0 |
| | | | | | kWh/(m²a) |

# Energy Balance Calculation — Energy Carriers

| | code | | A_C_ref | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001.001 | conditioned floor area | 3129,1 | m² |
| System | DE.<Oil.B_NC_LT.MUH.01>.<El.E_IWH.Gen.01>.<-.Gen.01>.<Gen> | | | |

## Assessment of Energywares

version of energy carrier specification: Gen

### Standard Calculation

| | delivered energy | total primary energy | | non-renewable primary energy | | carbon dioxide emissions | | energy costs | |
|---|---|---|---|---|---|---|---|---|---|
| | $q_{del,i}$ | $f_{p,total,i}$ | $q_{p,total,i} = q_{del,i} \cdot f_{p,total,i}$ | $f_{p,nonren,i}$ | $q_{p,nonren,i} = q_{del,i} \cdot f_{p,nonren,i}$ | $f_{CO2,i}$ | $m_{CO2,i} = q_{del,i} \cdot f_{CO2,i}$ | $p_i$ (energyware price) | $c_i = q_{del,i} \cdot p_i$ |
| **Heating (+ Ventilation) System** | | | | | | | | | |
| Oil | 204,1 | 1,10 | 224,5 | 1,10 | 224,5 | 310 | 63,3 | 6,0 | 12,25 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| auxiliary energy | 1,8 | 3,00 | 5,4 | 2,60 | 4,7 | 680 | 1,2 | 20,0 | 0,36 |
| electricity production / export | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| **Domestic Hot Water System** | | | | | | | | | |
| El | 16,4 | 3,00 | 49,2 | 2,60 | 42,6 | 680 | 11,2 | 20,0 | 3,28 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| auxiliary energy | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| electricity production / export | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| | kWh/(m²a) | | | | | | | | |

| Summary and Expenditure Factors | heat need $q_{nd}$ | $\Sigma q_{del}$ | $e_{p,total} = \frac{q_{p,total}}{q_{nd}}$ | $q_{p,total} = \Sigma q_{p,total}$ | $e_{p,nonren} = \frac{q_{p,nonren}}{q_{nd}}$ | $q_{p,nonren} = \Sigma q_{p,nonren,i}$ | $f_{CO2,heat} = \frac{m_{CO2}}{q_{nd}}$ | $m_{CO2,i} = \Sigma m_{CO2,i}$ | $p_{heat} = \frac{c_i}{q_{nd}}$ | $c = \Sigma c_i$ |
|---|---|---|---|---|---|---|---|---|---|---|
| heating (+ ventilation) system | 151,6 | 205,9 | 1,52 | 229,9 | 1,51 | 229,2 | 425 | 64,5 | 8,3 | 12,61 |
| domestic hot water system | 15,0 | 16,4 | 3,28 | 49,2 | 2,84 | 42,6 | 743 | 11,2 | 21,9 | 3,28 |
| total | 166,6 | 222,3 | 1,68 | 279,1 | 1,63 | 271,8 | 454 | 75,6 | 9,5 | 15,89 |
| | kWh/(m²a) | kWh/(m²a) | | kWh/(m²a) | | kWh/(m²a) | g/kWh | kg/(m²a) | Cent/kWh | Euro/(m²a) |

### Typical Values of the Measured Consumption - Empirical Calibration

code: DE.M.01

The empirical calibration factor describes a typical ratio of the energy uses determined by measurements for a large number of buildings and by the TABULA method for the given value of the TABULA method.

| | | | |
|---|---|---|---|
| application field | central heating systems: fuels and district heating | | |
| determination method | experience values | | |
| accuracy level | C | = | estimated (e.g. on the basis of few example buildings) |

| | empirical relation | | | | | | | current value |
|---|---|---|---|---|---|---|---|---|
| delivered energy (without auxiliary electricity) according to standard calculation method | 0 | 100 | 200 | 300 | 400 | 500 | | 220,5 |
| adaptation factor | 1,10 | 1,00 | 0,84 | 0,70 | 0,60 | 0,50 | 3 | 0,81 |

| Summary (including subcategories) | | Standard Calculation | | | Typical Measured Consumption | | |
|---|---|---|---|---|---|---|---|
| | | heating | dhw | sum | heating | dhw | sum |
| Gas | $q_{del,\Sigma gas}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Oil | $q_{del,\Sigma oil}$ | 204,1 | 0,0 | **204,1** | 165,6 | 0,0 | **165,6** |
| Coal | $q_{del,\Sigma coal}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Bio | $q_{del,\Sigma bio}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| El | $q_{del,\Sigma el}$ | 0,0 | 16,4 | **16,4** | 0,0 | 13,3 | **13,3** |
| DH | $q_{del,\Sigma dh}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Other | $q_{del,\Sigma other}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Auxiliary Electricity | $q_{del,\Sigma aux}$ | 1,8 | 0,0 | **1,8** | 1,5 | 0,0 | **1,5** |
| Produced / exported electricity | $q_{exp,\Sigma el}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |

## Example Building – Refurbishment Package 1 / "Standard" Measures

### Thermal Insulation Measures — U-values

Building code DE.N.MFH.05.Gen.ReEx.001

| | | Roof 1 | Roof 2 | Wall 1 | Wall 2 | Wall 3 | Floor 1 | Floor 2 | Window 1 | Window 2 | Door 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| envelope area | $A_{env,i}$ | 0 | 971 | 2039 | 0 | 0 | 971 | 0 | 507 | 0 | 2 | m² |
| **Construction Element** | | | | | | | | | | | | |
| Code | | | DE.Ceiling.ReEx.06.01 | DE.Wall.ReEx.04.01 | | | DE.Floor.ReEx.05.01 | | DE.Window.ReEx.06.03 | | DE.Door.ReEx.01.01 | |
| U-value original state | $U_{original,i}$ | | 0,60 | 1,20 | | | 1,60 | | 3,50 | | 3,00 | W/(m²K) |
| included insulation thickness | $d_{insulation,i}$ | | 5,0 | 0,0 | | | 1,0 | | | | | cm |
| border type | | | Unh | Ext | | | Cellar | | | | | |
| additional thermal resistance | $R_{add,i}$ | | 0,30 | 0,00 | | | 0,30 | | | | | m²K/W |
| **Refurbishment Measure** | | | | | | | | | | | | |
| Code | | | DE.Ceiling.Insulation12cm.01 | DE.Wall.Insulation12cm.01 | | | DE.Floor.Insulation08cm.01 | | DE.Window.2p-LowE-arg.01 | | DE.Window.2p-LowE-arg.01 | |
| thermal resistance of refurbishment measure | $R_{measure,i}$ | | 3,43 | 3,45 | | | 2,29 | | 0,77 | | 0,77 | m²K/W |
| **Result** | | | | | | | | | | | | |
| type of refurbishment | | | Add | Add | | | Add | | Replace | | Replace | |
| thermal resistance before measures | $R_{before,i}$ | | 1,97 | 0,83 | | | 0,93 | | 0,29 | | 0,33 | m²K/W |
| | $R_{actual,i}$ | | 5,40 | 4,28 | | | 3,21 | | 0,77 | | 0,77 | m²K/W |
| | $U_{actual,i}$ | | 0,19 | 0,23 | | | 0,31 | | 1,30 | | 1,30 | W/(m²K) |

## Energy Balance Calculation — Building Performance

Standard Reference Calculation - based on: EN ISO 13790 / seasonal method

| | | | |
|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001 (1958...1968) | reference area (conditioned floor area) $A_{C,ref}$ | 3129,1 m² |
| Climate | DE.N (Germany) | | |

| code construction element | original U-value $U_{original,i}$ W/(m²K) | measure type | applied refurbishment measure | actual U-value $U_{actual,i}$ W/(m²K) | | area (basis: external dimensions) $A_{env,i}$ m² | | adjustment factor soil $b_{tr,i}$ | | $H_{tr,i}$ W/K | annual heat loss related to $A_{C,Ref}$ kWh/(m²a) | heat transfer coefficients related to $A_{C,Ref}$ W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roof 1 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Roof 2 | 0,60 | Add | DE.Ceiling.Insulation12cm.01 | 0,19 | x | 971,1 | x | 1,00 | = | 180,0 | 4,5 | 0,06 |
| Wall 1 | 1,20 | Add | DE.Wall.Insulation12cm.01 | 0,23 | x | 2039,0 | x | 1,00 | = | 476,3 | 12,0 | 0,15 |
| Wall 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Wall 3 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Floor 1 | 1,60 | Add | DE.Floor.Insulation08cm.01 | 0,31 | x | 971,1 | x | 0,50 | = | 151,2 | 3,8 | 0,05 |
| Floor 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Window 1 | 3,50 | Replace | DE.Window.2p-LowE-arg.01 | 1,30 | x | 507,5 | x | 1,00 | = | 659,7 | 16,6 | 0,21 |
| Window 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Door 1 | 3,00 | Replace | DE.Window.2p-LowE-arg.01 | 1,30 | x | 2,0 | x | 1,00 | = | 2,6 | 0,1 | 0,00 |
| thermal bridging: surcharge on the U-values | | | | $\Delta U_{tb}$ 0,10 | x | $\Sigma A_{envelope,i}$ 4490,7 | x | 1,00 | = | $H_{tr,tb}$ 449,1 | 11,3 | 0,14 |
| **Heat transfer coefficient by transmission $H_{tr}$** | | | | | | | | | sum | **1919** | 48,4 | 0,61 |

| **Heat transfer coefficient by ventilation $H_{ve}$** | volume-specific heat capacity air $c_{p,air}$ Wh/(m³K) | | air change rate by use $n_{air,use}$ 1/h | | air change rate by infiltration $n_{air,infiltration}$ 1/h | | $A_{C,ref}$ m³ | | room height (standard value) $h_{room}$ m | | W/K | kWh/(m²a) | W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0,34 | x ( | 0,40 | + | 0,20 | ) x | 3129,1 | x | 2,50 | = | **1596** | 40,3 | 0,51 |

| | | internal temp. $\vartheta_i$ °C | | external temp. $\vartheta_e$ °C | | heating days $d_{hs}$ d/a | | Kd/a |
|---|---|---|---|---|---|---|---|---|
| accumulated differences between internal and external temperature | ( | 20,0 | − | 4,4 | ) × | 222 | = | 3463 |

| | | $H_{tr}$ W/K | | $H_{ve}$ W/K | | temperature reduction factor $F_{red}$ ($h_{tr}$= 0,61 W/(m²K)) | | x 0,024 kKh/a | | kWh/a | kWh/(m²a) | W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total heat transfer $Q_{ht}$** | ( | 1919 | + | 1596 | ) × | 0,95 | × | 83,1 | = | **277530** | 88,7 | 1,12 |

| Window Orientation | reduction factors: external shading $F_{sh}$ | | frame area fraction $F_F$ | | non-perpendicular $F_W$ | | solar energy transmittance $g_{gl,n}$ | | window area $A_{window,i}$ m² | | solar global radiation $I_{sol,i}$ kWh/(m²a) | | kWh/a | kWh/(m²a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Horizontal | 0,80 | × (1 - | 0,30 | ) × | 0,90 | × | 0,60 | × | | × | 403 | = | | 0,0 |
| 2. East | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,60 | × | 22,2 | × | 271 | = | 1367 | 0,4 |
| 3. South | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,60 | × | 243,2 | × | 392 | = | 21625 | 6,9 |
| 4. West | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,60 | × | 22,2 | × | 271 | = | 1367 | 0,4 |
| 5. North | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,60 | × | 219,8 | × | 160 | = | 7974 | 2,5 |
| **Solar heat load during heating season $Q_{sol}$** | | | | | | | | | | | | sum | **32334** | 10,3 |

| | kh/d | | internal heat sources $\varphi_i$ W/m² | | heating days $d_{hs}$ d/a | | $A_{C,ref}$ m² | | kWh/a | kWh/(m²a) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Internal heat sources $Q_{int}$** | 0,024 | × | 3,00 | × | 222 | × | 3129,1 | = | **50015** | 16,0 |

| | | | |
|---|---|---|---|
| internal heat capacity per m² $A_{C,ref}$ | $c_m$ | 45 | Wh/(m²K) |
| time constant of the building | $\tau = \frac{c_m \cdot A_{C,ref}}{H_{tr} + H_{ve}}$ = | 40 | h |
| parameter | $a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$ = | 2,14 | |
| heat balance ratio for the heating mode | $\gamma_{h,gn} = \frac{Q_{sol}+Q_{int}}{Q_L}$ = | 0,297 | |
| **gain utilisation factor for heating** | $\eta_{h,gn} = \frac{1-\gamma^{a_H}}{1-\gamma^{a_H+1}}$ = | 0,95 | |

| | | kWh/a | kWh/(m²a) |
|---|---|---|---|
| **Energy need for heating $Q_{H,nd}$** | $Q_{ht} - \eta_{h,gn} \times (Q_{sol} + Q_{int})$ = | **199604** | 63,8 |

# Energy Balance Calculation — System Performance

| | code | | A_C_ref | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001.002 | conditioned floor area | 3129,1 | m² |
| System | DE.<Oil.B_C.MUH.01>.<Oil.B_C+Solar.MUH.01>.<-.Gen.01>.<Gen> | | | |

## Domestic Hot Water System

| | code |
|---|---|
| System | DE.Oil.B_C+Solar.MUH.01 |

| | code | | value | thereof recoverable for space heating: | value |
|---|---|---|---|---|---|
| energy need hot water | | $q_{nd,w}$ | 15,0 | | |
| + losses distrib. | DE.C_Circ_Ext.MUH.3 | $q_{d,w}$ | 6,4 | $q_{d,w,h}$ | 2,9 |
| + losses storage | DE.S_C_Ext.MUH.02 | $q_{s,w}$ | 1,0 | $q_{s,w,h}$ | 0,0 |
| | | $q_{g,w,out} = q_{nd,w} + q_{d,w} + q_{s,w}$ | 22,4 | $q_{w,h} = q_{d,w,h} + q_{s,w,h}$ | 2,9 |
| | | | kWh/(m²a) | | kWh/(m²a) |

| | energyware for domestic hot water (code) | heat generator (code) | $\alpha_{nd,w,i}$ | | heat generator output $q_{g,w,out}$ | | expenditure factor $e_{g,w,i}$ | | delivered energy $q_{del,w,i}$ | | combined heat and power: expenditure factor electricity generation $e_{g,el,w,i}$ | | electricity production $q_{prod,el,w,i}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Oil | DE.B_C.MUH.03 | 60% | x | 22,4 | x | 1,18 | = | 15,9 | : | 0,00 | = | 0,0 |
| 2 | | DE.Solar.Gen.01 | 40% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| 3 | | | 0% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| | | | | | kWh/(m²a) | | | | kWh/(m²a) | | | | |

**auxiliary energy**

| | | code | $q_{del,w,aux}$ |
|---|---|---|---|
| aux | el | DE.C_Circ_Sol.MUH.1 | 1,3 |
| | | | kWh/(m²a) |

## Heating System

| | code |
|---|---|
| System | DE.Oil.B_C.MUH.01 |

| | code | | value | unit | gain utilisation factor for heating $\eta_{h,gn}$ | | ventilation heat recovery $\eta_{ve,rec}$ | | $q_{ht,ve}$ |
|---|---|---|---|---|---|---|---|---|---|
| energy need space heating | | $q_{nd,h}$ | 63,8 | kWh/(m²a) | | | | | |
| – usable contribution of hot water system | | $q_{w,h}$ | 2,7 | kWh/(m²a) | 95% | x | | | |
| – usable contribution of ventilation heat recovery | | $q_{ve,h,rec}$ | 0,0 | kWh/(m²a) | 95% | x | 0% | x | 40,3 |
| + losses distribution and heat emission | DE.C_Ext.MUH.04 | $q_{d,h}$ | 5,7 | kWh/(m²a) | | | | | kWh/(m²a) |
| + losses storage | | $q_{s,h}$ | 0,0 | kWh/(m²a) | | | | | |
| | | $q_{g,h,out} = q_{nd,h} - q_{w,h} - q_{ve,h,rec} + q_{d,h} + q_{s,h}$ | 66,7 | kWh/(m²a) | | | | | |

| | energyware for space heating (code) | heat generator (code) | $\alpha_{nd,h,i}$ | | heat generator output $q_{g,h,out}$ | | expenditure factor $e_{g,h,i}$ | | delivered energy $q_{del,h,i}$ | | combined heat and power: expenditure factor electricity generation $e_{g,el,h,i}$ | | electricity production $q_{prod,el,h,i}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Oil | DE.B_C.MUH.03 | 100% | x | 66,7 | x | 1,13 | = | 75,4 | : | 0,00 | = | 0,0 |
| 2 | | | 0% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| 3 | | | 0% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| | | | | | kWh/(m²a) | | | | kWh/(m²a) | | | | |

**auxiliary energy**

| | | code | | value |
|---|---|---|---|---|
| heating system | | | | |
| aux | el | DE.C.MUH.1 | $q_{del,h,aux}$ | 1,8 |
| ventilation system | | | | |
| aux | el | DE.-.Gen.01 | $q_{del,ve,aux}$ | 0,0 |
| | | | | kWh/(m²a) |

# Energy Balance Calculation — Energy Carriers

| | code | | A_C_ref | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001.002 | conditioned floor area | 3129,1 | m² |
| System | DE.<Oil.B_C.MUH.01>.<Oil.B_C+Solar.MUH.01>.<-.Gen.01>.<Gen> | | | |

## Assessment of Energywares

version of energy carrier specification: Gen

### Standard Calculation

| | delivered energy | total primary energy | | non-renewable primary energy | | carbon dioxide emissions | | energy costs | |
|---|---|---|---|---|---|---|---|---|---|
| **Heating (+ Ventilation) System** | $q_{del,i}$ | $f_{p,total,i}$ | $q_{p,total,i} = q_{del,i} \cdot f_{p,total,i}$ | $f_{p,nonren,i}$ | $q_{p,nonren,i} = q_{del,i} \cdot f_{p,nonren,i}$ | $f_{CO2,i}$ | $m_{CO2,i} = q_{del,i} \cdot f_{CO2,i}$ | $p_i$ (energyware price) | $c_i = q_{del,i} \cdot p_i$ |
| Oil | 75,4 | 1,10 | 83,0 | 1,10 | 83,0 | 310 | 23,4 | 6,0 | 4,53 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| auxiliary energy | 1,8 | 3,00 | 5,4 | 2,60 | 4,7 | 680 | 1,2 | 20,0 | 0,36 |
| electricity production / export | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| **Domestic Hot Water System** | | | | | | | | | |
| Oil | 15,9 | 1,10 | 17,4 | 1,10 | 17,4 | 310 | 4,9 | 6,0 | 0,95 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| auxiliary energy | 1,3 | 3,00 | 3,9 | 2,60 | 3,4 | 680 | 0,9 | 20,0 | 0,26 |
| electricity production / export | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| | kWh/(m²a) | | | | | | | | |

| **Summary and Expenditure Factors** | heat need $q_{nd}$ | $\Sigma q_{del}$ | $e_{p,total} = \frac{q_{p,total}}{q_{nd}}$ | $q_{p,total} = \Sigma q_{p,total}$ | $e_{p,nonren} = \frac{q_{p,nonren}}{q_{nd}}$ | $q_{p,nonren} = \Sigma q_{p,nonren,i}$ | $f_{CO2,heat} = \frac{m_{CO2}}{q_{nd}}$ | $m_{CO2,i} = \Sigma m_{CO2,i}$ | $p_{heat} = \frac{c_i}{q_{nd}}$ | $c = \Sigma c_i$ |
|---|---|---|---|---|---|---|---|---|---|---|
| heating (+ ventilation) system | 63,8 | 77,2 | 1,39 | 88,4 | 1,37 | 87,6 | 386 | 24,6 | 7,7 | 4,89 |
| domestic hot water system | 15,0 | 17,2 | 1,42 | 21,3 | 1,39 | 20,8 | 387 | 5,8 | 8,1 | 1,21 |
| total | 78,8 | 94,4 | 1,39 | 109,7 | 1,38 | 108,5 | 386 | 30,4 | 7,7 | 6,10 |
| | kWh/(m²a) | kWh/(m²a) | | kWh/(m²a) | | kWh/(m²a) | g/kWh | kg/(m²a) | Cent/kWh | Euro/(m²a) |

### Typical Values of the Measured Consumption - Empirical Calibration

code: DE.M.01

The empirical calibration factor describes a typical ratio of the energy uses determined by measurements for a large number of buildings and by the TABULA method for the given value of the TABULA method.

| | | | |
|---|---|---|---|
| application field | central heating systems: fuels and district heating | | |
| determination method | experience values | | |
| accuracy level | C | = | estimated (e.g. on the basis of few example buildings) |

| | empirical relation | | | | | | | current value |
|---|---|---|---|---|---|---|---|---|
| delivered energy (without auxiliary electricity) according to standard calculation method | 0 | 100 | 200 | 300 | 400 | 500 | | 91,3 |
| adaptation factor | 1,10 | 1,00 | 0,84 | 0,70 | 0,60 | 0,50 | 1 | 1,01 |

| **Summary (including subcategories)** | | Standard Calculation heating | dhw | sum | Typical Measured Consumption heating | dhw | sum |
|---|---|---|---|---|---|---|---|
| Gas | $q_{del,\Sigma gas}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Oil | $q_{del,\Sigma oil}$ | 75,4 | 15,9 | **91,3** | 76,1 | 16,0 | **92,1** |
| Coal | $q_{del,\Sigma coal}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Bio | $q_{del,\Sigma bio}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| El | $q_{del,\Sigma el}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| DH | $q_{del,\Sigma dh}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Other | $q_{del,\Sigma other}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Auxiliary Electricity | $q_{del,\Sigma aux}$ | 1,8 | 1,3 | **3,1** | 1,8 | 1,3 | **3,1** |
| Produced / exported electricity | $q_{exp,\Sigma el}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |

## Example Building – Refurbishment Package 2 / "Advanced" Measures

**Thermal Insulation Measures** **U-values**

Building code DE.N.MFH.05.Gen.ReEx.001

| | | Roof 1 | Roof 2 | Wall 1 | Wall 2 | Wall 3 | Floor 1 | Floor 2 | Window 1 | Window 2 | Door 1 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| envelope area | $A_{env,i}$ | 0 | 971 | 2039 | 0 | 0 | 971 | 0 | 507 | 0 | 2 | m² |
| **Construction Element** | | | | | | | | | | | | |
| Code | | | DE.Ceiling.ReEx.06.01 | DE.Wall.ReEx.04.01 | | | DE.Floor.ReEx.05.01 | | DE.Window.ReEx.06.03 | | DE.Door.ReEx.01.01 | |
| U-value original state | $U_{original,i}$ | | 0,60 | 1,20 | | | 1,60 | | 3,50 | | 3,00 | W/(m²K) |
| included insulation thickness | $d_{insulation,i}$ | | 5,0 | 0,0 | | | 1,0 | | | | | cm |
| border type | | | Unh | Ext | | | Cellar | | | | | |
| additional thermal resistance | $R_{add,i}$ | | 0,30 | 0,00 | | | 0,30 | | | | | m²K/W |
| **Refurbishment Measure** | | | | | | | | | | | | |
| Code | | | DE.Ceiling.Insulation30cm.04 | DE.Wall.Insulation24cm.02 | | | DE.Floor.Insulation12cm.01 | | DE.Window.3pInsulatedFrame.01 | | DE.Window.3pInsulatedFrame.01 | |
| thermal resistance of refurbishment measure | $R_{measure,i}$ | | 8,57 | 6,88 | | | 3,43 | | 1,25 | | 1,25 | m²K/W |
| **Result** | | | | | | | | | | | | |
| type of refurbishment | | | Add | Add | | | Add | | Replace | | Replace | |
| thermal resistance before measures | $R_{before,i}$ | | 1,97 | 0,83 | | | 0,93 | | 0,29 | | 0,33 | m²K/W |
| | $R_{actual,i}$ | | 10,54 | 7,71 | | | 4,35 | | 1,25 | | 1,25 | m²K/W |
| | $U_{actual,i}$ | | 0,09 | 0,13 | | | 0,23 | | 0,80 | | 0,80 | W/(m²K) |

# Energy Balance Calculation — Building Performance

Standard Reference Calculation - based on: EN ISO 13790 / seasonal method

| | | | | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001 (1958...1968) | reference area | $A_{C,ref}$ | 3129,1 m² |
| Climate | DE.N (Germany) | (conditioned floor area) | | |

| code construction element | original U-value $U_{original,i}$ W/(m²K) | measure type | applied refurbishment measure | actual U-value $U_{actual,i}$ W/(m²K) | | area (basis: external dimensions) $A_{env,i}$ m² | | adjustment factor soil $b_{tr,i}$ | | $H_{tr,i}$ W/K | annual heat loss related to $A_{C,Ref}$ kWh/(m²a) | heat transfer coefficients related to $A_{C,Ref}$ W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Roof 1 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Roof 2 | 0,60 | Add | DE.Ceiling.Insulation30cm.04 | 0,09 | x | 971,1 | x | 1,00 | = | 92,2 | 2,3 | 0,03 |
| Wall 1 | 1,20 | Add | DE.Wall.Insulation24cm.02 | 0,13 | x | 2039,0 | x | 1,00 | = | 264,5 | 6,7 | 0,08 |
| Wall 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Wall 3 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Floor 1 | 1,60 | Add | DE.Floor.Insulation12cm.01 | 0,23 | x | 971,1 | x | 0,50 | = | 111,5 | 2,8 | 0,04 |
| Floor 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Window 1 | 3,50 | Replace | DE.Window.3pInsulatedFrame.01 | 0,80 | x | 507,5 | x | 1,00 | = | 406,0 | 10,2 | 0,13 |
| Window 2 | | | | | x | | x | | = | | 0,0 | 0,00 |
| Door 1 | 3,00 | Replace | DE.Window.3pInsulatedFrame.01 | 0,80 | x | 2,0 | x | 1,00 | = | 1,6 | 0,0 | 0,00 |
| thermal bridging: surcharge on the U-values | | | | $\Delta U_{tb}$ 0,05 | x | $\Sigma A_{envelope,i}$ 4490,7 | x | 1,00 | = | $H_{tr,tb}$ 224,5 | 5,7 | 0,07 |

**Heat transfer coefficient by transmission $H_{tr}$** — sum **1100** — 27,8 — 0,35

| | volume-specific heat capacity air $c_{p,air}$ Wh/(m³K) | | air change rate by use $n_{air,use}$ 1/h | | by infiltration $n_{air,infiltration}$ 1/h | | $A_{C,ref}$ m³ | | room height (standard value) $h_{room}$ m | | W/K | kWh/(m²a) | W/(m²K) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Heat transfer coefficient by ventilation $H_{ve}$** | 0,34 | x ( | 0,40 | + | 0,10 | ) x | 3129,1 | x | 2,50 | = | **1330** | 33,6 | 0,43 |

| | | internal temp. $\vartheta_i$ °C | | external temp. $\vartheta e$ °C | | heating days $d_{hs}$ d/a | | Kd/a |
|---|---|---|---|---|---|---|---|---|
| accumulated differences between internal and external temperature | ( | 20,0 | – | 4,4 | ) x | 222 | = | 3463 |

x 0,024

| | | $H_{tr}$ W/K | | $H_{ve}$ W/K | | temperature reduction factor $F_{red}$ ($h_{tr}$= 0,35 W/(m²K)) | | kKh/a | | kWh/a | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Total heat transfer $Q_{ht}$** | ( | 1100 | + | 1330 | ) x | 0,95 | x | 83,1 | = | **191887** | 61,3 | 0,78 |

| Window Orientation | reduction factors: external shading $F_{sh}$ | | frame area fraction $F_F$ | | non-perpendicular $F_W$ | | solar energy transmittance $g_{gl,n}$ | | window area $A_{window,i}$ m² | | solar global radiation $I_{sol,i}$ kWh/(m²a) | | kWh/a | kWh/(m²a) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Horizontal | 0,80 | × (1 - | 0,30 | ) × | 0,90 | × | 0,50 | × | | × | 403 | = | | 0,0 |
| 2. East | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,50 | × | 22,2 | × | 271 | = | 1139 | 0,4 |
| 3. South | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,50 | × | 243,2 | × | 392 | = | 18021 | 5,8 |
| 4. West | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,50 | × | 22,2 | × | 271 | = | 1139 | 0,4 |
| 5. North | 0,60 | × (1 - | 0,30 | ) × | 0,90 | × | 0,50 | × | 219,8 | × | 160 | = | 6645 | 2,1 |

**Solar heat load during heating season $Q_{sol}$** — sum **26945** — 8,6

| | kh/d | | internal heat sources $\varphi_i$ W/m² | | heating days $d_{hs}$ d/a | | $A_{C,ref}$ m² | | kWh/a | kWh/(m²a) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Internal heat sources $Q_{int}$** | 0,024 | × | 3,00 | × | 222 | × | 3129,1 | = | **50015** | 16,0 |

internal heat capacity per m² $A_{C,ref}$ — $c_m$ = 45 Wh/(m²K)

time constant of the building — $\tau = \frac{c_m \cdot A_{C,ref}}{H_{tr} + H_{ve}}$ = 58 h

parameter — $a_H = a_{H,0} + \frac{\tau}{\tau_{H,0}}$ = 2,73

heat balance ratio for the heating mode — $\gamma_{h,gn} = \frac{Q_{sol}+Q_{int}}{Q_L}$ = 0,401

**gain utilisation factor for heating** — $\eta_{h,gn} = \frac{1-\gamma^{a_H}}{1-\gamma^{a_H+1}}$ = 0,95

**Energy need for heating $Q_{H,nd}$** — $Q_{ht} - \eta_{h,gn} \times (Q_{sol} + Q_{int})$ = **118857** kWh/a — 38,0

# Energy Balance Calculation — System Performance

| | code | | A_C_ref | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001.003 | conditioned floor area | 3129,1 | m² |
| System | DE.<Bio_WP.B_WP.MUH.01>.<Bio_WP.B_WP+Solar.MUH.01>.<Bal_Rec.Gen.02>.<Gen> | | | |

## Domestic Hot Water System

| | code |
|---|---|
| System | DE.Bio_WP.B_WP+Solar.MUH.01 |

| | code | | value | | thereof recoverable for space heating: | |
|---|---|---|---|---|---|---|
| energy need hot water | | $q_{nd,w}$ | 15,0 | | | |
| + losses distrib. | DE.C_Circ_Ext.MUH.3 | $q_{d,w}$ | 6,4 | → | $q_{d,w,h}$ | 2,9 |
| + losses storage | DE.S_C_Ext.MUH.02 | $q_{s,w}$ | 1,0 | → | $q_{s,w,h}$ | 0,0 |
| | | $q_{g,w,out} = q_{nd,w} + q_{d,w} + q_{s,w}$ | 22,4 | | $q_{w,h} = q_{d,w,h} + q_{s,w,h}$ | 2,9 |
| | | | kWh/(m²a) | | | kWh/(m²a) |

**energyware for domestic hot water**

| | code (energyware) | heat generator code | $\alpha_{nd,w,i}$ | | heat generator output $q_{g,w,out}$ | | expenditure factor $e_{g,w,i}$ | | delivered energy $q_{del,w,i}$ | | combined heat and power: expenditure factor electricity generation $e_{g,el,w,i}$ | | electricity production $q_{prod,el,w,i}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bio_WP | DE.B_WP.MUH.03 | 60% | x | 22,4 | x | 1,32 | = | 17,7 | : | 0,00 | = | 0,0 |
| 2 | | DE.Solar.Gen.01 | 40% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| 3 | | | 0% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| | | | | | kWh/(m²a) | | | | kWh/(m²a) | | | | |

**auxiliary energy**

| | | code | $q_{del,w,aux}$ |
|---|---|---|---|
| aux | el | DE.C_Circ_Sol.MUH.1 | 1,3 |
| | | | kWh/(m²a) |

## Heating System

| | code |
|---|---|
| System | DE.Bio_WP.B_WP.MUH.01 |

| | code | | value | unit | gain utilisation factor for heating $\eta_{h,gn}$ | | ventilation heat recovery $\eta_{ve,rec}$ | | $q_{ht,ve}$ |
|---|---|---|---|---|---|---|---|---|---|
| energy need space heating | | $q_{nd,h}$ | 38,0 | kWh/(m²a) | | | | | |
| – usable contribution of hot water system | | $q_{w,h}$ | 2,8 | kWh/(m²a) | 95% | x | ← $q_{w,h}$ | | |
| – usable contribution of ventilation heat recovery | | $q_{ve,h,rec}$ | 25,5 | kWh/(m²a) | 95% | x | 80% | x | 33,6 |
| + losses distribution and heat emission | DE.C_Ext.MUH.04 | $q_{d,h}$ | 5,7 | kWh/(m²a) | | | | | kWh/(m²a) |
| + losses storage | DE.BS_Wood.Gen.02 | $q_{s,h}$ | 7,2 | kWh/(m²a) | | | | | |
| | | $q_{g,h,out} = q_{nd,h} - q_{w,h} - q_{ve,h,rec} + q_{d,h} + q_{s,h}$ | 22,7 | kWh/(m²a) | | | | | |

**energyware for space heating**

| | code (energyware) | heat generator code | $\alpha_{nd,h,i}$ | | heat generator output $q_{g,h,out}$ | | expenditure factor $e_{g,h,i}$ | | delivered energy $q_{del,h,i}$ | | combined heat and power: expenditure factor electricity generation $e_{g,el,h,i}$ | | electricity production $q_{prod,el,h,i}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bio_WP | DE.B_WP.MUH.03 | 100% | x | 22,7 | x | 1,25 | = | 28,3 | : | 0,00 | = | 0,0 |
| 2 | | | 0% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| 3 | | | 0% | x | | x | 0,00 | = | 0,0 | : | 0,00 | = | 0,0 |
| | | | | | kWh/(m²a) | | | | kWh/(m²a) | | | | |

**auxiliary energy**

| | | code | |
|---|---|---|---|
| heating system | | | $q_{del,h,aux}$ |
| aux | el | DE.C.SUH.1 | 6,1 |
| ventilation system | | | $q_{del,ve,aux}$ |
| aux | el | DE.Bal_Rec.Gen.02 | 2,6 |
| | | | kWh/(m²a) |

## Energy Balance Calculation — Energy Carriers

| | code | | A_C_ref | |
|---|---|---|---|---|
| Building | DE.N.MFH.05.Gen.ReEx.001.003 | conditioned floor area | 3129,1 | m² |
| System | DE.<Bio_WP.B_WP.MUH.01>.<Bio_WP.B_WP+Solar.MUH.01>.<Bal_Rec.Gen.02>.<Gen> | | | |

### Assessment of Energywares

version of energy carrier specification: Gen

**Standard Calculation**

| | delivered energy | total primary energy | | non-renewable primary energy | | carbon dioxide emissions | | energy costs | |
|---|---|---|---|---|---|---|---|---|---|
| | $q_{del,i}$ | $f_{p,total,i}$ | $q_{p,total,i} = q_{del,i} \cdot f_{p,total,i}$ | $f_{p,nonren,i}$ | $q_{p,nonren,i} = q_{del,i} \cdot f_{p,nonren,i}$ | $f_{CO2,i}$ | $m_{CO2,i} = q_{del,i} \cdot f_{CO2,i}$ | $p_i$ (energyware price) | $c_i = q_{del,i} \cdot p_i$ |
| **Heating (+ Ventilation) System** | | | | | | | | | |
| Bio_WP | 28,3 | 1,20 | 34,0 | 0,20 | 5,7 | 40 | 1,1 | 5,0 | 1,42 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| auxiliary energy | 8,7 | 3,00 | 26,1 | 2,60 | 22,6 | 680 | 5,9 | 20,0 | 1,74 |
| electricity production / export | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| **Domestic Hot Water System** | | | | | | | | | |
| Bio_WP | 17,7 | 1,20 | 21,3 | 0,20 | 3,5 | 40 | 0,7 | 5,0 | 0,89 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| | 0,0 | 0,00 | 0,0 | 0,00 | 0,0 | 0 | 0,0 | 0,0 | 0,00 |
| auxiliary energy | 1,3 | 3,00 | 3,9 | 2,60 | 3,4 | 680 | 0,9 | 20,0 | 0,26 |
| electricity production / export | 0,0 | 3,00 | 0,0 | 2,60 | 0,0 | 680 | 0,0 | 20,0 | 0,00 |
| | kWh/(m²a) | | | | | | | | |

**Summary and Expenditure Factors**

| | heat need $q_{nd}$ | $\Sigma q_{del}$ | $e_{p,total} = \frac{q_{p,total}}{q_{nd}}$ | $q_{p,total} = \Sigma q_{p,total}$ | $e_{p,nonren} = \frac{q_{p,nonren}}{q_{nd}}$ | $q_{p,nonren} = \Sigma q_{p,nonren,i}$ | $f_{CO2,heat} = \frac{m_{CO2}}{q_{nd}}$ | $m_{CO2,i} = \Sigma m_{CO2,i}$ | $p_{heat} = \frac{c_l}{q_{nd}}$ | $c = \Sigma c_i$ |
|---|---|---|---|---|---|---|---|---|---|---|
| heating (+ ventilation) system | 38,0 | 37,0 | 1,58 | 60,1 | 0,74 | 28,3 | 186 | 7,0 | 8,3 | 3,16 |
| domestic hot water system | 15,0 | 19,0 | 1,68 | 25,2 | 0,46 | 6,9 | 106 | 1,6 | 7,6 | 1,15 |
| total | 53,0 | 56,1 | 1,61 | 85,3 | 0,66 | 35,2 | 163 | 8,6 | 8,1 | 4,30 |
| | kWh/(m²a) | kWh/(m²a) | | kWh/(m²a) | | kWh/(m²a) | g/kWh | kg/(m²a) | Cent/kWh | Euro/(m²a) |

### Typical Values of the Measured Consumption - Empirical Calibration

code: DE.M.01

The empirical calibration factor describes a typical ratio of the energy uses determined by measurements for a large number of buildings and by the TABULA method for the given value of the TABULA method.

| | |
|---|---|
| application field | central heating systems: fuels and district heating |
| determination method | experience values |
| accuracy level | C = estimated (e.g. on the basis of few example buildings) |

| | empirical relation | | | | | | | current value |
|---|---|---|---|---|---|---|---|---|
| delivered energy (without auxiliary electricity) according to standard calculation method | 0 | 100 | 200 | 300 | 400 | 500 | | 46,1 |
| adaptation factor | 1,10 | 1,00 | 0,84 | 0,70 | 0,60 | 0,50 | 1 | 1,05 |

| Summary (including subcategories) | | Standard Calculation | | | Typical Measured Consumption | | |
|---|---|---|---|---|---|---|---|
| | | heating | dhw | sum | heating | dhw | sum |
| Gas | $q_{del,\Sigma gas}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Oil | $q_{del,\Sigma oil}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Coal | $q_{del,\Sigma coal}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Bio | $q_{del,\Sigma bio}$ | 28,3 | 17,7 | **46,1** | 29,8 | 18,7 | **48,5** |
| El | $q_{del,\Sigma el}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| DH | $q_{del,\Sigma dh}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Other | $q_{del,\Sigma other}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |
| Auxiliary Electricity | $q_{del,\Sigma aux}$ | 8,7 | 1,3 | **10,0** | 9,2 | 1,4 | **10,5** |
| Produced / exported electricity | $q_{exp,\Sigma el}$ | 0,0 | 0,0 | **0,0** | 0,0 | 0,0 | **0,0** |