Building energy performance tool

Documentation – v0.1

Working version

guidehouse.com

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List of Abbreviations

Abbreviation	Name	Unit
P_{inst}	Installed power	W
t	Time a system is running	H
T_{amb}	Ambient temperature outside the building	°C
$T_{av,amb}$	Average ambient temperature over the calculation period	°C
$T_{amb,design}$	Ambient design temperature	°C
$T_{amb,min}$	Minimum ambient temperature over the year	°C
u	U-value	W/(m²*K)
A_{use}	Conditioned area in the building	m²
A_{env}	Area of the envelope elements (e.g. wall)	m²
AC_{total}	Total air-change rate	1/h
c_p	Specific heat coefficient	J/(kg*K)
ρ	Density	kg/m³
$k_{1,2}$	Heat transmission coefficient	W/(m²*K) or W/(m²*K²)
k (subscript)	Variable at the current state (usually 1 hour)	-
QF	Quality factor for systems	-
η_{k,P_n}	Efficiency at design capacity	-
$\eta_{k,P_{int}}$	Efficiency at part load	-
η_k	Effective efficiency at the current state	-
Factor A, B, C, D	Factors to describe boiler efficiencies from the Norm DIN 18599-5	-
$q_{P0,70}$	Specific standby heat demand loss	Wh/m²
T_{supply}	Temperature of the heating supply water	°C
T_{design}	Temperature of the heating supply water at design capacity	°C
T_{part}	Temperature of the heating supply water at part load	°C
T_{min}	Lower limit temperature (for supply temperature)	°C
G_{rad}	Global radiation on a surface	Wh/m²
COP	Coefficient of performance	-
SCOP	Seasonal coefficient of performance	-

$q_{u,DHW}$	Specific usefule energy demand (domestic hot water)	Wh/m²
$q_{f,DHW}$	Specific final energy demand (domestic hot water)	Wh/m²
$q_{loss,DHW}$	Specific losses for domestic hot water demand	Wh/m²
$q_{loss,X}$	Specific losses in systems, e.g. for distribution, storage	Wh/m²
l_{pipe}	Pipe length	M
k_{pipe}	Specific heat loss factor	W/(mK)
$k_{storage}$	Specific heat loss factor	W/(m³K)
T_{in}	Temperature within the conditioned zone of the building	°C
$V_{storage}$	Storage volume	m³
ε	(Optical) conversion factor	-
H_T	Envelope quality factor (insulation)	W/(m²*K)
SFP	Specific fan power	W/m³
AER	Air-exchange rate	1/h
HR	Heat recovery rate	%
z(t)	Time variable for profile	-
GWP	Global warming potential	-
CO_2-eq	Carbon dioxide equivalent	kg

Introduction

Building energy performance tool

The building energy performance tool (BEP) is crated to calculate the useful, final and primary energy demand of single buildings. In addition, it calculates the global cost of the energy related construction measures, to determine the cost-efficiency of renovation or new building projects. The tool can be accessed at https://globco.buildings-mena.com/.

Document

Purpose

This document accompanies the BEP online tool. It provides more detailed information about the assumptions made, the system selection possibilities and the calculation method.

Structure

The **documentation** follows the structure of the online mask, which is divided into:

- General information
- Input
- Results
- Detailed results
- (Funding)
- Project storage

Subsequently, the **calculation methodology** is explained in more detail and the definition and creation of the used **baseline buildings** are described.

1.0 Documentation online tool

Detailed explanation of the possible input values and selections, incl. additional information about the HVAC systems covered.

1.1 General information

This is the introduction tab. It includes all the general information to set the baseline building.

1.1.1 Project

A name for the current project must be entered. This name will later be used in the output graph and table as well as to save the project.

1.1.2 Building type

1.1.2.1 Select building type

The **building type** must be selected by clicking on the icons. Currently, there are six types of buildings available:

- Single-family house (SFH)
- Multi-family house (MFH)
- Office
- Educational building (e.g. university, school)
- Shop
- Hospital

Further explanation regarding the building types, there specification and photos of representative buildings are found on the BUILD_ME website.

This selection (and the location in the next step) defines the baseline building, that is used to compare the energy performance of the project building. The parameters of the baseline building are also set as default values in the next tab (“Input”). An overview of the baseline buildings is published on the BUILD_ME website.

1.1.2.2 Age group

The selection of the **age group** is relevant for multiple reasons, (1) Different price assumption. The “renovation” case includes 5% additional cost, since it generally is related to higher installation cost compared to a new build. (2) Consideration of envelope insulation cost. The insulation cost for the envelope are considered, if the insulation is better (u-value is lower) than in the baseline case. However, for the “renovation” case the theoretical additional cost for the envelope, can be not considered (selection in the “Input” tab), e.g. to reflect that the envelope has already been refurbished in a former project. If “new building” is selected, the theoretical additional cost is always considered, since it is part of the current project.

1.1.3 Location

1.1.3.1 Country

Select the country where the project is located.

1.1.3.2 Reference city

The reference city is used to select the representative climate according to the region the project is located. For each country there are various reference cities to choose from, to ensure the building project is calculated with the correct regional climate input. In the following, the available reference cities for the three BUILD_ME countries are listed, incl. a more detailed description of the climatic zone they represent, if applicable.

Egypt

Table 1: Reference cities Egypt

Reference city	Climatic zone
Qalyubia	
Port Said	
Cairo	
Alexandria	
Luxor	
El-Arish	
Asyut	
Aswan	
Hurghada	

Jordan

Table 2: Reference cities Jordan

Reference city	Climatic zone
Zarqa	
Ruwaished	
Irbid	
Ma'an	
Amman	
Aqaba	
Ajloun	
Dead sea	

Lebanon

The table below shows an overview of the relevant climate zones in Lebanon. Detailed list of cities related to each climate can be found on the webpage of the LCEC or directly in this link.

Table 3: Reference cities Lebanon and the according climatic zones

Reference city	Climatic zone
Beirut	1a - Coastal below 200 m altitudes
Bayssour	1b - Coastal above 200 m altitudes
Qartaba	2 - Western Mid Mountain
Haouch El Oumaraa	3 - Inland Plateau
Bcharre	4 - High Mountain
Cedars	
Zahlé	
Tyros	
Tripoli	

1.1.3.3 Specify region

Besides the reference climate and the type of building, the region – in terms of urban, sub-urban, village, certain part of country, etc. – has also an impact on the baseline standard. Depending on the country, current average buildings in urban areas have different refurbishment levels, geometries or HVAC systems than in rural areas or there are differences between the western and eastern part of the country (e.g. Jordan). An detailed overview of the effects on the baseline buildings is published on the BUILD_ME website.

1.1.4 System selection

The systems that are installed in the project building should be selected here (green button = installed). The default selection depends on the baseline building and represents the typical local standard, however, this can be changed.

The selection can be still adapted in the following tab “Input”.

1.1.5 Mode

This selection allows to differentiate the subsequent tab “Input” for unexperienced and expert users. If the “Advanced mode” is enabled, the following **additional selections** can be made:

- Wall area according to orientation
- Window area according to orientation
- Thermal heat bridges
- Envelope elements
    - Specific heat capacity and mass distribution
    - Wall & roof color
- Operational parameters
    - Internal heat gains
    - Additional electricity consumption
    - Cooling & heating set point temperature
    - Night set back

The mode can be still changed later (after clicking next), by going back to the “General information” tab.

1.2 Input

The following sections provide an overview of the input parameters for the calculation, incl. a more detailed description and a list of aspects of the calculation these parameters have a relevant impact on.

1.2.1 Geometry-related parameters

Parameter	**Description**	**Relevant for…**
Building levels (floors)	Number of floors in the building.	…hot water and heat distribution pipes and the related losses.
Number of dwellings	Number of separated apartments in residential buildings (SFH = 1).	…hot water demand, which is related to the living area.
Net floor height [m]	Room height within the living areas.	…air volume in the building (conversion of air exchange rate into actual volume)
Net floor area [m²]	The entire conditioned area of the building. *MFH: Building area (not apartment area)*	• … the output of specific energy demand and cost • …air volume in the building • …hot water demand • …building’s other electricity demand *It has a high impact on the calculation.*
Roof area opaque [m²]	The area of the upper conditioned zone to the outside.	• …cooling/heating losses through transmission • …insulation cost of the roof • …design cooling capacity
Façade area opaque (excl. windows) [m²]	Vertical (not transparent) area of the conditioned zones to the outside.	• …cooling/heating losses through transmission • …insulation cost of the wall • …design cooling capacity
Share of façade to orientation. [m²] *(only “Advanced mode”)*	Divide the total façade area into the part facing North, East, South, West, respectively.	• …more detailed calculation of the heat gains (depending on sun radiation on the façade)
Window area [m²]	Transparent vertical and horizontal area of the conditioned zones to the	• …cooling/heating losses through transmission

	outside, incl. the frame area of the windows.	• … cost of the windows • …design cooling capacity
Share of windows to orientation. [m²] *(only "Advanced mode")*	Divide the total window area into the part facing North, East, South, West, respectively.	• …more detailed calculation of the heat gains (depending on sun radiation on the façade)
Area floor slap [m²]	The area of the lowest conditioned zone against an unconditioned zone (cellar) or the soil.	• …cooling/heating losses through transmission • …insulation cost of the wall • …design cooling capacity

1.2.2 Wall

Parameter	**Description**	**Relevant for…**
Wall renovation	Only relevant for renovation cases. Indication if the element renovation was part of the project. If selected "No", no costs are considered for this element.	… cost of the element.
Type (material)	Select the type of the wall.	…no impact at the moment
Absorption	Select the color type of your building in three different categories (dark, intermediate, light). Dark elements absorb more heat from the sunlight than light colors.	…heat gains through solar radiation on the element *Low effect on results.*
Specific heat capacity [J/(m²K)]	This depends on the construction material. Materials with higher heat capacity store heat longer. Click here for more information.	• …thermal dynamic behavior of the building (e.g. adaption to temperature changes) *Low effect on results.*
Mass distribution	Mass distribution is the spatial distribution of mass within the solid building element. If mostly one homogenous material is used, the mass is rather equally distributed. A displacement is caused if high proportions of insulation material are used. In this case, the mass core of the element shifts away from the insulated side (e.g. outside is insulated -> "Class M: Mass concentrated inside"). More information here.	• … thermal dynamic behavior of the building (e.g. adaption to temperature changes) *Low effect on results.*
U-value [W/(m²K)]	Heat transfer coefficient of the building material. It describes the amount of heat transferred to the	• …heat/cooling gains/losses transmitting through the element

	element depending on the temperature difference between outside and inside. A higher u-value causes more heat transfer and has higher cooling / heating demands as consequence. Click here (or simple here) for more information.	• …sizing of cooling capacity • …necessary insulation thickness and therefore cost of element *It has a high impact on the energy calculation.*
Thermal heat bridge [W/(m²K)]	Like the u-value. Only it considers the additional heat transfer caused by no insulation in element corners, borders, etc. Is added on top of the u-value in this tool.	• …heat/cooling gains/losses transmitting through corners and borders of the element

1.2.3 Roof

Parameter	Description	Relevant for…
Roof renovation	Only relevant for renovation cases. Indication if the element renovation was part of the project. If selected “No”, no costs are considered for the element.	… cost of the element.
Type (material)	Select the type of the roof.	…no impact at the moment
Absorption	Select the color type of your building in three different categories (dark, intermediate, light). Dark elements absorb more heat from the sunlight than light colors.	…heat gains through solar radiation on the element *Low effect on results.*
Specific heat capacity [J/(m²K)]	This depends on the construction material. Materials with higher heat capacity store heat longer. Click here for more information.	• …thermal dynamic behavior of the building (e.g. adaption to temperature changes) *Low effect on results.*
Mass distribution	Mass distribution is the spatial distribution of mass within the solid building element. If mostly one homogenous material is used, the mass is rather equally distributed. A displacement is caused if high proportions of insulation material are used. In this case, the mass core of the element shifts away from the insulated side (e.g. outside is insulated -> "Class M: Mass concentrated inside"). More information here.	• … thermal dynamic behavior of the building (e.g. adaption to temperature changes) *Low effect on results.*

U-value [W/(m²K)]	Heat transfer coefficient of the building material. It describes the amount of heat transferred to the element depending on the temperature difference between outside and inside. A higher u-value causes more heat transfer and has higher cooling / heating demands as consequence. Click here (or simple here) for more information.	• …heat/cooling gains/losses transmitting through the element • …sizing of cooling capacity • …necessary insulation thickness and therefore cost of element *It has a high impact on the energy calculation.*
Thermal heat bridge [W/(m²K)]	Like the u-value. Only it considers the additional heat transfer caused by no insulation in element corners, borders, etc. Is added on top of the u-value in this tool.	• …heat/cooling gains/losses transmitting through corners and borders of the element

1.2.4 Slab

Parameter	Description	Relevant for…
Slab renovation	Only relevant for renovation cases. Indication if the element renovation was part of the project. If selected "No", no costs are considered for the element.	… cost of the element.
Specific heat capacity [J/(m²K)]	This depends on the construction material. Materials with higher heat capacity store heat longer. Click here for more information.	• …thermal dynamic behavior of the building (e.g. adaption to temperature changes) *Low effect on results.*
U-value [W/(m²K)]	Heat transfer coefficient of the building material. It describes the amount of heat transferred to the element depending on the temperature difference between outside and inside. A higher u-value causes more heat transfer and has higher cooling / heating demands as consequence. Click here (or simple here) for more information.	• …heat/cooling gains/losses transmitting through the element • …sizing of cooling capacity • …necessary insulation thickness and therefore cost of element *It has a high impact on the energy calculation.*
Thermal heat bridge [W/(m²K)]	Like the u-value. Only it considers the additional heat transfer caused by no insulation in element corners, borders, etc. Is added on top of the u-value in this tool.	• …heat/cooling gains/losses transmitting through corners and borders of the element

1.2.5 Window

Parameter	Description	Relevant for…
Window renovation	Only relevant for renovation cases. Indication if the element renovation was part of the project. If selected "No", no costs are considered for the element.	… cost of the element.
Type (material)	The window type indicates the relevant window parameters – u-value and g-value (see below).	• …u-value and g-value of window • … cost of window
G-value	A g-value of 1.0 represents full transmittance of all solar radiation while 0.0 represents a window with no solar energy transmittance. In practice though, most g-values will range between 0.2 and 0.7, with solar control glazing having a g-value of less than 0.5. Click here for more information on window parameters.	• …solar transmittance through window (heat gains) • …cost of window
U-value [W/(m²K)]	Heat transfer coefficient of the building material. It describes the amount of heat transferred to the element depending on the temperature difference between outside and inside. A higher u-value causes more heat transfer and has higher cooling / heating demands as consequence. Click here (or simple explanation here) for more information.	• …heat/cooling gains/losses transmitting through the element • …sizing of cooling capacity • … cost of element *It has a high impact on the energy calculation.*
Thermal heat bridge [W/(m²K)]	Like the u-value. Only it considers the additional heat transfer caused by no insulation in element corners, borders, etc. Is added on top of the u-value in this tool.	• …heat/cooling gains/losses transmitting through frames and borders of the element
Shading variant	Selection of different shading elements that can be installed to the building's transparent elements.	• …solar radiation (heat gains) • …cost for shading elements
Shading factor	Many simplified models work with general shading factors (the proportion of the sunlight onto the window, hence not blocked by the shading element). Therefore, this gives an information of the factor related to the selected shading element.	• …informational

1.2.6 Air-change rate

Parameter	Description	Relevant for…
Free ventilation [1/h]	The free ventilation reflects the air-change in the building caused by opening windows. The factor in 1/h is the proportion of total air-volume of the building that is exchanged per hour. This should be set to (0) if mechanical ventilation is installed. Factor is not affected by setbacks (e.g. night-setback), so provide average value.	• …heat gains/losses through convection *It has a high impact on the energy calculation.*
Infiltration [1/h]	The infiltration reflects the (unwanted) air-change in the building caused by cracks, door slots, etc. in the building. The factor in 1/h is the proportion of total air-volume of the building that is exchanged per hour. Click here for more information.	• …heat gains/losses through convection • …cost (additional to the envelope, since less infiltration implies better construction quality)

1.2.7 Space heating

Parameter	Description	Relevant for…
Space heating system	Up to nine space heating systems are currently available (see below). If one of these systems is not selectable, it is no relevant or accessible system in the selected country. For further information on the calculation methodology click here and for system specific efficiencies click on the system. • Gas non-condensing • Gas condensing • Oil non-condensing • Oil condensing • Portable gas heater • Portable kerosene heater • Heat pump (air-water) • Heat pump (ground source) • Air-conditioning system (reversible for heating; air-air heat pump)	• …final energy demand for heating • …investment cost of heating system *It has a high impact on the final energy and global cost calculation.*

Efficiency class heating system	Select one of five efficiency classes, which reflect the spectrum of the systems available on the market. To give an indication of the resulting efficiency for the selected class, the standard efficiency at design capacity is displayed online ("Resulting efficiency"). The detailed parameters of all efficiency classes are available in the following links: • Gas non-condensing • Gas condensing • Oil non-condensing • Oil condensing • Portable gas heater • Portable kerosene heater • Heat pump (air-water) • Heat pump (ground source) • Air-conditioning system (reversible for heating; air-air heat pump)	• …final energy demand • …cost (better efficiency class, results in higher investment cost, but less energy cost)

1.2.8 Hot water generator

Parameter	Description	Relevant for…
Primary technology	Hot water can be provided with dedicated hot water systems, such as dedicated gas or electric heaters or is part of the space heating system (combi system). If the latter is selected, the energy carrier and system type is chosen by the selection above "Space heating". Be aware, that only the gas- and oil-fired fixed boiler systems or air-water/ground source heat pumps can be used for hot water supply as well. For further information on the calculation methodology click here	• …final energy demand for hot water • …investment cost of hot water system *It has a high impact on the final energy and global cost calculation.*
Efficiency class heating system	Select one of five efficiency classes, which reflect the spectrum of the systems available on the market. To give an indication of the resulting efficiency for the selected class, the standard efficiency at design capacity is displayed online ("Resulting efficiency"). The detailed	• …final energy demand • …cost (better efficiency class, results in higher investment cost but less energy cost)

	parameters of all efficiency classes are available in the following links or, if it is combined system, depend on the space heating system. • Dedicated gas heater • Dedicated electric heater	
Solar system for DHW	Select "Yes" if solar system is installed for DHW supply	• …final DHW energy demand
Type of solar system	Flat collectors or tube collectors can be selected. Flat collectors are cheaper regarding the investment cost; however, tube collectors are more efficient	• …final DHW energy demand • …investment and energy cost
Installed area of solar collector	Enter the installed area of solar collectors. Rough rule of thumb is 1 – 1.5m² of solar collector area is enough to supply the hot water demand of one person (assumed 35l/day with 60°C)	• …coverage rate of solar at the entire DHW demand • …investment cost

1.2.9 Space cooling

Parameter	Description	Relevant for…
Space heating system	Up to nine space cooling systems are currently available (see below). If one of these systems is not selectable, it is not relevant or accessible in the selected country. For further information on the calculation methodology click here and for system specific efficiencies click on the systems. • Centralised multi-split system | Consisting of one outdoor unit (e.g. located on the rooftop) supplying several indoor units • VRF - Centralised multi-split with Variable Refrigerant Flow • Mounted single-split or window air conditioner | Usually a visible smaller system mounted outside the wall or above the window just supplying one room • Movable system | No fixed A/C system you can move around in the building units	• …final energy demand for cooling • …investment cost of cooling system *It has a high impact on the final energy and global cost calculation.*

	• Central system | Air vent distribution • Central system | Fan coil distribution • Central system | Surface distribution	
Efficiency class cooling system	Select one of five efficiency classes, which reflect the spectrum of the systems available on the market. To give an indication of the resulting efficiency for the selected class, the standard efficiency at design capacity is displayed online ("Resulting efficiency"). The efficiency classes for the split and single units are designed to reflect the spectrum of the energy efficiency classes of air-conditioning system by the European Commission from A++ - G (see here). The calculation methodology is explained here. The central systems are designed to reflect the different available system types, from scroll to turbo compressors, demand controlled, air-vent or surface distribution, etc. For detailed information on central systems click here. The detailed parameters of all efficiency classes available in the tool are in the following links: • Centralised multi-split system | Consisting of one outdoor unit (e.g. located on the rooftop) supplying several indoor units • VRF - Centralised multi-split with Variable Refrigerant Flow • Mounted single-split or window air conditioner | Usually a visible smaller system mounted outside the wall or above the window just supplying one room • Movable system | No fixed A/C system you can move around in the building units • Central system | Air vent distribution • Central system | Fan coil distribution	• …final energy demand • …cost (better efficiency class, results in higher investment cost, but less energy cost)

	• Central system | Surface distribution	

1.2.10 Mechanical Ventilation

Parameter	**Description**	**Relevant for…**
Type of ventilation system	Mechanical ventilation system replaces the free ventilation and ensures a constant air exchange, also with the possibility to reduce heat losses through heat recovery. Three systems are available: conventional mechanical ventilation, and two systems with heat recovery. The heat recovery results in significantly higher investment costs but saves energy cost (especially for heating). The difference between the two systems with heat recovery is the type of heat exchanger. Cross flow heat exchanger are cheaper but achieve only about 70% heat recovery, whereas the rotary heat exchangers are more expensive and achieve up to 90% heat recovery (in the model the exact values of 70% and 90% are assumed). Free ventilation should be set to (0) if mechanical ventilation is installed.	• …heat gains/losses through convection • …investment cost *It has a high impact on the energy calculation and on the investment cost.*
Air change rate [1/h]	The air-change rate reflects the volume of air that is exchanged by the mechanical ventilation system. The factor in 1/h is the proportion of total air-volume of the building that is exchanged per hour. Factor is affected by setbacks, hence if e.g. “night-setback” is selected, provide rather maximum, not average value.	• …heat gains/losses through convection • …energy cost (higher airflow results can result in higher energy cost)
Heat recovery rate [%]	The heat recovery avoids losses caused by heated air flowing outside. Heat exchanger achieve, depending on the quality, 70 – 90% of heat recovery, meaning the convective heat losses are reduced to 30 – 10%.	• …heat losses by ventilation

	The detailed calculation methodology for heat recovery is described here.	

1.2.11 Photovoltaic

Parameter	Description	Relevant for…
Capacity	The capacity of the Photovoltaic (PV) system describes the power output of the entire system at standard conditions, hence its size. In the following informational field, the approximate size to achieve the given capacity is displayed. The detailed calculation methodology for the electricity generation by PV is described here.	• …remaining electricity demand • …investment cost
Total module area	The area that is approximately needed to achieve the set capacity. Note: If the PV is installed on a flat roof, additional roof space might be needed if the panels are not horizontal to avoid self-shading. The exact area depends on the angle in which the panels are lifted from the horizontal.	-

1.2.12 Lighting

Parameter	Description	Relevant for…
Capacity	The lighting technology can be selected. The electricity demand is calculated with a standard profile for residential or non-residential buildings (see here for more information).	• …electricity demand • …investment cost
Lighting sensors	Not implemented, yet.	-

1.2.13 Other operating parameters

Parameter	Description	Relevant for…
Internal heat gains	Enter the specific power [W/m²] of the daily average internal heat gains in the building. Example 1: If the total daily internal heat gains are 240 kWh/m², the	• …heating (and less cooling) energy demand

	entered value is 240 Wh/m^2 / 24h = 10 W/m^2 If only the maximum internal heat gains in W/m^2 is known (not the average), it is recommended to consider the profile (see here) to calculate the resulting average, which can be entered. Internal heat gains result from appliances (e.g. cooking stove), people or lighting. In general, they variy significantly by building and type of use. The specific heat gains in multi-family buildings are higher than in single-family houses, since the population density is higher. Non-residential buildings, such as retailers can have even higher internal heat gains if they are very crowded. Orientation values for common use cases are: • Singel-family house: 1.9 W/m^2 • Multi-family house: 3.8 W/m^2 • Office (general): 3.0 W/m^2 • Retailer (crowded): 4.5 W/m^2 More values are listed here. Factor is affected by setbacks, hence if e.g. “night-setback” is selected, provide rather higher, not average value.	
Additional electricity consumption	Additional electricity consumption includes all the electricity consumption that is not related to the HVAC systems or lighting. This is especially important, when Photovoltaik is considered, since it has a high impact on the self-consumption rate. Therfore, a general user profile (see manual) is defined to distribute the selected electricity demand over the calculation period.	•

	Note: No additional internal heat gains are derivied from the electricity consumption level.	
Set point temperature heating	Defines the lowest acceptable temperature within the conditioned area. The useful heating demand is determined to maintain this temperature level. During single hours this temperature may be undercut, due to power restrictions of the heating system. If this border temperature should vary (e.g. during the night), it can be considered by enabling the "Night setback" (see following parameter).	• … useful heating demand *High influence on energy demand*
Set point temperature cooling	Defines the highest acceptable temperature within the conditioned area over the entire calculation period. The useful cooing demand is determined to maintain this temperature level. During single hours this temperature may be exceeded, due to power restrictions of the cooling system. If this border temperature should vary (e.g. during the night), it can be considered by enabling the "Night setback" (see following parameter).	• … useful cooling demand *High influence on energy demand*
Conditioned area (heating)*	Reduces the part of the conditioned area in comparison to the entire living area, as defined in the geometry inputs. The calculated final heating demand is adapted by the factor provided here.	-
Conditioned area (cooling)*	Reduces the part of the conditioned area in comparison to the entire living area, as defined in the geometry inputs. The calculated final cooling demand is adapted by the factor provided here.	-
Night Setback	Select if an adaption of the set point temperatures during a regular period withing the day should be considered. Most buildings are not	• …useful cooling / heating demand

	conditioned to the same temperatures during the night as during the day. This counts especially for offices and schools (outside the operational hours), but also for residential buildings.	
Heating	Enter the set point temperature for heating (the lowest acceptable temperature within the conditioned area) during the night setback (e.g. outside operating time, during the night).	-
Cooling	Enter the set point temperature for cooling (the highest acceptable temperature within the conditioned area) during the night setback (e.g. outside operating time, during the night).	-
Start	Enter the time (24h-mode) when the night set back starts (e.g. end of operating time, begin of night).	-
End	Enter the time (24h-mode) when the night set back ends (e.g. start of operating time, end of night). Example of "Night set back": Start = 22.0, End = 6.0 -> Night setback temperatures are applied from 22 p.m. - 6:00 a.m.	-

*might be not available in the current version.

2.0 Methodology Calculation

Overview…

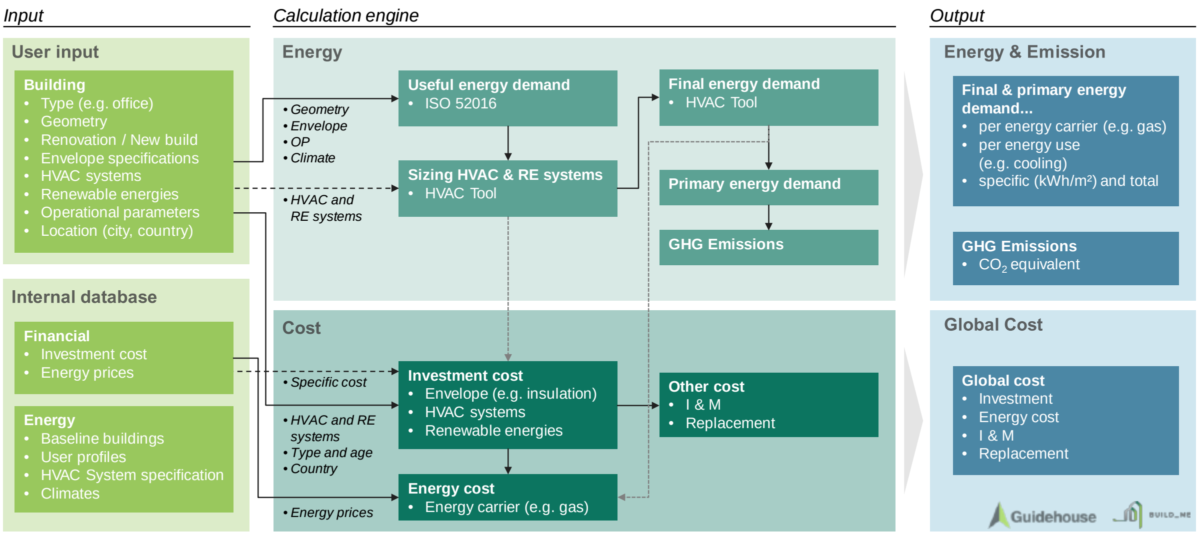

Figure 1: BEP tool calculation methodology

2.1 Useful energy demand calculation

The useful energy demand calculation is based on the international standard for building's thermal energy calculation EN ISO 52016 (external link). This section provides relevant information for the data input and an overview which factors are considered by the norm. The detailed calculation procedure is only described for the final energy demand in the next chapter, since this is not covered by an international standard methodology.

2.1.1 Envelope elements

2.1.1.1 Wall, roof, slab

The envelope elements have a major impact on the useful energy demand. They cause the conductive heat gains / losses, according to their u-value as:

$$q_{envelope} = u * t * (T_{amb} - T_{in})$$

with the u-value in W/m²K, the calculation time t and the temperature difference between the outside and inside.

2.1.1.2 Windows

Additionally, to the conductive heat gains / losses, windows effect the thermal behavior of the building mainly by the solar gains through the glass. The amount of solar irradiation let into the building is defined by the window's g-value [0, 1]. A g-value of 0 allows no radiation to enter through the window, so it is completely closed, whereas a g-value of 0.85 (single-glas) would allow 85% of the radiation to enter the building. The entering solar radiation share is further decreased by the window's frame. Note, that the window area is per default considered to have a frame share of 15%. This cannot be changed.

2.1.1.3 U-value

In general, the u-value is calculated as follows:

$$u = \frac{\lambda}{material\ \text{thickness}}$$

λ = thermal conductivity of the material. In the following the thermal conductivity of common building materials is listed:

Material	λ [W/(mK)]
Blockwork (light)	0.38
Blockwork (medium)	0.51
Blockwork (dense)	1.63
Brick (exposed)	0.84
Brick (protected)	0.62
Chipboard	0.15
Concrete (aerated)	0.16
Concrete (dense)	1.4
Fibreglass quilt	0.033
Glass	1.05
Glass foam aggregate (dry)	0.08
Hemp slabs	0.40
Hempcrete	0.25
Mineral wool	0.038
Mortar	0.80
Phenolic foam (PIR)	0.020
Plaster (gypsum)	0.46
Plasterboard (gypsum)	0.16
Polystyrene foam	0.032
Polyurethane foam (PUR)	0.025
Render (sand/cement)	0.50
Screed (cement/sand)	0.41
Steel	16 - 80
Stone (limestone)	1.30
Stone (sandstone)	1.50
Stone (granite)	1.7 - 4.0
Stone chippings	0.96
Straw bale	0.09
Timber (softwood)	0.14
Timber (hardwood - commonly used)	0.14 - 0.17

Woodfibre board	0.11

If the building element consists of different material layers, the reciprocal values of the single u-values are summed, as:

$$\frac{1}{u_{total}} = \frac{1}{u_1} + \frac{1}{u_2} + \ldots + \frac{1}{u_n}$$

2.1.1.4 Mass distribution

Mass distribution is the spatial distribution of mass within the solid building element. If mostly one homogenous material is used, the mass is rather equally distributed. A displacement is caused if high proportions of insulation material are used. In this case, the mass core of the element shifts away from the insulated side (e.g. outside is inulated -> "Class M: Mass concentrated inside"). Four different classes are considered in the tool (see

Table 4: Mass concentration classes (according to EN ISO 52016-1)

Class	Specification of class
Class I (mass concentrated on the inside)	Construction with insulation material on the outside or similar
Class E (mass concentrated on the outside)	Construction with insulation material on the inside or similar
Class IE (mass distributed over inside and outside)	Construction with insulation material between two mass components on the inside and outside or similar
Class D (mass distributed equally)	Not insulated construction (e.g. only bricks, concrete) or similar

2.1.1.5 Solar absorption

The solar absorption factor reflects the color of the outer building element and thereby the absorption factor of solar radiation on the surface. The three categories are available:

- Light color: 0.3
- Medium color: 0.6
- Dark color: 0.9

2.1.1.6 Specific heat capacity

Specific heat capacity refers to a material's capacity to store heat for every kilogram of mass. A material of high thermal mass has a high specific heat capacity. The heat capacity classes distinguished by the EN ISO 52016-1 are listed in Table 5.

Table 5: Specific heat capacity classes (according to EN ISO 52016-1)

Class	$J/(m^2*K)$	Specification of class
Very light	50,000	Wood as construction material with < 10 cm thickness, or similar

Light	75,000	Light bricks or concrete with 5 - 10 cm thickness, or similar
Medium	110,000	Light bricks or concrete with 5 - 10 cm thickness; Bricks < 7 cm thickness or dense concrete, or similar
Heavy	175,000	Bricks or dense concrete with 7 - 12 cm thickness, or similar
Very heavy	250,000	Bricks or dense concrete > 12 cm thickness, or similar

2.1.2 Heating and cooling

The useful energy demand for heating and cooling is mainly calculated based on the geometry, envelope parameters, local weather data and air-exchange rate. The detailed calculation methodology is described in the international standard: EN ISO 52016-1.

2.1.3 Hot water

The hot water demand is calculated as described in 2.2.2.1 Domestic hot water demand.

2.1.4 Internal heat gains

The internal heat gains reflect the heat generated by appliances or people within the building. In the tool, they are entered as average, specific value over the day (24h), hence the total daily internal heat gains are calculated as:

$$q_{gain} = p_{av,gain} * 24h$$

In Table 4 are average heat gain values provided, depending on the building type and usage. The total daily heat gains are then distributed according to the profiles in Figure 2.

The following example demonstrates the calculation: If the average internal heat gain is entered as $p_{av,gain}$ = 10 W/m², then the total daily heat gain is q_{gain} = 10 W/m² * 24 h = 240 Wh/m². The building is a residential building and according to the profile graph (see Figure 2), 6% of the daily heat gain is “happening” from 6:00 a.m. to 7:00 a.m., which means the internal heat gain in this hour is 240 Wh/m² * 6% = 14.4 Wh/m².

Table 6: Overview of internal heat gains (according to DIN 18599-10)

Building Type	**Medium heat transmission**	**average heat gain**	**Per Person**	**Considered aspects**
	Wh/m²/d	**W/m²**	**W**	
Residential Building (SFH)	45.0	1.9	70.0	
Residential Building (MFH)	90.0	3.8	70.0	
Single office	73.0	3.0	70.0	consists of people + work appliance

Big area office	73.0	3.0	70.0	consists of people + work appliance
Conference room	101.0	4.2	70.0	consists of people + work appliance
Retailer	108.0	4.5	70.0	consists of people + work appliance
Retailer (food section, incl. cooling)	- 86.0	- 3.6	70.0	consists of people + work appliance
School (class room)	120.0	5.0	60.0	consists of people + work appliance
Auditorium	444.0	18.5	70.0	consists of people + work appliance
Hotel room	114.0	4.8	70.0	consists of people + work appliance
Restaurant	247.0	10.3	70.0	consists of people + work appliance
Fair	152.0	6.3	70.0	consists of people + work appliance
Gym (no spectators)	63.0	2.6	125.0	consists of people
Treatment room (hospital)	117.0	4.9	70.0	consists of people + work appliance
Special treatment room, e.g. emergency room (hospital)	340.0	14.2	70.0	consists of people + work appliance
Storage hall	-	-	-	No internal heat gains

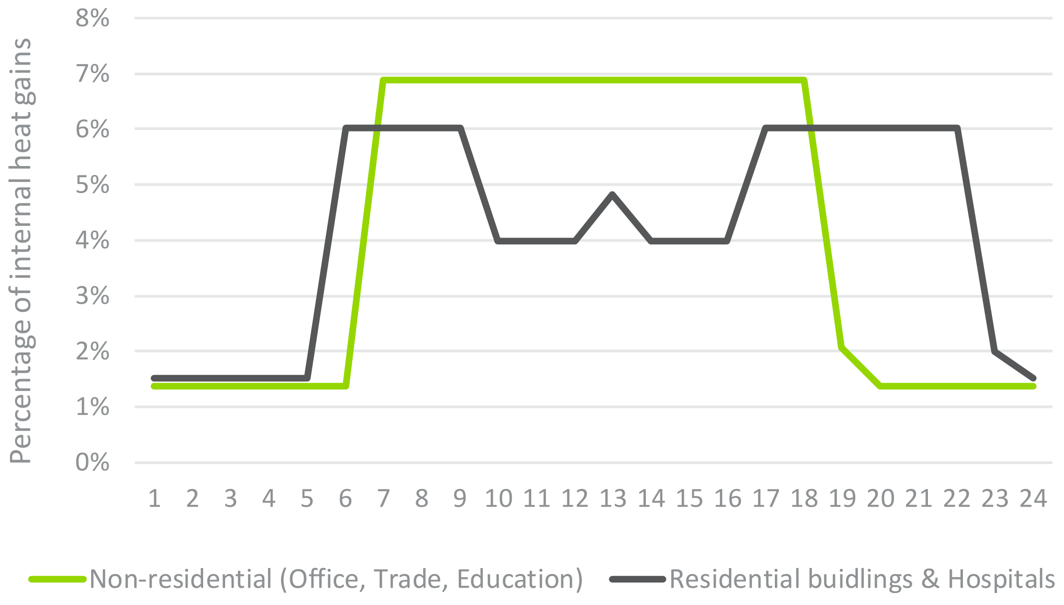

Figure 2: User profiles according to building type

- Methodology for the ventilation

2.2 Final energy demand calculation

2.2.1 Space heating

Up to six space heating systems are currently available (see below). If one of these systems is not selectable, it is no relevant or accessible system in the selected country.

After selecting the system an efficiency class is chosen. Each efficiency class contains a set of parameters (depending on the type of heating system) to calculate the efficiency of the heating system according to operating status, e.g. running on partial load or ambient conditions. In the following, all selectable systems are listed incl. a table with the parameters of the efficiency classes and the formulae used to calculate the final energy demand.

2.2.1.1 Installed heating load

The installed power is determined to enable heating up to 20°C at the coldest hour of the year, by considering the actual transmission and ventilation losses of the building at that temperature.

$$P_{inst} = (20 - T_{amb,design}) * (u \bullet A_{env} + AC_{total} * \rho_{air} * c_{p,air})$$

With the sum product of u-values and envelope areas u *x* A_{env}, the total air-change rate, the density ρ and heat coefficient c_p of air and the ambient temperature for the design capacity $T_{amb,design} = T_{amb,\ min}$.

2.2.1.2 Heat boiler systems

The calculation is based on the German industry norm for energy calculations of buildings (DIN 18599) and is consistent for all available boiler systems. The system specific efficiency parameters that depend on the type of boiler system are listed in tables below. Since the detailed input parameters for HVAC systems are not available, the following standard formulae are used for the efficiency at full load and part load.

$$\eta_{k,P_n} = (A + B \cdot log10\,(P_n))/100$$
$$\eta_{k,P_{int}} = (C + D \cdot log10\,(P_n))/100$$

With η_{k,P_n} as full load efficiency, $\eta_{k,P_{int}}$ as part load efficiency and the factory A, B, C, D as in the tables below. Standby heat demand losses are calculated with:

$$q_{P0,70} = \frac{(E \cdot (P_n)^F)}{100} * t$$

To determine the exact efficiency in the calculated hour depending on the heating need, the actual load demand is calculated by determining the necessary heat supply temperature.

$$T_{supply} = T_{design} - (T_{design} - T_{min}) * \left(1 - \frac{T_{min} - T_{amb}}{T_{min} - T_{amb,design}}\right)$$

With the supply temperature at the design capacity T_{design} = 70°C, the mimimum supply temperature T_{min} = 25°C, the ambient temperature T_{amb}, the ambient temperature for the design capacity $T_{amb,design} = T_{amb,\ min}$ – 3 K and T_{supply} = [25°C, 70°C].

The actual supply temperature is used to calculate the effective boiler efficiency η_k.

$$\eta_k = \eta_{k,P_{int}} - (\eta_{k,P_{int}} - \eta_{k,P_n}) * \frac{(T_{supply} - T_{part})}{(T_{design} - T_{part})}$$

With the part load temperature T_{part} as defined in the tables below.
The resulting final energy demand is calculated as:

$$q_f = \frac{q_u}{\eta_k}$$

2.2.1.2.1 Gas (non-condensing)

Parameter	Unit	1	2	3	4	5
Standard efficiency at design capacity	%	91%	89%	86%	86%	84%
Factor *B*	-	1.50	1.50	1.50	1.50	1.50
Standard Efficiency at part load	%	91%	89%	85%	82%	82%
Factor *D*	-	1.30	1.30	1.50	1.50	1.50
Factor *E*	-	5.00	5.00	7.00	7.00	7.00

Factor *F*	-	-0.37	-0.37	-0.37	-0.37	-0.37
Temperature at part load	°C	30.0	30.0	30.0	40.0	50.0
Demand controlled	-	Yes	Yes	Yes	No	No

2.2.1.2.2 Gas (condensing)

Parameter	Unit	1	2	3	4	5
Standard efficiency at design capacity	%	97%	94%	94%	92%	89%
Factor *B*	-	1.00	1.00	1.00	1.00	1.50
Standard Efficiency at part load	%	105%	103%	98%	92%	89%
Factor *D*	-	1.00	1.00	1.00	1.00	1.50
Factor *E*	-	4.00	4.00	4.00	4.00	7.00
Factor *F*	-	-0.40	-0.40	-0.40	-0.40	-0.37
Temperature at part load	°C	30.0	30.0	30.0	40.0	50.0
Demand controlled	-	Yes	Yes	Yes	No	No

2.2.1.2.3 Oil (non-condensing)

Parameter	Unit	1	2	3	4	5
Standard efficiency at design capacity	%	91%	89%	86%	86%	84%
Factor *B*	-	1.50	1.50	1.50	1.50	1.50
Standard Efficiency at part load	%	91%	89%	85%	82%	82%
Factor *D*	-	1.30	1.30	1.50	1.50	1.50
Factor *E*	-	5.00	5.00	7.00	7.00	7.00
Factor *F*	-	-0.37	-0.37	-0.37	-0.37	-0.37
Temperature at part load	°C	30.0	30.0	30.0	40.0	50.0
Demand controlled	-	Yes	Yes	Yes	No	No

2.2.1.2.4 Oil (condensing)

Parameter	Unit	1	2	3	4	5
Standard efficiency at design capacity	%	97%	94%	94%	92%	89%
Factor *B*	-	1.00	1.00	1.00	1.00	1.50

Standard Efficiency at part load	%	105%	103%	98%	92%	89%
Factor *D*	-	1.00	1.00	1.00	1.00	1.50
Factor *E*	-	4.00	4.00	4.00	4.00	7.00
Factor *F*	-	-0.40	-0.40	-0.40	-0.40	-0.37
Temperature at part load	°C	30.0	30.0	30.0	40.0	50.0
Demand controlled	-	Yes	Yes	Yes	No	No

2.2.1.2.5 Portable LPG (gas) heaters

Parameter	**Unit**	**1**	**2**	**3**	**4**	**5**
Standard efficiency at design capacity	%	80%	78%	75%	72%	69%
Factor *B*	-	1.50	1.50	1.50	1.50	1.50
Standard Efficiency at part load	%	82%	80%	77%	75%	72%
Factor *D*	-	1.30	1.30	1.50	1.50	1.50
Factor *E*	-	5.00	5.00	7.00	7.00	7.00
Factor *F*	-	-0.37	-0.37	-0.37	-0.37	-0.37
Temperature at part load	°C	80%	78%	75%	72%	69%
Demand controlled	-	1.50	1.50	1.50	1.50	1.50

Power restrictions

- Maximum output power: 4.5 kW/System
- Minimum output power: 1.5 kW/System

Figure 3: Image - Example LPG portable gas heater

2.2.1.2.6 Portable kerosene heaters

Parameter	Unit	1	2	3	4	5
Standard efficiency at design capacity	%	63%	60%	58%	55%	50%
Factor *B*	-	1.50	1.50	1.50	1.50	1.50
Standard Efficiency at part load	%	65%	62%	60%	57%	52%
Factor *D*	-	1.30	1.30	1.50	1.50	1.50
Factor *E*	-	5.00	5.00	7.00	7.00	7.00
Factor *F*	-	-0.37	-0.37	-0.37	-0.37	-0.37
Temperature at part load	°C	63%	60%	58%	55%	50%
Demand controlled	-	1.50	1.50	1.50	1.50	1.50

Power restrictions

- Maximum output power: 6.8 kW/System
- Minimum output power: 1.5 kW/System

Figure 4: Image - Example portable kerosene heater

2.2.1.3 Heat pumps (air-water / ground source)

Two heat pump systems are available for selection (if applicable in the selected country), namely air-source and ground-source heat pumps. The system specific efficiency parameters that depend on the type of heat pump are listed separately in tables below. The calculation methodology, however, is similar for all heat pump types and is explained here.

The final energy demand is calculated with the useful energy demand (pre-calculated by the tool) and the efficiency, depending on the load status and ambient conditions. To reflect the current load status, the necessary heat supply temperature is calculated first.

$$T_{supply} = T_{design} - \left(T_{design} - T_{min}\right) * \left(1 - \frac{T_{min} - T_{amb}}{T_{min} - T_{amb,design}}\right)$$

With the supply temperature at the design capacity T_{design} depending on the efficiency class (see tables below), the mimimum supply temperature T_{min} = 25°C, the ambient temperature T_{amb} (which is the ground temperature for ground-source heat pumps), the ambient temperature for the design capacity $T_{amb,design} = T_{amb, min}$ – 3 K and T_{supply} = [25°C, T_{design}].

The resulting efficiency of the heat pump is calculated as

$$\eta_k = \frac{T_{supply} + 273.15}{T_{supply} - (T_{amb})} * QF$$

with $T_{amb} \geq 12$°C and the quality factor of the heat pump *QF* as

$$QF = \frac{COP * (T_{supply} - T_{design})}{(T_{supply} + 273.15)}$$

With the COP at standard conditions and the standard supply temperature T_{design} as listed in the tables below.

The resulting final energy demand is calculated as:

$$q_f = \frac{q_u}{\eta_k}$$

Bivalence point of air-source heat pump

When the outside temperature is very los, air-source heat pumps have technical boundaries to supply the necessary heat power. Also, the heat pump is not designed for the coldest conditions, since it is only needed on a few days in the year. To still ensure the heat demand is met, an electrical resistance heater is installed (COP = 1) that provides the additional heat power.

Therefore, additional components must be considered in the calculation of the final energy demand for air-source heat pumps. First, the maximum possible heat power, the heat pump can deliver at the given ambient temperature (P_k), must be calculated. This is compared with the needed useful power demand (Q_{heat}/t). If the necessary power demand is higher, the difference must be provided by the electrical resistance heater $P_{resistance}$.

The maximum heat power output of the heat pump $P_{k,max}$ at a given ambient temperature is calculated as:

$$P_k = \frac{\eta_k}{\eta_{design}} * P_{design} = \frac{\frac{T_{supply} + 273.15}{T_{supply} - (T_{amb})} * QF}{\eta_{design}} * P_{design} = \frac{(T_{supply} - T_{design})}{(T_{supply} - T_{amb})} * P_{design}$$

The difference between the possible output and the useful heat demand provides the power that will be supplied by the electrical resistance heater. It will only count, if the following equation is less than zero, which means the demand P_{heat} is higher than the maximum power output $P_{k,max}$

$$\Delta P = P_{resistance} = -\min\left[0;\ P_{k,max} - \frac{Q_{heat}}{t}\right] = -\min[0; P_{k,max} - P_{heat}]$$

$P_{resistance}$ is provided with an efficiency / COP of 1.

2.2.1.3.1 *Air-source heat pump*

Parameter	Unit	1	2	3	4	5
Standard design system supply temperature	°C	35.00	35.00	40.00	40.00	40.00
Standard design system return temperature	°C	27.00	27.00	30.00	30.00	30.00
COP at standard conditions	-	3.84	3.20	2.70	2.00	1.90
Bivalence point	°C	-15.00	-7.00	-7.00	-7.00	-7.00
Standard supply temperature	°C	2.00				

2.2.1.3.2 *Ground-source heat pump*

Parameter	Unit	1	2	3	4	5

Standard design system supply temperature	°C	35.00	35.00	40.00	40.00	40.00
Standard design system return temperature	°C	27.00	27.00	30.00	30.00	30.00
COP at standard conditions	-	5.16	4.30	3.40	2.60	2.00
Bivalence point	°C	-15.00	-7.00	-7.00	-7.00	-7.00
Standard supply temperature	°C	0.00				

2.2.1.4 Air-air heat pump / reversible split unit

The air-air heat pump is, in contrast to the air-water and ground-source heat pumps, calculated with the operational parameters at certain ambient temperatures as given in the following table. The efficiency values (SCOP) are selected to reflect the available spectrum according to the energy efficiency labelling directive of the European Commission (see here – Energy efficiency classes for air conditioners, except double ducts and single ducts). The according class is indicated in the last row of the table.

Parameter	Unit	1	2	3	4	5
Efficiency at -7°C	-	4.80	4.00	3.30	2.70	1.50
Efficiency at +2°C	-	5.00	4.20	3.50	2.80	1.70
Efficiency at +7°C	-	5.40	4.60	3.90	3.00	2.10
Efficiency at +10°C	-	5.70	4.90	4.20	3.20	2.40
Reflects European energy efficiency class	-	A++/A+++	A+	B/A	D/C	G

The actual efficiency is determined by linear interpolating of the actual ambient temperature outside with the corresponding value of the chosen efficiency class.

Example: If efficiency class 1 is taken and the ambient temperature is -2.5°C than the efficiency of the air-air heat pump is:

$$\eta = 4.8 + (5.0 - 4.8) * \frac{-7°C - (-2.5)°C}{-7°C - 2°C} = 4.9$$

The resulting final energy demand is calculated as:

$$q_f = \frac{q_u}{\eta}$$

2.2.1.5 Heat losses

2.2.1.5.1 Distribution

Currently not considered since all the heating pipes are assumed to be within the conditioned areas.

2.2.1.5.2 Storage

Currently not considered.

2.2.1.5.3 Auxiliary energy demand

No auxiliary energy demand for portable heaters.

2.2.2 Domestic hot water (DHW)

Hot water demand is only recommended and tailored for residential buildings. The calculation method is tailored to this application, since the DHW demand is less relevant in non-residential buildings. It is either produced by dedicated DHW systems (gas, electric) or in combination with the central space heating system. Additionally, Solar panels can be used to support the DHW supply. It is, however, always a primary conventional system to select, since Solar DHW systems are usually sized to meet around 30 - 60% of the total DHW demand. The residual demand is than always covered by the selected system.

2.2.2.1 Domestic hot water demand

The specific useful hot water energy demand of an apartments or single-family house is estimated as:

$$q_{u,DHW} = (16.5 - 0.05 * A_{use}) * \left(\frac{45 - T_{av,amb}}{35}\right) * t$$

with the living area A_{use}, the average annual ambient temperature $T_{av,amb}$ to consider a regional factor and $q_{u,DHW}$ = [8.5, 16.5] in kWh/(m²a). Subsequently, this demand is distributed with the profile in Figure 2 over 24 hours.

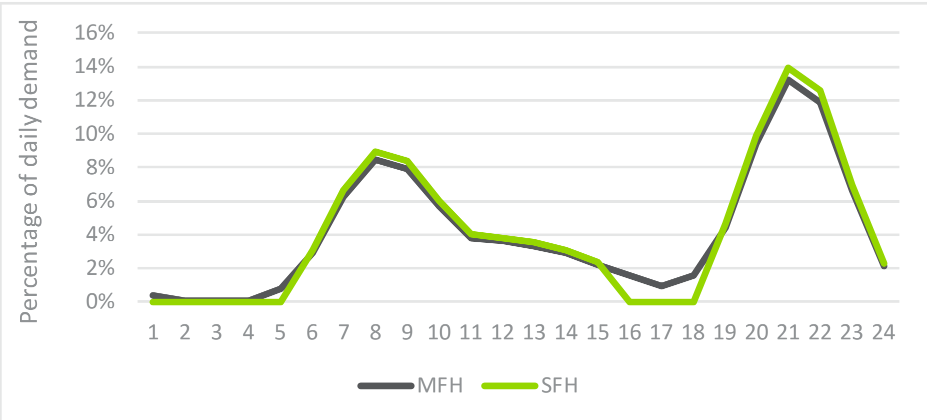

Figure 5: DHW demand profiles for residential buildings

2.2.2.2 Dedicated gas and electric heater

The final energy demand of the dedicated heaters is calculated as:

$$q_{f,DHW} = \frac{q_{u,DHW} + q_{loss,DHW}}{\eta_k}$$

with the boiler's efficiency η as listed in tables below and the losses calculated as indicated in the following section.

2.2.2.3 Combined heater systems

If a combined heating system is selected the hot water is produced by the space heating system. Therefore, is the calculation of the final energy demand for hot water production analogue to the space heating calculation of the selected space heating system, respectively.

2.2.2.4 Solar DHW

The solar panel's energy production is calculated as

$$Q_{solar} = G_{rad,h} * A_{panel} * \left(\varepsilon - k_1 * \frac{T_{supply} - T_{amb}}{G_{rad,h}} - k_2 * G_{rad,h} * \left(\frac{T_{supply} - T_{amb}}{G_{rad,h}} \right)^2 \right) - k_2 * \frac{T_{supply} - T_{amb,comp}}{G_{rad}}$$

with $G_{rad,h}$ the global radiation on a horizontal surface, A_{panel} the panel surface, ε the conversion factor, k_1 and k_2 as heat transmission coefficients and the DHW supply temperature T_{supply} as well as the temperature of the system components $T_{amb,comp}$. Be aware that the collector is assumed to be located on the horizontal, which should be deeper assessed depending on the global location, if detailed system sizing is relevant.

All relevant distribution losses are considered in the formulae above. Only the additional energy for the circulation pump is added as auxiliary energy (see sections below). The storage losses are calculated as follows in the general DHW storage losses, since the same storage for conventional and solar DHW production is assumed.

2.2.2.5 Storage and distribution losses

The distribution system losses are only relevant if there is a circulation system. For single-family houses, this is by default off, whereas all other buildings have a circulation system for DHW. All installed pipes are considered to be located within the conditioned area.

$$q_{loss,dis} = l_{pipe} * k_{pipe} * \left(T_{supply} - T_{in}\right) * t$$

with the specific heat loss factor k_{pipe} as listed in the tables below, the hot water temperature T_{water} and the indoor temperature T_{in} and the length of the indoor pipelines as

$$l_{pipe} = 0.005 * A_{use}^{1.38} + 0.11 * \left(\frac{A_{use}}{Number\ apparments} \right)^{1.24}$$

2.2.2.6 Auxiliary energy demand for boilers

If a dedicated hot water system is installed or the central space heating system is selected to provide domestic hot water, too, it is assumed that the hot water is distributed via circulation pumps. Consequently, there is an additional (electric) energy demand, depending on the pumps power load P_{pump}, which depends on the efficiency class of the DHW system and is indicated in the tables below.

$$q_{loss,circ} = P_{pump} * t$$

Every hot water system is considered to have a hot water storage to ensure stable DHW supply over the day. The necessary volume is calculated as:

$$V_{storage} = \frac{5}{3} * A_{use}$$

The specific heat losses of the storage are defined as

$$k_{storage} = \frac{V_{storage}}{1000} * Storage\ Factor$$

With the "Storage Factor" depending on the efficiency class as listed in the tables below.

The final storage losses depend on the temperature difference between the conditioned area (storages are located within the conditioned area) and the hot water in the storage.

$$q_{loss,storage} = k_{storage} * \left(T_{supply} - T_{in}\right) * t$$

With T_{supply} as the hot water supply temperature (65°C) and T_{in} the temperature in the conditioned area.

2.2.2.7 Dedicated DHW systems

2.2.2.7.1 Dedicated gas water heater

Parameter	Unit	1	2	3	4	5
Efficiency	-	90%	85%	80%	75%	65%
Power of DHW circulation pump	W	5	18	83	123	136
Storage heat loss factor	W/K	2	3	4	5	6

2.2.2.7.2 Dedicated electric water heater

Parameter	Unit	1	2	3	4	5
Efficiency	-	99%	99%	99%	99%	99%
Power of DHW circulation pump	W	5	18	83	123	136
Storage heat loss factor	W/K	2	3	4	5	6

2.2.2.7.3 Combined DHW system

The combined generation of space heating and DHW is possible with the gas and oil-fired boiler systems and the air-water and ground source heat pumps. One of these systems must be selected under space heating if combi-DHW system is chosen.

Consequently, the final energy demand for the DHW supply is calculated in a similar manner to these systems, however, the necessary supply temperature is generally higher (especially for heat pumps). This is considered when calculating the actual system efficiency as follows:

$$\eta_k = \eta_{part} * \left(\eta_{part} - \eta_{design}\right) * \frac{T_{supply,max} - T_{supply,part}}{70°C - T_{supply,part}}$$

with the efficiencies of the space heating at desing and part load, and the maximum supply temperature for DHW $T_{supply,max}$ = 85°C.

The resulting final energy demand is calculated as:

$$q_{f,DHW} = \frac{q_{u,DHW}}{\eta}$$

2.2.3 Space cooling

2.2.3.1 Installed cooling load

The design cooling capacity or installed cooling load is determined according to the envelope standard of the building and its ground area. The quality of the building envelope is determined as the sum product of the vector of u-values with the areas of the corresponding envelope elements:

$$H_T = u \bullet A$$

Depending on this, the necessary cooling load is chosen from the following table, distinguished between residential and non-residential buildings:

	1	**2**	**3**	**4**	**5**
H_T	< 0.15	< 0.3	< 0.5	< 1.0	≥ 1.0
Installed cooling load (residential) [W/m²]	20	40	70	100	130
Installed cooling load (non-residential) [W/m²]	60	70	90	110	150

Example: If all envelope elements have a u-value of 0.4 W/(m²*K) in a residential building with 120m² living area, the building has a H_T = 0.4 that leads to the system sizing as:

$$P_{cool} = 70\frac{W}{m^2} * 120m^2 = 8.4kW$$

2.2.3.2 Split-units, window mounted and moveable systems

This section describes the calculation methodology for all single- and multi-split units (incl. VRF) and window mounted or moveable systems. Although their efficiencies vary and the application must be verified (e.g. window mounted system is unlikely to condition an entire building), the used calculation methodology is similar.

The split unit's efficiency depends mainly on the ambient temperature. Therefore, the selectable systems have pre-defined efficiencies for four different ambient temperatures as listed in the tables below. Additionally, the seasonal energy efficiency ratio (SEER) is indicated which is also displayed online and used for the classification within the European efficiency labeling scheme (as indicated in the last row).

The actual efficiency is calculated with a linear approximation between the given efficiency values, depending on the outside temperature. To consider the fact, that the efficiency values are standardized at 26°C indoor temperature, the actual outside temperature is increased, if the indoor temperature is lower than 26°C and decreased if it is higher than 26°C, as follows:

$$T_k = T_{amb} + 26 - T_{in}$$

With the reference temperature Tk, the linear approximation of the efficiency at every hour is calculated with the values in the tables below as fix points. An example is given for the calculation of the efficiency if T_k ≥ 33°C and T_k < 35°C:

$$\eta_k = \frac{35°C - T_k}{35°C - 33°C} * (\eta_{33°C} - \eta_{35°C}) + \eta_{35°C}$$

The resulting final energy demand is calculated as:

$$q_f = \frac{q_u}{\eta_k}$$

2.2.3.2.1 Movable system

Parameter	Unit	1	2	3	4	5
Efficiency at 35°C	-	3.80	3.05	2.24	1.59	1.28
Efficiency at 33°C	-	4.12	3.31	2.43	1.69	1.35
Efficiency at 26°C	-	5.64	4.53	3.33	2.09	1.67
Efficiency at 20°C	-	7.73	6.21	4.56	2.59	2.08
ESEER	**-**	**5.49**	**4.41**	**3.24**	**2.03**	**1.63**
Energy efficiency class*	-	A+++	A++	A+	F	G

*according to European energy labeling of air-conditioners (REGULATION (EU) No 626/2011)

2.2.3.2.2 Mounted single-split or window air conditioner

Parameter	Unit	1	2	3	4	5
Efficiency at 35°C	-	5.63	4.52	3.32	2.36	1.89
Efficiency at 33°C	-	6.10	4.90	3.60	2.50	2.00
Efficiency at 26°C	-	8.36	6.71	4.93	3.10	2.48
Efficiency at 20°C	-	11.45	9.20	6.76	3.84	3.08
ESEER	**-**	**8.13**	**6.53**	**4.80**	**3.01**	**2.41**
Energy efficiency class*	-	A++	A++	B	F	G

*according to European energy labeling of air-conditioners (REGULATION (EU) No 626/2011)

2.2.3.2.3 Centralised multi-split system

Parameter	Unit	1	2	3	4	5
Efficiency at 35°C	-	5.43	4.68	3.65	2.95	2.53
Efficiency at 33°C	-	5.80	5.00	3.90	2.80	2.40
Efficiency at 26°C	-	7.48	6.45	5.03	2.35	2.02
Efficiency at 20°C	-	9.65	8.32	6.49	1.98	1.69
ESEER	**-**	**7.27**	**6.27**	**4.89**	**2.41**	**2.07**
Energy efficiency class*	-	A++	A++/A+	B	F/G	G

*according to European energy labeling of air-conditioners (REGULATION (EU) No 626/2011)

2.2.3.2.4 VRF - Centralised multi-split with variable refrigerant flow

Parameter	Unit	1	2	3	4	5
Efficiency at 35°C	-	4.30	4.00	3.70	3.40	-
Efficiency at 33°C	-	7.47	6.29	5.12	3.95	
Efficiency at 26°C	-	10.00	8.13	6.26	4.39	
Efficiency at 20°C	-	14.00	11.22	8.44	5.66	
ESEER	**-**	**9.77**	**8.00**	**6.22**	**4.45**	
Energy efficiency class*	-	A+++	A++	A+	B/C	

*according to European energy labeling of air-conditioners (REGULATION (EU) No 626/2011)

2.2.3.3 Central systems

The calculation of the system efficiency is similar to the methodology for decentralized split-units (see above). Depending on the type of central air-conditioning system, however, there are additional factors to be taken into consideration. Central systems are distinguished, among other things, by:

- Compressor type: Turbo, screw or piston / scroll
- Temperature of the cooling fluid (6°C, 10°C, 14°C)

The compressor type restricts the cooling load that can be achieved to:

- Piston / scroll: 10 - 1,500 kW
- Screw: 200 – 2,000 kW
- Turbo: 500 – 8.000 kW

Also, it becomes clear, that the installation of these type of systems are not relevant for smaller cooling loads (e.g. Single-family house).

To reduce the level of complexity, these compressor options are not selectable in the tool. However, they are considered in the design of the five efficiency classes. The following description provides project developers, who have advanced knowledge of their system, with reference systems for the given efficiencies.

System specification	Factors	1	2	3	4	5
Example 1 **Turbo compressor** (500 – 8.000 kW)	**Quality**	Good	Medium	-	-	-
	Fluid T.	14°C, 10°C	10°C, 6°C			

Example 2 **Screw compressor** (200 – 2,000 kW)	**Quality**	-	Best	Good	Medium	-
	Fluid T.		14°C	14°C, 10°C, 6°C	10°C, 6°C	
Example 3 **Scroll compressor** (10 - 1,500 kW)	**Quality**	-	-	Good	Good	Medium
	Fluid T.			14°C	10°C, 6°C	10°C, 6°C

The 'core' energy efficiency parameters are the same for all the three central system options, since the cool generating units do not change (see table below). However, they are distinguished by the way of distributing the cooling load within the building. It is either distributed by air ventilation (through air-ducts), fan coil units located in the rooms (comparable to indoor units of split-systems) or surface cooling elements (the wall's / ceiling's core is cooled). Differences in the calculation are described in the following.

Parameter	**Unit**	**1**	**2**	**3**	**4**	**5**
Efficiency at 35°C	-	6.78	5.12	3.30	2.92	1.50
Efficiency at 26°C	-	10.18	7.67	4.95	3.50	1.80
Efficiency at 22°C	-	11.68	8.81	5.68	3.76	1.93
ESEER	**-**	9.92	7.48	4.83	3.46	1.78
Reflects European energy efficiency class	-	A+++	A+	B	F	G

Efficiencies are excluding distribution losses.

The distribution needs additional energy, either for a fan to allow the airflow through the building or to transport the cooling liquid to the rooms. The power is defined as specific value of the amount of air / power of system, which depends on the buildings size and the efficiency class. The air-ventilation distribution energy is calculated as:

$$q_{vent} = \frac{P_{cool}}{P_{design}} * (V_{air} - V_{mech}) * SFP$$

With the specific fan power (SFP) as listed in the table below, the air volume flow reduced by the air volume moved by the mechanical ventilation and, in case demand control is enabled, the reduction through part-load operation (P_{cool}/P_{design}).

The internal power for the cooling fluid, is calculated as follows:

$$q_{pump} = \frac{P_{cool}}{P_{design}} * P_{design} * p_{pump}$$

With the specific pump power p_{pump} depending on the efficiency class (see table) and the actual cooling load P_{cool}.

In the following the specific power requirements are listed per distribution type and efficiency class (omitted if not applicable).

2.2.3.3.1 Central cooling - Air vent distribution

Parameter	Unit	1	2	3	4	5
SFP	W/m³	0.70	0.90	1.20	1.50	2.00
Fan demand controlled	-	TRUE	TRUE	TRUE	TRUE	FALSE
Specific power of system pumps	W/kW	2.5	5.0	10.0	15.0	20.0

2.2.3.3.2 Central system - Fan coil distribution

Parameter	Unit	1	2	3	4	5
SFP	W/m³	0.15	0.19	0.26	0.32	0.43
Fan demand controlled	-	TRUE	TRUE	TRUE	TRUE	TRUE
Specific power of system pumps	W/kW	7.5	15	30.0	45	60

2.2.3.3.3 Central system | Surface distribution

Parameter	Unit	1	2	3	4	5
SFP	W/m³	*No airflow*				
Fan demand controlled	-	*No airflow*				
Specific power of system pumps	W/kW	22.5	45.0	90.0	135.0	180.0

2.2.4 Mechanical ventilation

The final energy demand for ventilation purposes is determined as:

$$q_{vent} = V_{vent} * SFP$$

With the specific fan power (SFP) set to 0.6 W/m³ and the volume of the airflow V_{vent}.

The volume is determined as the total air volume within the building (living area times room height) times the air-exchange rate *AER* [1/h] as given in the input:

$$V_{vent} = AER_{mech} * A_{living} * h_{room}$$

The **heat recovery** rate has no influence on the ventilation volume, but the heat losses caused by air-exchange. With the following formula the general heat losses through ventilation are described. Here, the percentage of heat recovery reduces the ventilation heat losses by reducing the air-exchange rate of the mechanical ventilation with the factor: 1-HR_{mech}.

$$Q_{vent} = \rho_{air} * c_{air} * V_{vent} * (AER_{mech} * (1 - HR_{mech}) + AER_{infiltration} + AER_{free})$$

with HR_{mech} as heat recovery rate of the mechanical ventilation [0,1], AER as air-exchange rates and the density and specific heat capacity of air ρ_{air} / c_{air}.

Note, that a constant air-exchange and therefore heat loss (depending on the outside temperature) is modelled.

2.2.5 Photovoltaic

The electricity generation by the installed Photovoltaic (PV) capacity is calculated as:

$$q_{PV} = P_{PV} * \left(G_h - \left(G_h * 0.005 * \left(\frac{G_h}{25}\right)\right)\right)$$

with the installed capacity P_{pv}, the global radiation on the horizontal G_h and the reference temperature of 25°C (standard conditions PV panel specification).

2.2.6 Lighting

The different lighting technologies are assumed to have the following specifications:

Lighting Technology	Lumen/W	Lumen per Lamp
Linear fluorescent lamps (LFL)	58	1,000
Compact fluorescent lamps (CFL)	60	1,000
Halogen lamps	25	1,000
Classical incandescent lamps	16	800
LED (Light emitting diode lamps)	100	1,000

The necessary lighting is indicated in the following table per building type.

Building Type	Lumen/m²
SFH (Single family house)	300
MFH (Multi family house/Apartment block)	300
Office building	500
Educational building	500
Retail / Trade	500
Hospital	500

The necessary lighting electricity demand is calculated as:

$$Q_{light} = q_{light} * z(t) * \frac{A_{use}}{p_{light}}$$

with q_{light} the specific light demand per building type [Lumen/m²], A_{use} the conditioned area and p_{light} the specific lighting power [Lumen/W]. This is multiplied by a time depending factor z(t), which reflects the standard profile [0, 1], depending on the building type, as displayed in the following diagram.

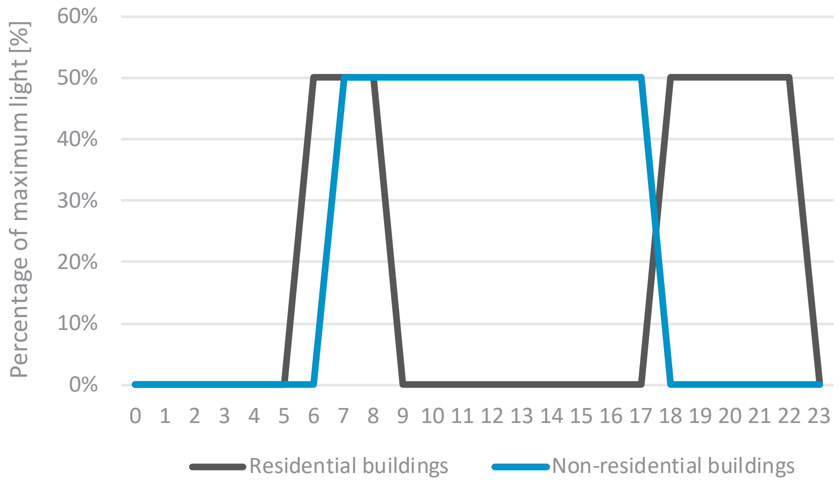

Figure 6: Lighting profile of residential and non-residential buildings

2.3 Additional

2.3.1 Primary energy factors

Table 7: Primary energy factors according to energy carrier

Country	Electricity	Gas	LPG	Kerosene	Oil
Egypt	2.1	1.0	1.0	1.0	1.0
Jordan	2.1	1.0	1.0	1.0	1.0
Lebanon	2.515	1.0	1.0	1.0	1.0

2.3.2 GHG / CO_2-eq emission

Typically, greenhouse gas emissions are reported in units of carbon dioxide (CO_2) equivalent. Gases are converted to CO_2-eq by multiplying by their global warming potential (GWP), compared to the GWP of CO_2. Therefore, CO_2 has a GWP of 1, while N_2O has a GWP of 298. Gives an overview of some common greenhouse gases and their GWP. The resulting CO_2-eq emission for the used energy carrier are listed in Table 8. Not considered are emissions that are not directly related to combustion or heat / cool generation process, namely transport, refinery and mining of the energy carrier.

Table 8: CO2-eq emission according to energy carrier

Country	Electricity	Gas	LPG	Kerosene	Oil
	gCO_2-eq/kWh	gCO_2-eq/kWh	gCO_2-eq/kWh	gCO_2-eq/kWh	gCO_2-eq/kWh
Egypt	679.0	209.9	236.2	260.4	283.7

Jordan	679.0	209.9	236.2	260.4	283.7
Lebanon	650.0	209.9	236.2	260.4	283.7

Table 9: Global warming potential of selected gases

Molecule	Global warming potential
CO_2	1
CH_4	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-41	92
HFC-125	3,500
HFC-134	1,100
HFC-134a	1,430
SF_6	22,800
NF_3	17,200
CF_4	7,390
C_2F_6	12,200
C_3F_8	8,830
C_4F_8	10,300
C_4F_{10}	8,860
C_5F_{12}	9,160
C_6F_{14}	9,300

2.4 Global cost

This section will describe how the cost are calculated and which assumptions are in the underlying data base. *(to come till December '20)*

2.4.1 Envelope

The calculation of the envelope cost considers the insulation of roof, façade and surface, the windows and cost to increase the general airtightness of the building's envelope.

To determine the cost for insulation, first it's checked if the given u-value of the envelope element is better than the baseline (which results from the baseline buildings, see chapter 3.0). If this not the case, there are no additional energy efficiency related cost applied for this element. If the u-value is better than the baseline case, it is assumed additional insulation has been added to the envelope element. The necessary additional centimeters of insulation are calculated to improve the baseline's u-value from the baseline to the given u-value. The additional material results in the envelope cost for the element. The reference values depend on the country, region and type of building and are listed in Table 2.

2.4.1.1 External walls, roof and floor

As described initially to this section, the u-value of the entered project is compared to the baseline's u-value for each element. If the u-value is lower (= higher quality), the additional insulation material thickness is calculated as follows:

Based on the formula to calculate the resulting u-value of multiple material layers, the necessary u-value of the added insulation layer is calculated as:

$$U_{insulation} = \frac{1}{\frac{1}{U_{project}} - \frac{1}{U_{refBuild}}}$$

With the u-value of the insulation layer, the thickness can be calculated with:

$$d_{insulation} = \frac{\lambda}{U_{insulation}}$$

Lambda (specific heat coefficient) is assumed to be $\lambda = 0.035$ W/m²K, a typical value for insulation material, such as glass wool or polystyrene.

The cost data base has specific cost per centimeter insulation material added, hence the resulting investment cost are:

$$Cost_{element} = d_{insulation} * price_{insulation}$$

With the prices listed in the

Element	Egypt	Jordan	Lebanon	Others
	EUR/m²	EUR/m²	EUR/m²	EUR/m²
Wall	1.0	2.5	3.0	*tbd*
Roof	1.0	2.5	3.0	*tbd*
Floor	1.0	2.5	3.0	*tbd*

2.4.1.2 Windows

The data collection in the three countries provided an adequate overview of the market prices for windows, depending on their u-value, as shown in Table 7. The tool offers a wide variety of windows. To derive the specific cost, the values in the table were interpolated. Additionally, windows with solar glazing are assumed to cost an additional 30 EUR/m², independent from the u-value. The complete cost table of all selectable windows in each country can be found in A.1.1.

Table 10: Window cost overview, according to u-values

U-Value	Egypt	Jordan	Lebanon	Reference
W/(m²K)	EUR/m²	EUR/m²	EUR/m²	EUR/m²
5.7	52.0	64.0	113.6	*tbd*
2.9	75.0	89.6	136.4	*tbd*
2.0	116.0	128.0	150.0	*tbd*
1.1	155.0	153.0	163.6	*tbd*
0.9	170.0	200.0	181.8	*tbd*

3.0 Baseline buildings

Baseline buildings are currently only available for Egypt, Jordan and Lebanon.

The data for the baseline buildings was collected in 2020 and reflects only real constructions (not older than 3 years) and there are at least 5 real cases used to form one baseline for a building type.

3.1 Comparison of the entered project with the baseline

By default, every project is compared to its according baseline (relevant for Egypt, Jordan and Lebanon). If the project is not located in one of these countries, XXX is taken as reference. A new created project starts always with the according baseline building as default values in the input tab. This means, if no inputs are changed, the baseline building is calculated.

When the specific project is calculated, the default values must be changed. These effects the baseline building in different ways. Some elements need to be adapted to the project building to guarantee a valuable reference case, whereas others need to stay fixed so the improvements in the specific projects are considered.

The parameters of the baseline building that are not changed:

- Envelope
    - U-values
    - Windows
    - Shading
- Air-change rate
    - Infiltration
- HVAC-System
    - Systems that are installed in the baseline building. E.g. if the baseline building has a heater installed by default, this system (e.g. oil boiler) will stay fixed. If, however, no space heating system is installed in the baseline building, the baseline to compare will have the same system as the entered project.

The parameters of the baseline building that are adapted to the entered project:

- Envelope
    - Geometry (wall area, net floor area, etc.)
- Air-change rate
    - Free / mechanical ventilation
- HVAC Systems
    - Systems that are not installed in the baseline building.
- Operational parameters
    - Internal heat gains
    - Other electricity consumption
    - Operational temperatures
    - Night set back

o

3.2 Configuration of baseline buildings

The detailed configuration of the building that is selected to compare it with the currently loaded project is shown by the default values in the input tab (they reflect exactly the baseline building) or in the BUILD_ME database (link). Table 7 contains for example the specification of the baseline buildings envelope.

Table 11: Baseline u-values

Elements	**Wall**	**Roof**	**Floor**	**Window**
Units	**W/m²K**	**W/m²K**	**W/m²K**	**W/m²K**
Jordan				
SFH (Single family house)	0.7	0.8	2.2	2
MFH (Multi family house/Apartment block)	1	1.3	2.2	2.9
Office building	0.9	0.4	2	2
Educational building	0.76	0.68	1.2	2
Retail / Trade	0.9	0.8	2.2	1.4
Hospital	1.22	3.2	2.2	2.2
Egypt				
SFH (Single family house)	2.2	0.96	2.3	5.7
MFH (Multi family house/Apartment block)	2.4	0.76	2.2	5.7
Office building	2.4	0.76	2.2	2.9
Educational building	2.4	0.96	2.58	2.9
Retail / Trade	2	0.7	2.5	2.4
Hospital	2	0.48	3.01	2.35
Lebanon				
SFH (Single family house)	0.7	0.8	2.2	2
MFH (Multi family house/Apartment block)	1	1.3	2.2	2.9
Office building	0.9	0.4	2	2
Educational building	0.76	0.68	1.2	2
Retail / Trade	0.9	0.8	2.2	1.4
Hospital	1.22	3.2	2.2	2.2

4.0 Appendix - Investment cost

4.1 Envelope

4.1.1 Windows

Window	Egypt	Jordan	Lebanon	Reference
-	EUR/m²	EUR/m²	EUR/m²	EUR/m²
Single glass (U:5.7 | G: 0.85 | 4 mm)	52.0	64.0	113.6	*tbd*
Double glass - air (U: 3.0 | G: 0.7 | 4-12-4 mm)	79.6	88.7	135.6	*tbd*
Double glass - air (U: 2.9 | G: 0.7 | 4-16-4 mm)	84.1	89.6	136.4	*tbd*
Double glass - air (U: 2.8 | G: 0.7 | 4-20-4 mm)	88.7	93.9	137.9	*tbd*
Double glass - Argon (U: 2.6 | G: 0.7 | 4-12-4 mm)	88.7	102.4	140.9	*tbd*
Double glass - Argon (U: 2.5 | G: 0.7 | 4-16-4 mm)	93.2	106.7	142.4	*tbd*
Double glass - Argon (U: 2.4 | G: 0.7 | 4-20-4 mm)	97.8	110.9	144.0	*tbd*
Double glass - lowE - air (U: 1.5 | G: 0.7 | 4-12-4 mm)	124.7	141.9	157.6	*tbd*
Double glass - lowE - air (U: 1.4 | G: 0.7 | 4-16-4 mm)	133.3	144.7	159.1	*tbd*
Double glass - lowE - air (U: 1.3 | G: 0.7 | 4-20-4 mm)	137.7	147.4	160.6	*tbd*
Double glass - lowE - Argon (U: 1.3 | G: 0.7 | 4-12-4 mm)	137.7	147.4	160.6	*tbd*
Double glass - lowE - Argon (U: 1.2 | G: 0.7 | 4-16-4 mm)	142.0	150.2	162.1	*tbd*
Double glass - lowE - Argon (U: 1.1 | G: 0.7 | 4-20-4 mm)	142.0	153.0	163.6	*tbd*
Double glass - solar - lowE - air (U: 1.5 | G: 0.3 | 4-12-4 mm)	184.7	171.9	187.6	*tbd*
Double glass - solar - lowE - air (U: 1.4 | G: 0.3 | 4-16-4 mm)	193.3	174.7	189.1	*tbd*
Double glass - solar - lowE - air (U: 1.3 | G: 0.3 | 4-20-4 mm)	197.7	177.4	190.6	*tbd*
Double glass - solar - lowE - Argon (U: 1.3 | G: 0.3 | 4-12-4 mm)	197.7	177.4	190.6	*tbd*
Double glass - solar - lowE - Argon (U: 1.2 | G: 0.3 | 4-16-4 mm)	202.0	180.2	192.1	*tbd*
Double glass - solar - lowE - Argon (U: 1.1 | G: 0.3 | 4-20-4 mm)	202.0	183.0	193.6	*tbd*
Triple glass - lowE - air (U: 0.9 | G: 0.55 | 4-12-4-12-4 mm)	150.7	200.0	181.8	*tbd*
Triple glass - lowE - air (U: 0.85 | G: 0.55 | 4-16-4-16-4 mm)	162.5	211.8	186.4	*tbd*
Triple glass - lowE - air (U: 0.8 | G: 0.55 | 4-20-4-20-4 mm)	170.0	223.5	190.9	*tbd*
Triple glass - lowE - Argon (U: 0.7 | G: 0.55 | 4-12-4-12-4 mm)	162.5	247.0	200.0	*tbd*

Triple glass - lowE - Argon (U: 0.65 | G: 0.55 | 4-16-4-16-4 mm)	170.0	258.8	204.6	*tbd*
Triple glass - lowE - Argon (U: 0.6 | G: 0.55 | 4-20-4-20-4 mm)	170.0	270.5	209.1	*tbd*
Triple glass - solar - lowE - air (U: 0.9 | G: 0.25 | 4-12-4-12-4 mm)	210.7	230.0	211.8	*tbd*
Triple glass - solar - lowE - air (U: 0.85 | G: 0.25 | 4-16-4-16-4 mm)	222.5	241.8	216.4	*tbd*
Triple glass - solar - lowE - air (U: 0.8 | G: 0.25 | 4-20-4-20-4 mm)	230.0	253.5	220.9	*tbd*
Triple glass - solar - lowE - Argon (U: 0.7 | G: 0.25 | 4-12-4-12-4 mm)	222.5	277.0	230.0	*tbd*
Triple glass - solar - lowE - Argon (U: 0.65 | G: 0.25 | 4-16-4-16-4 mm)	230.0	288.8	234.6	*tbd*
Triple glass - solar - lowE - Argon (U: 0.6 | G: 0.25 | 4-20-4-20-4 mm)	230.0	300.5	239.1	*tbd*

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