CONCERTO Premium

Workpackage 1/3

Indicator Guide

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1. Annex A: CONCERTO Premium Indicator Guide

Covered aspects (Overview):

Level of aggregation	Energy flows	Indicators	Comments
Building-integrated energy supply units	X	X	-
Building-integrated energy demand units	X	-	-
Individual buildings	X	X	-
Set of buildings	X	X	-
Large-scale units	X	X	-
Set of large-scale units	X	X	Production based point of view
Set of large-scale units supplying a set of buildings	X	-	Consumption based point of view
CONCERTO area	-	X	Indicators that are not based on energy flows
European/national/regiona l level	-	-	Covered by guide for up-scaling

Indicator dimension	Mathematical description (MD)	Textual description (TD)
Environmental	X	X
Economic	X	X
Technical	X	X
Implementation process	X	X
Social	-	-

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1.1 Overview of the document

1.1.1 Objective

The **objective** of this document is to

- give a clear mathematical description of the CONCERTO Premium indicators (cf. chapters 1.3, 1.4, 1.5, 1.6)
- identify the data requirements of the CONCERTO Premium indicators (cf. chapter 1.7)
- create a link between these data requirements and the CONCERTO Premium data collection sheets (cf. chapter 1.7)
- enable the implementation of the calculation procedures for the CONCERTO Premium indicators based on the CONCERTO Premium database
- provide an indicator pool for the assessment criteria
- improve the understanding of the calculation procedures and the indicators by providing selected examples
- give required definitions
    - Typologies of elements in the CONCERTO area (cf. chapter 1.2)
    - Energy flows in the CONCERTO area (cf. Chapter 1.2.2)
    - Typologies of energy carriers, areas of application, buildings and energy supply units (cf. 1.2.1)
    - Production and consumption of electricity (cf. 1.2.1 and 1.2.2)
    - Temporal resolution (cf. 1.2.1)
    - Allocation approach in case of cogeneration or polygeneration (cf. 1.2.1)
    - Primary energy and emission factors (cf. 1.2.1)
    - Balancing energy, system boundaries (cf. 1.2.1)
    - Build, operating and combined margin method (cf. 1.2.1)
    - Priorities: Local vs. national data (cf. 1.2.1)
    - District heating/cooling (cf. 1.2.1)
    - Calculation of climate corrected energy ouput and consumption (cf. 1.2.1)
    - Reference buildings and reference energy supply units (cf. chapter 1.2.3)

The objective of this document is **not** to

- discuss and interpret the CONCERTO Premium indicators
- cover the social CONCERTO Premium indicators

1.1.2 Structure of the document

The core content of this document is the mathematical description of the CONCERTO Premium indicators. This description requires basics that are described in chapter 1.2.

The indicators can be calculated for different aggregation levels (e.g. for individual buildings, sets of buildings, energy supply units). Therefore, after a definition of the "CONCERTO area", its elements had to be structured and named (cf. chapter 1.2). The majority of indicators is based on the energy flows between these elements. Therefore, the energy flows are described in chapter 1.2.2. For describing the energy flows a typology of energy carriers and sources as well as several balancing principles and conventions are required and described in chapter 1.2.1 (e.g. temporal resolution, production and consumption of electricity). Other balancing principles, conventions and typologies that concern the indicator calculation are included in chapter 1.2.1 as well (e.g. allocation approach in case of cogeneration or polygeneration). Reference objects are described in chapter 1.2.3 since several indicators require reference objects (e.g. the reduction of greenhouse gas emissions).

Chapters 1.3, 1.4, 1.5 and 1.6 encompass the mathematical description of the environmental, economic, technical and planning & implementation process indicators.
Often, a formula describing an indicator requires other indicators that have been described in this document. The indicator descriptions are ordered in such a way that a formula predominantly references on other indicators that have been described before. Generally, each indicator is described at least (if applicable) for four aggregation levels, i.e. (1) individual building, (2) set of buildings, (3) building-integrated and large-scale energy supply units, and (4) set of large-scale units. In some cases the level (5) CONCERTO area is added. The description of the same indicator for several aggregation levels implies a lengthy but applicable document.

The variables required for the indicator calculation that are not calculated with formulas from this document are assembled in chapter 1.7. These required data are linked to the CONCERTO Premium data collection sheets. While in some cases an unambiguous link can be specified, in other cases only an area of cells can be specified because of the "flexibility" of the CONCERTO Premium data collection sheets.

Chapter 1.8 encompasses exemplary data for the exemplary calculation of selected indicators in chapters 1.3, 1.4, 1.5 and 1.6. This data is a mixture of data from the "Scharnhauser Park" (part of the POLYCITY CONCERTO project) and assumptions.

Chapter 1.9 contains exemplary emission factors and primary energy factors for several countries.

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1.2 Basics

The majority of indicators is based on the energy flows entering or leaving the object of interest. The objects of interest can be clustered. The object clustering is shown in Table 1.

Table 1: Clustering of objects in the CONCERTO area and overview of corresponding energy flows and indicators covered by this guide; "X" means covered by this guide, "(X)" means partially covered by this guide, "-" means not covered by this guide

Object of interest		Covered by this guide	
		Energy flows	Indicators
Component of a building		X	X/-
	Building-integrated energy supply unit	X	X
	Building-integrated energy demand unit	X	-
Individual building		X	X
Set of buildings		X	X
Large-scale unit		X	(X)
	Large-scale energy supply unit	X	X
	Large-scale spatial transformation unit	X	-
	Large-scale temporal transformation unit	X	-
	Building-integrated energy supply unit producing electricity	X	X
Set of large-scale units		X	(X)
Set of large-scale units supplying a set of buildings		X	-
CONCERTO area		-	X

The indicators are described – if applicable - for

- Individual building
- Set of buildings
- Large-scale or building-integrated energy supply unit
- Set of large-scale units
- CONCERTO area

Approach for the identification and declaration of indicators: The indicators that have been proposed by CONCERTO Premium are based on the three pillars of sustainability, i.e. the economic, the environmental and the social dimensions. The process of indicator identification and declaration aims at covering each dimension. During this process, indicators used in literature and by CONCERTO Plus have been screened in a first step. In a second step, the calculability and adequateness of these

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indicators had to be checked against the maximum availability of data within CONCERTO projects and the focus of the CONCERTO initiative. Usually, the discrepancy between available and required data is a decisive factor in indicator selection. As the social dimension was not mentioned within the proposal of CONCERTO Premium, but favored by the European Commission, a concentrated version of the social dimension from the CONCERTO Plus Socio-Economic-Matrix has been adapted. In a third step, especially the economic dimension – that was almost excluded by CONCERTO Plus – has been expanded according to the focus of the CONCERTO Premium proposal. Especially, within this dimension the point of view of different stakeholders has to be taken into account.

Finally, the three dimensions of sustainability have been extended by technical and implementation process dimensions. The technical dimension has been included since monitoring is another main pillar of the CONCERTO Premium proposal. The planning implementation process has been considered because of the unique neighborhood-oriented implementation within the CONCERTO initiative. Throughout the whole process of indicator identification and declaration, a stakeholder-specific approach was chosen according to the CONCERTO Premium proposal. This approach caused the enlargement of the economic dimension and the extension of the three pillars of sustainability by technical and implementation process indicators.

Definition: A CONCERTO area is a "clearly defined geographical area[s] or zone[s] (citie[s], town[s], rural area[s] or island[s])" (European Commission o. J.)

In a formal model (cf. Figure 1) a **CONCERTO area A** can be defined as a set encompassing **each building i**, **each large-scale energy supply unit** s_{large}, **each large-scale spatial transformation unit** $s_{spatial}$ (electricity grids, gas grids, district heating networks, district cooling networks as well as the transportation infrastructure of energy carriers like oil, coal etc.), and **each large-scale temporal transformation unit** $s_{temporal}$ (storages) located in the CONCERTO area. The corresponding sets of buildings, large-scale energy supply units, large-scale spatial transformation units, and large-scale temporal transformation units located in the CONCERTO area are denoted by I_A, $S_{A,large}$, $S_{A,spatial}$, and $S_{A,temporal}$.

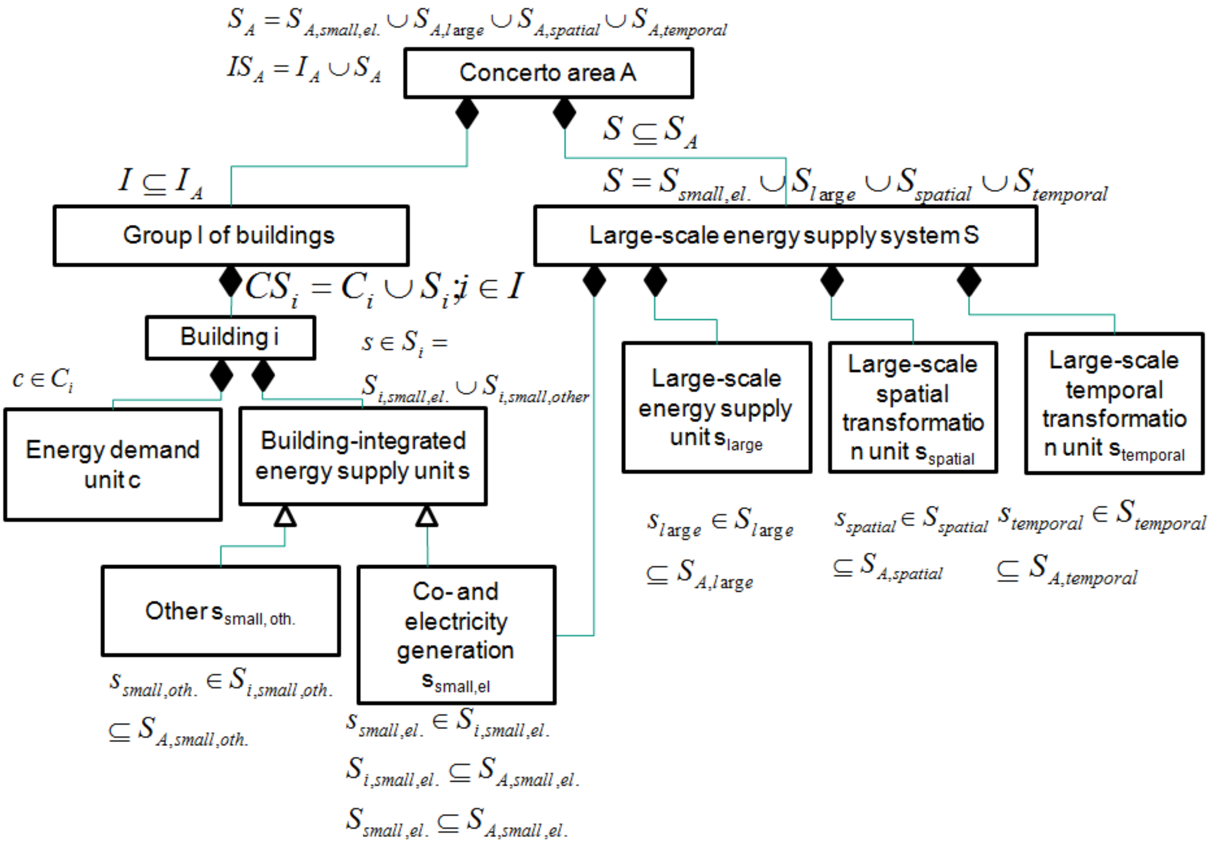

Figure 1: Interdependence of different aggregation levels

A **building i** is element of the set I_A of buildings, i.e. $i \in I_A$. For each building i, a set $CS_i = C_i \cup S_i$ exists that is a conjunction of two sets of building components: a set C_i of **energy demand units** (thermal energy: walls, windows, roofs, floors, ventilation; electrical appliances: lighting, refrigerator, etc.) $c \in C_i$ and a set S_i of **(building-integrated) energy supply units** (heating/cooling/electricity production system) $s \in S_i$. The set $S_i = S_{i,small,el.} \cup S_{i,small,other}$ is a conjunction of set $S_{i,small,el.}$ of (building-integrated) cogeneration and electricity generation energy supply units $s_{small,el.} \in S_{i,small,el.}$ and set $S_{i,small,other}$ of other (building-integrated) energy supply units $s_{small,oth.} \in S_{i,small,oth.}$. The set of all (building-integrated) cogeneration and electricity generation energy supply units located in the CONCERTO area is denoted by $S_{A,small,el.}$, the corresponding set of other (building-integrated) energy supply units by $S_{A,small,other}$.

The **energy supply system** of the CONCERTO area A is denoted by $S_A = S_{A,small,el.} \cup S_{A,large} \cup S_{A,spatial} \cup S_{A,temporal}$. Thus, the **CONCERTO area A** can be formally defined as $IS_A = I_A \cup S_A$.

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Furthermore, there are **subsets of the overall sets of the CONCERTO area**, i.e. a set $I \subseteq I_A$ of buildings, a set $S \subseteq S_A$ of large-scale units $s \in S$, a set $S_{large} \subseteq S_{A,large}$ of large-scale energy supply units $s_{large} \in S_{large}$, a set $S_{spatial} \subseteq S_{A,spatial}$ of large-scale spatial transformation units $s_{spatial} \in S_{spatial}$, a set $S_{temporal} \subseteq S_{A,temporal}$ of large-scale temporal transformation units $s_{temporal} \in S_{temporal}$, a set $S_{small,el.} \subseteq S_{A,small,el.}$ of (building-integrated) cogeneration and electricity generation energy supply units $s_{small,el.} \in S_{small,el.}$, and a set $S_{small,other} \subseteq S_{A,small,other}$ of other (building-integrated) energy supply units $s_{small,other} \in S_{small,other}$. These subsets are introduced here since in chapters 1.2.2, 1.3, 1.4, 1.5, and 1.6 several energy flows and indicators are formally defined for these subsets.

1.2.1 Conventions

1.2.1.1 Typology of energy carriers and sources (EC)

Firstly, the **considered energy** corresponds to the net calorific value (lower heating value) for combustibles and the totally transferred energy in case of electricity and district heat (at the delivery station) or cold. The energy flows are distinguished by a combination of the **location, energy carrier and source (EC). Three locations are distinguished (cf. Table 2).** Several formulas in the following chapters reference to this typology in order to increase the transparency. For programming purposes the differentiation in the locations could be neglected.

Table 2: Typology of energy carriers

Energy carrier or source				Location		
Level 1		Level 2		Entry of CONCERTO area or location of depletion within the CONCERTO area	Entry of a building or export from CONCERTO area	Input or Output of a specific large-scale energy supply plant, a distribution unit or a building-integrated energy supply (electricity, heat, cold etc.) or demand unit
1	Oil	a	Light oil <10 mg S/kg	C1a	B1a	IO1a
		b	Light oil >10 mg S/kg	C1b	B1b	IO1b
		c	Heavy oil	C1c	B1c	IO1c
2	Gas	a	Domestic gas – grid-bound	C2a	B2a	IO2a
		b	Domestic gas – from gas tank	C2b	B2b	IO2b
		c	LPG (liquefied petroleum gas)	C2c	B2c	IO2c
3	Coal	a	Hard coal	C3a	B3a	IO3a
		b	Lignite	C3b	B3b	IO3b
4	Biomass	a	Wood Chips, 30% humidity	C4a	B4a	IO4a
		b	Pellets	C4b	B4b	IO4b
		c	Biowaste	C4c	B4c	IO4c
		d	Energy crop	C4d	B4d	IO4d
		e	Biogas	C4e	B4e	IO4e
		f	Local specification	C4f	B4f	IO4f
5	Direct thermal energy	a	Heat/district heat	C5a	B5a	IO5a
		b	Cold/district cold	C5b	B5b	IO5b
6	Other	a	Solar radiation thermal	C6a	B6a	IO6a

	renewables: heat		(heat/cold that is absorbed) [sun]			
		b	Ambient air heat	C6b	B6b	IO6b
		c	Geothermal heat	C6c	B6c	IO6c
		d	Ground water heat	C6d	B6d	IO6d
		e	Surface water heat	C6e	B6e	IO6e
7	Other renewables: electricity	a	Solar radiation electric (electricity produced) [sun]	C7a	B7a	IO7a
		b	Wind energy (electricity produced)	C7b	B7b	IO7b
		c	Potential energy (electricity produced) [surface water]	C7c	B7c	IO7c
8	Electricity	a	Electricity	C8a	B8a (In)	IO8a
		b	'Green' electricity	C8b	B8b (In)	IO8b
9	Electricity for export out of the CONCERTO area	a	Electricity for export (large-scale)	-	B9a (Out)	-
		b	Electricity for export (building-integrated)	-	B9b (Out)	-
10	Losses	a		-	-	IO10

1.2.1.2 Typology of application areas (AA)

In analogy to EC applications areas (AA) are differentiated regarding buildings:

- (AA1) Space heating
- (AA2) Domestic water heating
- (AA3) Space cooling
- (AA4) Electrical appliances (excl. space cooling/heating, incl. lighting, household appliances, auxiliary energy)
    - (AA4.1) Lighting
    - (AA4.2) Household appliances, computer etc. (excl. space cooling/heating/hot water)
    - (AA4.3) Auxiliary energy (for heating, ventilation and air conditioning)
    - (AA4.4) Other auxiliary energy
- (AA5) Electricity export (from building or area)
- (AA6, AA7, AA8,...) Combinations of 1-5

1.2.1.3 Building types [i]

The following building types are differentiated in this document:

- (RB) Residential building
    - (RB1) Detached one-family house
    - (RB2) Semi-detached one-family house
    - (RB3) Apartment building
- (NRB) Non-residential building
    - (NRB1) Public building
    - (NRB2) Office building
    - (NRB3) Department store
    - (NRB4) Industrial building

  - (NRB5) Building for education and research
  - (NRB6) Building for cultural purposes
  - (NRB7) Building for health care
  - (NRB8) Building for sport purposes
  - (NRB9) Others

1.2.1.4 Types of energy supply units [s]

The following types of energy supply units are differentiated in this document:

- (LS) Large-scale energy systems
  - (LS1) Heating
    - (LS1-1) Heating plant using biomass
    - (LS1-2) Heating plant using geothermal source (with heat pump)
    - (LS1-3) Heating energy from geothermal source (without heat pump)
    - (LS1-4) Solar thermal collectors
  - (LS2) Cogeneration
    - (LS2-1) Combined Heat and Power (CHP) plant
  - (LS3) Electricity
    - (LS3-1) Photovoltaics
    - (LS3-2) Wind power plants
    - (LS3-3) Hydro power plants
  - (LS4) Cooling
    - (LS4-1) Cooling energy from geothermal source
  - (LS5) Spatial transformation - grids/networks
    - (LS5-1) District heating network
    - (LS5-2) District cooling network
  - (LS6) Temporal transformation – storages
    - (LS6-1) Electrical storages
    - (LS6-2) Thermal storages
  - (LS7) Biogas plant
    - (LS7-1) Biogas plant
  - (LS8) Others
- (BI) Building-integrated energy systems
  - (BI1) Space heating and domestic hot water generation
    - (BI1-1) Boiler
    - (BI1-2) Condensing boiler
    - (BI1-3) District heating (DH) transfer station
    - (BI1-5) Compression heat pump
    - (BI1-6) Absorption heat pump

    - (BI1-7) Adsorption heat pump
    - (BI1-8) Solar thermal collectors
    - (BI1-9) Solar air collectors
    - (BI1-10) Electrical heating system
    - (BI1-11) Night-storage heater
    - (BI1-12) Stove
    - (BI1-13) Continuous flow water heater
  - (BI2) Cooling
    - (BI2-1) Compression refrigeration machine
    - (BI2-2) Adsorption chiller
    - (BI2-3) Absorption chiller
    - (BI2-4) District cooling (DC) transfer station
  - (BI3) Electricity
    - (BI3-1) Photovoltaic
    - (BI3-2) Connection to electricity grid
  - (BI4) Cogeneration
    - (BI4-1) Micro CHP
    - (BI4-2) Reversible heat pump for heating and cooling
    - (BI4-3) Conventional HVAC system
  - (BI5) Others

1.2.1.5 Types of energy supply units from a demand side perspective [s]*

The following types of energy supply units are differentiated in this document from a demand-side perspective with respect to their main functionality:

  - (DS1) Space heating
  - (DS2) Domestic hot water generation
  - (DS3) Cooling
  - (DS4) Electricity

1.2.1.6 Typology of (emitted) materials M

The following (emitted) materials are differentiated in this document:

- (M1) CO_2 equivalent
- (M2) CO_2
- (M3) SO_2 equivalent
- (M4) SO_2
- (M5) NO_x
- (M6) PM_{10}
- (M7) $PM_{2.5}$

1.2.1.7 Temporal resolution (time index t)

A **temporal resolution of one year** is chosen. Energy flows correspond to the real energy consumption or to the calculated energy demand. As possible extension data with a higher temporal resolution can be used. In several cases no time index is required. Usually, a time index is required for the energy consumption and not for the energy demand.

1.2.1.8 Allocation approach in case of cogeneration or polygeneration

In case of cogeneration or polygeneration, **a split up of the inputs $In_{EC,s,t}$ in regard to the outputs $Out_{EC',s,t}$ has to be assumed (cf. chapter 1.2.2).** Different approaches exist. CONCERTO Premium uses the **exergy-based approach**, i.e. the input is matched with the output proportionally to the exergy of the output.

Example: Gas CHP (Combined Heat and Power) plant excl. distribution

- Input: 90 MWh/a domestic gas
- Output 1: 55 MWh/a heat at 100°C, with ambient temperature of 20°C → (1-[273,15+20]/[273,15+100])*55 = 0,21*55 = 12 MWh/a exergy
- Output 2: 25 MWh/a electricity → 25 MWh/a exergy
- Input attributable to output 1: 12/(12+25)*90=29 MWh/a domestic gas
- Input attributable to output 2: 25/37*90=61 MWh/a domestic gas

1.2.1.9 Primary energy factors

The approach of CONCERTO Premium is based on flexibility. Therefore, several primary energy factors can be selected and interpreted. They differ with respect to:

- The types of energy
    - Renewable primary energy
    - Non-renewable primary energy
- The covered parts of the supply chain
    - Cumulative primary energy demand until the initial operation of an energy supply unit/building excluding its use (*)
    - Cumulative primary energy demand for energy carriers (*)

(*) Incl. construction: For the upstream chains material requirements for non-energy-related use are accounted for.

1.2.1.10 Emission factors

Several emission factors can be selected and interpreted. They differ with respect to:

- The emitted materials
    - CO_2 equivalents

  - CO_2
  - SO_2 equivalents
  - SO_2
  - NO_x
  - PM_{10}
  - $PM_{2.5}$
- The covered parts of the supply chain
  - Cumulative emissions for energy carriers excluding their use (*)
  - Cumulative emissions until the initial operation of an energy supply unit/building excluding its use (*)
  - Direct emission factors of energy carriers in case of combustion (use)

(*) Incl. construction: For the upstream chains material requirements for non-energy-related use are accounted for.

1.2.1.11 Balancing energy, system boundaries

Renewable energy is included in the (final) energy demand/consumption of a building/large-scale energy supply unit. The metering points are specified in the CONCERTO Premium Technical Monitoring Guide.

The following balancing approach for **electricity** import and export is used:

Consumption mix = national mix

The following balancing approach for **heat/cold** import and export is used:

Consumption mix = min{1,total production/total consumption} * production mix + max{0,1-total production/total consumption} * national mix

In the base case, it is assumed that the **electricity** produced within a building or the CONCERTO area is **used NEITHER within the producing building** (**AA=electricity export**) **NOR within the CONCERTO area (EC= (B9) electricity for export out of the CONCERTO area).** The building-integrated production (B9b) is fed into the local grid and is regarded as part of the large-scale energy supply system. The energy from the large-scale energy supply system is exported from the CONCERTO area. The imported energy corresponds to the national or the European electricity mix. For some indicators other assumptions are necessary and described in the corresponding chapter.

In case of **electricity** the analysis is **amended by** the following approach

Consumption mix = min{1,total production/total consumption} * production mix + max{0,1-total production/total consumption} * national mix

With respect to the energy supply system, there exist two points of view: consumption based and production based. The consumption based energy supply system encompasses (if the data is available) the pure transport of combustibles (e.g. oil) from the border of the CONCERTO area to the buildings as well. The production based energy supply system contains only the distribution of energy if a corresponding energy supply plant exists within the CONCERTO area.

1.2.1.12 Build, operating and combined margin method

In case of electricity production the following approaches are applied and compared (cf. chapter 1.2.3):

- Build margin (use of a reference technique)
- Operating margin (use of national mix)

1.2.1.13 Priorities: Local data vs. national data

Requisite for the utilization of data is the comparability. As long as the comparaibility of data (e.g. same approach for primary energy factor and emission factor calculation) can be ensured and local data is available, local data is preferred. If not, national data has to be used.

1.2.1.14 District heating/cooling

In case of district heating/cooling primary energy factors and emission factors are calculated using the energy flows and non-district-heating/cooling primary energy and emission factors. The conventions described above are used in order to perform these calculations.

1.2.1.15 Calculation of climate-corrected energy output and consumption

1.2.1.15.1 *Scope*

In CONCERTO heating and cooling energy in buildings as well as the energy output by solar systems (thermal collectors or photovoltaics) play an important role and one objective is to compare them by the calculation of indicators, described in this document. The CONCERTO sites are dispersed all over Europe and the indicators have to be revised by climate correction to make them directly comparable.

The consumption of heating and cooling energy (final or primary) in buildings is strongly dependent on the climate, primarily on the ambient air temperature. The influence of solar irradiation is secondarily and grows with an increasing share of glazed surface of a building's envelope, but is usually not considered when correcting heating energy consumption. However for comparing the output of solar systems the provided solar irradiation is taken into account.

In the building sector heat is used for heating and preparing domestic hot water. Only the heating part is influenced by the climate so that one has to make sure that the amount contributing to domestic hot water is subtracted first. If the value for domestic hot water is not specified separately, its share can be guessed according to common empirical values.

We will find calculated heating energy (demand) and measured heating energy (consumption) of buildings at the different CONCERTO locations. For normalizing measured values from a certain time period the actual climate data of the location in the same time period has to be available.

An application on calculated energy demand values – usually performed on base of the energy certification standard in every single country – is only sensible if the input climate data is known. And even then it can only be considered as an approximate calculation as in addition the calculation algorithms for building services and building envelope can differ from country to country. For an exact normalized comparison all building parameters would have to be known and used by one standardized algorithm to calculate the building's energy demand.

1.2.1.15.2 *Heating degree days*

For normalizing heating energy consumption in different climate conditions the so-called "heating degree days" (HDD) are used and well established. However, their definition differs and two main algorithms are known: one implementing the building's threshold heating temperature alone, the other one implementing the targeted set temperature of the building additionally.

Both methods calculate the sum of a temperature difference on all days, when the heating has to be turned on (heating day). On non-heating days the temperature difference is not included into the sum.

$$HDD_{t_i/t_{ht}} = \sum_{1}^{z} (t_i - t_a) \; [K * d] \qquad t_a < t_{ht}$$

$HDD_{t_i/t_{ht}}$	Heating degree days for a time period with z heating days (ambient air temperature being below the heat threshold temperature t_{ht})
z	number of heating days in the time period
t_i	inside set temperature of the building
t_a	daily average ambient air temperature

$$HDD_{t_{ht}} = \sum_{1}^{z} (t_{ht} - t_a) \; [K * d] \qquad t_a < t_{ht}$$

HDD_{htt}	Heating degree days for a time period with z heating days (ambient air temperature being below the heat threshold temperature t_{ht})
z	number of heating days in the time period
t_{ht}	heating threshold temperature of the building
t_a	daily average ambient air temperature

When looking at European countries you will find different application of the methodology and with both different threshold and different set temperatures. That hampers a unified calculation. In 1996 the European Commission asked for an assessment of climatic correction methods applied in various member states. Eurostat [1] presented the findings to the Energy Statistics Committee and the Member States in principle approved a common method for heating-temperature correction. The method is described in "Panorama of Energy" [2]. It employs the first described formula and defines 15°C as the heating threshold temperature and 18°C as the heating set temperature. The average daily temperature is defined as the arithmetic mean of the minimum and maximum air temperature of that specific day.

Concerning correction of heating energy consumption within CONCERTO this definition will be adopted.

$$\mathrm{HDD}_{18/15} = \sum_{1}^{z} (18°C - t_a) \; with \; t_a = \frac{t_{min} + t_{max}}{2}$$

Calculation method of heating degree days used in CONCERTO

1.2.1.15.3 *Cooling degree days*

Definition

There is no standardized method for cooling degree days available and Eurostat doesn't propose a procedure either. However, in literature and different projects a method has become commonly accepted. The calculation is analogue to the heating degree-days and as it is applied to air-conditioning systems very often there is no distinction between ambient air temperature and room set temperature. The supply air with a specific set temperature has to be cooled down exactly at the time when the temperature of the ambient air temperature exceeds that value. According to the common use, the base temperature is defined as 18°C (65°F).

$$\mathrm{CDD_{st}} = \sum_{1}^{z} (\, t_a - t_{st} \,) \; [K * d]$$

$\mathrm{CDD_{st}}$	Cooling degree days for a time period with z days when ambient air temperature exceeds the cooling set temperature st (cooling days)
z	number of cooling days in the time period
st	cooling set temperature
t_a	daily average ambient air temperature

$$\mathrm{CDD_{st}} = \sum_{1}^{z} (\, t_a - 18°C \,) \; [K * d]$$

Calculation method of cooling degree days used in CONCERTO

1.2.1.15.4 *Solar Irradiation*

Definition

The total solar irradiation that hits a horizontal surface is called global radiation and it consists of the direct radiation and the diffuse radiation. The diffuse radiation emerges from reflection by clouds and dust or water particles. The unit is W/m^2 for instant radiation power or kWh/m^2 for radiation energy in a time period.

Solar irradiation is a factor that influences the heating energy consumption as well as the ambient temperature, but a standardized normalization method does not exist.

But for the calculation of climate corrected outputs by solar energy systems (solar thermal collectors or photovoltaics) and for their comparison the monthly or annual solar radiation is the appropriate measure.

If comparing systems to each other the output is normalized to one of the systems, when assessing a lot of systems a reference value is chosen according to the approach on heating degree-days.

$$W_{out,system\,A} \quad \text{compared to} \quad W_{out,system\,B} \times \frac{sol\,Irradiation_A}{sol\,Irradiation_B} \; [\mathrm{kWh}]$$

$$W_{out,system\,A} \times \frac{sol\,Irradiation_{ref}}{sol\,Irradiation_A} \quad \text{compared to} \quad W_{out,system\,B} \times \frac{sol\,Irradiation_{ref}}{sol\,Irradiation_B} \; [\mathrm{kWh}]$$

If regarding the performance indicator as division of IN by OUT as described in chapter XY, the correction by actual solar irradiation is already implied.

1.2.1.15.5 *Reference Values*

For making different energy consumption values at various locations comparable a reference value is needed. If comparing two or another small number of objects with each other it is adequate to define one of the objects as a reference. But as in CONCERTO there are 58 sites to be considered on a European level, a neutral reference value should be chosen.

Eurostat describes the method as creating "relative degree-days" (page 154 f. [2]) by dividing actual heating degree days from the observed time period by the long-term average degree-days in a first step and then weighting them by population in a second step.

This is a plausible approach, but due to complexity and due to lack of data it is inapplicable in the scope of CONCERTO. Relative and population-weighted heating degree-days for the EU from the Eurostat report exist only for the years 2000 to 2004. As the majority of CONCERTO projects started after that time period another reference value is defined: within CONCERTO the relative heating degree-days will be calculated by using an arithmetical mean value of the long-term values at the 58 sites.

For comparing values from one single site for different years the method using the long-term reference value from that specific site is sufficient.

Table 3: Procedure when comparing different sites and different time periods

	Same time period	Different time periods
Same location	No correction by climate	Use HDD of one time period or long-term average as reference value
Different locations	Correction by reference climate (average of CONCERTO sites) of the time period	Step 1: Use HDD of one time period or long-term average as reference value Step 2: Correction by reference climate (average of CONCERTO sites) of the chosen time period

For correction by cooling degree-days and by solar irradiation the analog procedure is applied.

1.2.1.15.6 *Data Availability*

Climate data should be measured onsite to achieve most accurate climate correction (see funding requirements of CONCERTO). At least ambient air temperature and solar irradiation should be stored in an hourly interval. If there is no measuring onsite different sources can be found on the Internet where climate data can be extracted, mostly providing temperatures, only few providing solar radiation.

From the website http://www.degreedays.net you can calculate the heating and cooling degree days for many European locations in a time period going back 3 years. The problem is, they are using their own calculation methods and weather stations are located in larger cities. So for not-listed locations you have to chose a station nearby.

Temperatures can also be obtained from the European Climate Assessment & Dataset project. ECA&D was initiated by the ECSN in 1998 and has received financial support from the EUMETNET and the European Commission. The ECA dataset contains series of daily observations at meteorological stations throughout Europe and the Mediterranean from 1950 on. It is freely available for non-commercial and educational research and data can be calculated for every location by interpolating real climate data according to an approved scientific approach. The website is found at http://eca.knmi.nl/

Another source for climate data is the Crop Growth Monitoring System developed by MARS Project, located at European Commission Joint Research Centre. It provides the European Commission (DG Agriculture) with objective, timely and quantitative yield forecasts at regional and national scale. One of the main output of the CGMS system are the METEOREOLOGICAL INTERPOLATED data, including air temperature and solar radiation. It contains meteo interpolated data from 1975, covering the EU member states, the central European eastern countries, the new Independent states and the Mediterranean countries. In compliance with the Commission policy these data are available to the scientific community. The website is available under http://mars.jrc.ec.europa.eu/mars/About-us/AGRI4CAST/Data-distribution

Regarding long-term test reference years of climate values, the purchasable Meteonorm software provides an easy user interface and good export of the data.

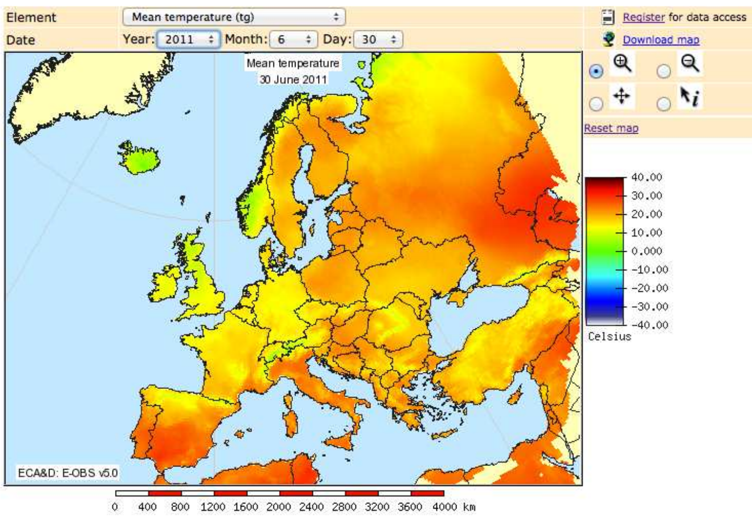

Figure 2: Map of ECA&D E-OBS mean temperatures for 30.6.2011

References:

[1] European Commission – Eurostat, http://epp.eurostat.ec.europa.eu

[2] Panorama of Energy – Energy Statistics to support EU policies and solutions, Eurostat and European Commission, 2007, ISBN 92-79-03894-X

1.2.2 Energy flows

1.2.2.1 Individual building

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B; cf. Table 2) [kWh/a]

$Out_{el.,i,t}$ Electricity output (>0) flow of building i in year t [kWh/a]

Example: A building consumes 5,000 kWh/a electricity for electrical water heating, 2,000 kWh/a electricity for space cooling and 8,000 kWh/a electricity for electrical appliances. A micro CHP (combined heat and power) system **with peak load boiler** is used for space heating. 6,000 kWh/a domestic gas enter the CHP system. Thereof 5,000 kWh/a are allocated to space heating using an exergy based allocation approach. The remaining 1,000 kWh/a are allocated to electricity production (and thus export), i.e. the production of 300 kWh/a electricity (exported from the building by assumption). Furthermore, 1,000 kWh/a electricity are produced (and exported) via building-integrated photovoltaics. In case of photovoltaics, it is assumed that the same amount of energy converted into electricity entered the building in form of "other renewables: electricity", i.e. solar radiation. In total, 1,300 kWh/a electricity are exported from the building and 15,000 kWh/a electricity are imported.

Table 4: Input and output energy flows of an individual building (example)

$In_{EC,AA,i,t}$ [kWh/a]		Area of application					$Out_{el.,i,t}$ [kWh/a]
		(AA1) space heating	(AA2) domestic water heating	(AA3) space cooling	(AA4) electrical appliances	(AA5) electricity export	
Entry of a building or export from CONCERTO area	(B1) oil	0	0	0	-	0	1,300
	(B2) gas	5,000	0	0	-	1,000	
	(B3) coal	0	0	0	-	0	
	(B4) biomass	0	0	0	-	0	
	(B5) direct thermal energy	0	0	0	-	-	
	(B6) other renewables: heat	0	0	0	-	-	
	(B7) other renewables: electricity	-	-	-	-	1,000	
	(B8) electricity	0	5,000	2,000	8,000	0	
	(B9) electricity for export out of the CONCERTO area	-	-	-	-	-	

1.2.2.2 Set of buildings

$$In_{EC,AA,I,t} = \sum_{i \in I} In_{EC,AA,i,t}$$

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$In_{EC,AA,I,t}$ Input (>0) energy flow into set I of buildings for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$$Out_{el.,I,t} = \sum_{i \in I} Out_{el.,i,t}$$

$Out_{el.,I,t}$ Electricity output (>0) flow of set I of buildings in year t [kWh/a]

$Out_{el.,i,t}$ Electricity output (>0) flow of building i in year t [kWh/a]

1.2.2.3 Large-scale units, building-integrated energy supply units, and building-integrated energy demand units

Designator	Description
$s \in S = S_{A,large} \cup S_{A,spatial} \cup S_{A,temporal} \cup S_{A,small,el.} \cup S_{A,small,oth.}$	Large-scale units
$S_{A,large}$	Overall set of large-scale energy supply units
$S_{A,spatial}$	Overall set of large-scale spatial transformation units
$S_{A,temporal}$	Overall set of large-scale temporal transformation units
$S_{A,small,el.}$	Overall set of (building-integrated) cogeneration and electricity generation energy supply units
$s \in S_{A,small,oth.}$	Other (building-integrated) energy supply units
$S_{A,small,oth.}$	Overall set of other (building-integrated) energy supply units

$In_{EC,s,t}$ Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy supply unit s in year t [kWh/a]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$In_{EC,c,t}$ Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy demand unit c in year t [kWh/a]

$Out_{EC,c,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy demand unit c in year t [kWh/a]

Example: Several examples of energy flows of enery supply units and energy demand units are provided in Table 5. E.g. 90 kWh/a enter a "gas CHP plant excl. distribution". The output of this plant is 55 kWh/a direct thermal energy, 25 kWh/a electricity, and 10 kWh/a losses. The transport of 55 kWh/a direct thermal energy via the district heating network causes another 15 kWh/a of losses. Thus, only 40 kWh/a of direct thermal energy are transferred in the domestic delivery station. The other examples should be self-explaining.

Table 5: Input and output energy flows of large-scale units, building-integrated energy supply units and building-integrated energy demand units (example)

[kWh/a]		Input or Output of a specific large-scale energy supply unit, a spatial/temporal transformation unit or a building-integrated energy supply (electricity, heat, cold etc.) or demand unit (or of combinations)								
		(IO1) oil	(IO2) gas	(IO3) coal	(IO4) biomass	(IO5) direct thermal energy	(IO6) other renewables: heat	(IO7) other renewables: electricity	(IO8) electricity	(IO10) Losses
Gas CHP plant incl. distribution	$In_{EC,s,t}$		90							
	$Out_{EC,s,t}$					40			25	25
Gas CHP plant excl. distribution	$In_{EC,s,t}$		90							
	$Out_{EC,s,t}$					55			25	10
District Heating network	$In_{EC,s,t}$					55				
	$Out_{EC,s,t}$					40				15
Micro-CHP gas plant incl. distribution	$In_{EC,s,t}$		6.000							
	$Out_{EC,s,t}$		5.000						350	650
Gas boiler incl. distribution	$In_{EC,s,t}$		1.000							
	$Out_{EC,s,t}$					950				50
Insulated wall	$In_{EC,s,t}$					285				
	$Out_{EC,s,t}$									285
Biomass collection and preparation	$In_{EC,s,t}$	10			100					
	$Out_{EC,s,t}$				100					10

1.2.2.4 Set of large-scale units (production based)

Designator	**Description**
$S = S_{large} \cup S_{spatial} \cup S_{temporal} \cup S_{small,el.}$	Set of large-scale units
$S_{large} \subseteq S_{A,large}$	Set of large-scale energy supply units
$S_{spatial} \subseteq S_{A,spatial}$	Set of large-scale spatial transformation units
$S_{temporal} \subseteq S_{A,temporal}$	Set of large-scale temporal transformation units
$S_{small,el.} \subseteq S_{A,small,el.}$	Set of (building-integrated) cogeneration and electricity generation energy supply units

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$$Out_{EC,S,t} = \left[\left(\sum_{s\in S\cap S_{A,l\arg e}} Out_{EC,s,t}\right) + 1_{EC\neq directthermalenergy} * \left(\sum_{s\in S\cap S_{A,small,el.}} Out_{EC,s,t}\right)\right] * \left(\frac{\sum_{s\in S\cap S_{A,spatial}} Out_{EC,s,t}}{\sum_{s\in S\cap S_{A,spatial}} In_{EC,s,t}}\right) * \left(\frac{\sum_{s\in S\cap S_{A,temporal}} Out_{EC,s,t}}{\sum_{s\in S\cap S_{A,temporal}} In_{EC,s,t}}\right)$$

Verbal explanation of formula:

Output of energy supply units (e.g. heating plant or building-integrated photovoltaics) * Factor for losses of spatial transformation (e.g. district heating network) * Factor for losses of temporal transformation (e.g. thermal storage)

$Out_{EC,S,t}$ **Local production based** output (>0) energy flow of energy carrier (or source) EC (type C) from energy supply system S in year t [kWh/a]

$In_{EC,s,t}$ Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy supply unit s in year t [kWh/a]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$$In_{EC,EC',S,t} = \sum_{s\in S\cap S_{A,l\arg e}} \left[\frac{Out_{EC',s,t} * EX_{s,EC'}}{\sum_{EC''}(Out_{EC'',s,t} * EX_{s,EC''})} * In_{EC,s,t}\right]$$
$$+ 1_{EC\neq directthermalenergy} \sum_{s\in S\cap S_{A,small,el.}} \left[\frac{Out_{EC',s,t} * EX_{s,EC'}}{\sum_{EC''}(Out_{EC'',s,t} * EX_{s,EC''})} * In_{EC,s,t}\right]$$
$$+ 1_{EC\neq EC'} * \sum_{s\in S\cap S_{A,spatial}\cap S_{A,temporal}} \left[In_{EC,s,t} * \mathrm{sgn}(Out_{EC',s,t})\right]$$

$In_{EC,EC',S,t}$ **Local production based** input (>0) energy flow of energy carrier (or source) EC (type C) into energy supply system S for the production of energy carrier (or source) EC' (type B) in year t [kWh/a]

$Out_{EC,S,t}$ **Local production based** output (>0) energy flow of energy carrier (or source) EC (type C) from energy supply system S in year t [kWh/a]

$In_{EC,s,t}$ Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy supply unit s in year t [kWh/a]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EX_{s,EC}$ exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

Note: Losses by spatial and temporal transformation are set as average losses in S.

Example: A set of large-scale units (production based) consists of a wood chip plant, a district heating network with gas boiler, a photovoltaics park and the building integrated-electricity production units described above. The wood chip plants uses 10 kWh/a of oil (e.g. for transport) and 110 kWh/a of biomass (harvested within the CONCERTO area) in order to produce 100 kWh/a of wood chips. 1,000 kWh/a of gas are burned within the gas boiler feeding the district heating network. 100 kWh/a of electricity are consumed for the pumps of the district heating network that delivers 900 kWh/a of heat at the delivery stations (losses: 100+100 kWh/a). For the photovoltaic park 2,000 kWh/a of solar radiation are allocated to the output of 2,000 kWh/a of electricity. The electricity produced within the building described in chapter 1.2.2.1 is 1,300 kWh/a. Thus, 3,300 kWh/a of electricity is produced in total.

Table 6: Production based input and output energy flows of large-scale units (example)

$In_{EC,EC',S,t}$ [kWh/a]		Entry of a building or export from CONCERTO area											
		(B1) oil	(B2) gas	(B3) coal	(B4) biomass	(B5a) heat/district heat	(B5b) cold/district cold	(B6) other renewables: heat	(B7) other renewables: electricity	(B8) electricity	(B9a) electricity for export (large-scale)	(B9b) electricity for export (building-integrated)	(B9) electricity for export (B9a+B9b)
Entry of CONCERTO area or location of depletion within the CONCERTO area	(C1) oil				10								
	(C2) gas					1000						1000	1000
	(C3) coal												
	(C4) biomass				110								
	(C5) direct thermal energy					0							
	(C6) other renewables: heat												
	(C7) other renewables: electricity										2000	1000	3000
	(C8) electricity					100							
$Out_{EC,S,t}$ [kWh/a]		0	0	0	100	900	0	0	0	0	2000	1300	3300

1.2.2.5 Set of large-scale units supplying a set of buildings (consumption based)

$$Out_{EC,S,I,t} = \sum_{AA=AA1}^{AA4} In_{EC,AA,I,t}$$

$Out_{EC,S,I,t}$ **Local consumption based** output (>0) energy flow of energy carrier (or source) EC (type C) from a set S of large-scale units supplying a set I of buildings in year t [kWh/a]

$In_{EC,AA,I,t}$ Input (>0) energy flow into set I of buildings for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

1.2.2.5.1 *National/European electricity mix*

$$In_{EC,EC',S,I,t} = Out_{EC',S,I,t} * \left[\begin{array}{l} \min\{\frac{Out_{EC',S,t}}{Out_{EC',S,I,t}},1\} * \frac{In_{EC,EC',S,t}}{Out_{EC',S,t}} + \\ \left(1-\min\{\frac{Out_{EC',S,t}}{Out_{EC',S,I,t}},1\}\right) * \left(\frac{\sum_{s\in S\cap S_{A,spatial}} In_{EC',s,t}}{\sum_{s\in S\cap S_{A,spatial}} Out_{EC',s,t}}\right) * \left(\frac{\sum_{s\in S\cap S_{A,temporal}} In_{EC',s,t}}{\sum_{s\in S\cap S_{A,temporal}} Out_{EC',s,t}}\right) \end{array} \right]$$

Verbal explanation of formula:

Consumption covered by energy supply system (incl. purely transported energy) *[Share of self-covered energy consumption * output-specific energy input + (Share of import-covered energy consumption * factor for losses of spatial transformation * factor for losses of temporal transformation)]

Note: The share of self-covered electricity is "0" as consumed electricity (B8) and produced electricity (B9, Electricity for export out of the CONCERTO area) are by assumption different energy carriers.

$In_{EC,EC',S,I,t}$ **Local consumption based** input (>0) energy flow of energy carrier (or source) EC (type C) into set S of large-scale units supplying a set I of buildings for the production of energy carrier (or source) EC' (type B) in year t using **national/European electricity mix** [kWh/a]

$Out_{EC,S,I,t}$ **Local consumption based** output (>0) energy flow of energy carrier (or source) EC (type C) from set S of large-scale units supplying a set I of buildings in year t [kWh/a]

$In_{EC,EC',S,t}$ **Local production based** input (>0) energy flow of energy carrier (or source) EC (type C) into energy supply system S for the production of energy carrier (or source) EC' (type B) in year t [kWh/a]

$Out_{EC,S,t}$ **Local production based** output (>0) energy flow of energy carrier (or source) EC (type C) from energy supply system S in year t [kWh/a]

Example: The production based example (cf. chapter 1.2.2.4) is supplemented by the import of gas and electricity.

Table 7: Consumption based input and output energy flows of large-scale units supplying a set of buildings (national/European electricity mix) (example)

$In_{EC, EC',S,t}$ [kWh/a]		Entry of a building or export from CONCERTO area								
		(B1) oil	(B2) gas	(B3) coal	(B4) biomass	(B5a) heat/district heat	(B5b) cold/district cold	(B6) other renewables: heat	(B7) other renewables: electricity	(B8) electricity
Entry of CONCERTO area or location of depletion within the CONCERTO	(C1) oil				10					
	(C2) gas		**900**			1000				
	(C3) coal									
	(C4) biomass				100					
	(C5) direct thermal energy									
	(C6) other renewables: heat							**200**		
	(C7) other renewables: electricity									
	(C8) electricity					100				**4000**
$Out_{EC,S,t}$ [kWh/a]		0	**900**	0	100	900	0	**200**	0	**4000**

Note: In this example the share of gas that is transported into a building and converted via Micro CHP into electricity is included neither in (B2) nor in (B8). It is assumed that the produced electricity is already part of the national/European electricity mix.

1.2.2.5.2 *Local electricity mix*

$$In^*_{EC,B8,S,I,t} = Out_{B8,S,I,t} * \left[\begin{array}{l} \min\{\frac{Out_{B9.,S,t}}{Out_{B8,S,I,t}},1\} * \frac{In_{EC,B9,S,t}}{Out_{B9.,S,t}} + \\ \left(1-\min\{\frac{Out_{B9.,S,t}}{Out_{B8,S,I,t}},1\}\right) * \left(\frac{\sum_{s \in S \cap S_{A,spatial}} In_{B8,s,t}}{\sum_{s \in S \cap S_{A,spatial}} Out_{B8,s,t}} \right) * \left(\frac{\sum_{s \in S \cap S_{A,temporal}} In_{B8,s,t}}{\sum_{s \in S \cap S_{A,temporal}} Out_{B8,s,t}} \right) \end{array} \right]$$

Verbal explanation of formula:

El. consumption covered by energy supply system (incl. purely transported energy)
*[Share of self-covered electricity * local electricity mix +
(Share of import-covered electricity consumption * factor for losses of spatial transformation (=1) * factor for losses of temporal transformation)]

Note: The share of self-covered electricity is **not** "0" as consumed electricity (B8) and produced electricity (B9, Electricity for export out of the CONCERTO area) are implicitly the same energy carriers.

$In^*_{EC,EC',S,I,t}$ **Local consumption based** input (>0) energy flow of energy carrier (or source) EC (type C) into set S of large-scale units supplying a set I of buildings for the production of energy carrier (or source) EC′ (type B) in year t using **local electricity mix** [kWh/a]

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$Out_{EC,S,I,t}$	**Local consumption based** output (>0) energy flow of energy carrier (or source) EC (type C) from set S of large-scale units supplying a set I of buildings in year t [kWh/a]
$In_{EC,EC',S,t}$	**Local production based** input (>0) energy flow of energy carrier (or source) EC (type C) into energy supply system S for the production of energy carrier (or source) EC' (type B) in year t [kWh/a]
$Out_{EC,S,t}$	**Local production based** output (>0) energy flow of energy carrier (or source) EC (type C) from energy supply system S in year t [kWh/a]

Example: Local electricity mix

Import of electricity (=total consumption) = 4,000 kWh/a

Export of electricity (=total production) = 3,300 kWh/a

- (Net) imported share of electricity (local electricity mix): 700/4,000 = 17.5%
- Mix for 82.5% self-production (kWh/kWh):
  - 1,000/3,300 = 0.3 (C2)
  - 3,000/3,300 = 0.91 (C7)

Example: Compared to the production based example (cf. chapter 1.2.2.5.1), only 700 kWh/a of electricity are imported. The remaining 3,300 kWh/a are self-produced (based on gas and photovoltaic) and consumed.

Table 8: Consumption based input and output energy flows of large-scale units supplying a set of buildings (local electricity mix)

$In_{EC, EC',S,t}$ [kWh/a]		Entry of a building or export from CONCERTO area								
		(B1) oil	(B2) gas	(B3) coal	(B4) biomass	(B5a) heat/district heat	(B5b) cold/district cold	(B6) other renewables: heat	(B7) other renewables: electricity	(B8) electricity
Entry of CONCERTO area or location of depletion within the CONCERTO	(C1) oil				10					
	(C2) gas		**900**			1000				1000
	(C3) coal									
	(C4) biomass				100					
	(C5) direct thermal energy									
	(C6) other renewables: heat							**200**		
	(C7) other renewables: electricity									3000
	(C8) electricity					100				**700**
$Out_{EC,S,t}$ [kWh/a]		0	**900**	0	100	900	0	**200**	0	**4000**

Note: In this example the share of gas that is transported into a building and converted via Micro CHP into electricity is included in (B8).

1.2.3 Reference buildings and energy supply units

About baselines or reference objects: Several indicators are calculated for different objects, e.g. the primary energy demand can be calculated for two different newly constructed buildings [kWh/(m^2 building floor area * a)] with different types of energy efficiency measures. Afterwards, these indicator values can be compared, interpreted and conclusions can be drawn for the energy efficiency measures that have been implemented.

Other indicators are calculated depdending on a reference object – this term is used in analogy to baseline. An example indicator would be the reduction of greenhouse gas emissions that has been caused by an energetic refurbishment or even the mitigation costs of greenhouse gas emissions. The basic idea is to quantify the effect caused by the implementation of a measure – e.g. a special thermal insulation. Thus, the baseline tries to answer the question "What would have happened, if the measure would not have been implemented?" This question cannot be answered in complete satisfaction. Instead, a comprehensible and clear-cut reference unit has to be used, whereat data availability strongly influences this choice.

In case of buildings that have been **refurbished** within CONCERTO, three important reference objects (cases) are distinguished. **Case A** corresponds to the building envelope, heating, cooling and electricity system after a non-energetic refurbishment of the envelope – **when (as soon as) required -** and the replacement of old systems with typical new heating and cooling supply systems - **when (as soon as) required**. In this case, the expected lifetimes of the building components before the refurbishments have to be known. Furthermore, investments in non-energetic refurbishments of the envelope as well as typical new heating and cooling supply systems have to be known. In dependence on the expected lifetime, these can be future investments.

Case B is a simplification of case A, i.e. the non-energetic refurbishment takes place at the same time as the refurbishment within CONCERTO if it is required at this time. Thus, expected lifetimes of the components and future investments don't have to be known.

Case C is a further simplification, i.e. the building envelope, heating, cooling and electricity system before the refurbishment is chosen as reference object. Thus, a replacement of building components is not considered at all in the reference case. The stronger the simplification the worse the answer to the question mentioned above, but the lower the data requirements are. Furthermore, the reference object becomes "cheaper" with increasing simplification and is increasingly favoured compared to the refurbishment within CONCERTO. The concrete reference object has to be chosen in dependence on the available data.

In case of **new constructions** it is assumed that a functionally comparable building according to the national minimum requirements would have been constructed without the CONCERTO initiative. Thus, the indicators can be interpreted as effect of strengthening the national minimum requirements.

In case of **energy supply units** the energy produced replaces another energy supply unit. In case of **heat and cold** typical new systems with a high market share are used as reference objects (cf. refurbishment and new construction of buildings). In case of refurbishments the replaced heating or cooling system can be used as well as reference object (cf. refurbishment). In case of electricity the squeezed system cannot be determined because of lacking data. In contrast to heat and cold, electricity is not a local issue. Therefore, either a national electricity mix or a typical new electricity supply system is used as baseline.

1.2.3.1 Reference buildings

1.2.3.1.1 *New construction*

The new constructed building is compared to

- a functionally comparable building that is constructed according to the national minimum requirements. The type of the heating system is chosen by the CONCERTO partners or CONCERTO Premium.

Definition of reference building (new construction): Functionally comparable building that is constructed according to the national minimum requirements.

Where to find the data:

- Major data:
    - On the data collection sheet of the new constructed building (D-NB)
    - In a separate data collection sheet for the reference building (D-REF)
- (Input) energy prices:
    - On the community data collection sheet (B)
    - On the CONCERTO area data sheets (C-A)

1.2.3.1.2 *Refurbishment*

The refurbished building can be compared to

- Case A
    - the building envelope, heating, cooling and electricity system after a non-energetic refurbishment of the envelope (**when -as soon as - required**)

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and the replacement of old systems with typical new heating and cooling supply systems (**when - as soon as - required**)

- Case B
    - the building envelope, heating, cooling and electricity system after a non-energetic refurbishment of the envelope (**if required**) and the replacement of old systems with typical new heating and cooling supply systems (**if required**)
- Case C
    - the building envelope, heating, cooling and electricity system before the refurbishment

Definition of reference building (<u>refurbishment</u>): Case C
Where to find the data: On the data collection sheet of the refurbished building (D-RB-C)

1.2.3.2 Large-scale energy supply units

The large-scale energy supply unit is compared to

- a typical new heating and cooling system AND concerning electricity
    - Case A ("**build margin**")
        - a typical new electricity supply system OR
    - Case B ("**operating margin**")
        - the national electricity mix

Definition of reference unit for <u>heat/cold</u> (large-scale, building-integrated new construction): Typical new heating/cooling system (high market share)
Where to find the data:

- Major data: On the data collection sheet for a building-integrated energy supply system (other) that has been filled-in for a reference unit (E-BIES-6)
- (Input) energy prices:
    - On the community data collection sheet (B)
    - On the CONCERTO area data sheets (C-A)

Definition of reference unit for electricity (large-scale, building-integrated): Case A **OR** Case B
Where to find the data:

- **Case A**
    - Major data: On the data collection sheet for a community energy system (other) that has been filled-in for a reference unit (E-CES-7)
    - (Input) energy prices
        - On the data collection sheet of the large-scale energy supply unit

        - On the community data collection sheet (B)
        - On the CONCERTO area data sheets (C-A)
- **Case B**
    - Major data: On the national data collection sheets (emissions, energy demand and price data etc.) (A)

1.2.3.3 Building-integrated energy supply units – new construction

Cf. large-scale energy supply units

1.2.3.4 Building-integrated energy supply units – refurbishment

The building-integrated energy supply unit is compared to

- Case A
    - a typical new heating and cooling supply systems AND concerning electricity
        - Case A1
            - a typical new electricity supply system OR
        - Case A2
            - the national electricity mix
- Case B
    - the heating, cooling and electricity system before the refurbishment, i.e. concerning electricity
        - Case B1 (“**build margin**”)
            - a typical new electricity supply system OR
        - Case B2 (“**operating margin**”)
            - the national electricity mix in case of electricity
- Case C
    - the heating, cooling and electricity system after a replacement of old systems with typical new heating and cooling supply systems (**when required**)

Definition of reference unit for <u>heat/cold</u> (building-integrated refurbishment):
Case A or case B

Where to find the data:

- **Case A**
    - Major data: On the data collection sheet for a building-integrated energy supply system (other) that has been filled-in for a reference unit (E-BIES-6)
    - (Input) energy prices:

- On the data collection sheet for the refurbished building (D-RB)
- On the community data collection sheet (B)
- On the CONCERTO area data sheets (C-A)

- **Case B**
  - Major data: On the data collection sheet for the refurbished building (D-RB)

1.3 Environmental indicators [A1-A5, AΔ1- AΔ5]

1.3.1 Achieved environmental performance [A1-A5]

Description: The achieved environmental performance of a building or an energy supply unit can be expressed by several indicators. They enable the comparison of different buildings and energy supply units.

1.3.1.1 (Final) energy demand and consumption [A1]

References:

- DIN EN 15603:2008-07. (2008) Energy performance of buildings – Overall energy use and definition of energy ratings

1.3.1.1.1 *Individual building [A1_1]*

Description: The final energy demand/consumption of a building corresponds to the energy entering the building (e.g. energy content of light oil, electricity, district heat) in order to be used in different areas of application (space heating, space cooling, domestic water heating, electrical appliances). Often, comparability with respect to electricity can only be achieved if only lighting and auxiliary energy are considered. Thus, user-dependant electricity consumer (computer, refrigerator etc.) are not considered. The energy demand is based on the calculated figures whereas the energy consumption is based on metered figures. To enable the comparability between buildings, the total energy demand is related to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered time interval (e.g. year).

Unit: kWh/(m² a)

Exemplary application: This indicator can be used in order to assess the energy efficiency of a building, i.e. the thermal quality of the building envelope, the efficiency of the heating system, the cooling system, the electrical appliances etc.

$$EN_{i,t} = \sum_{EC} \sum_{AA=AA1}^{AA4} In_{EC,AA,i,t} / Cap_i$$

$EN_{i,t}$	Final energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]
$In_{EC,AA,i,t}$	input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]
Cap_{i}	Floor area of building i [m²]

Reference building

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; the units of values used in examples are provided in the description of the corresponding formula (above).

$$EN_{i_1,t=2010} = (96{,}139.5 + 20{,}544 + 33{,}384) / 1{,}605 = 93.5$$

$$EN_{i_1} = (89{,}880 + 20{,}062.5 + 40{,}125) / 1{,}605 = 93.5$$

$$EN_{i_1=REF} = (144{,}450 + 20{,}062.5 + 51{,}360) / 1{,}605 = 134.5$$

$$EN_{i_2} = (99{,}176 + 22137.5 + 44{,}275) / 1{,}771 = 93.5$$

$$EN_{i_2=REF} = (159{,}390 + 22137.5 + 56{,}672) / 1{,}771 = 134.5$$

$$EN_{i_3} = (114{,}408 + 25{,}537.5 + 51{,}075) / 2{,}043 = 93.5$$

$$EN_{i_3=REF} = (183{,}870 + 25{,}537.5 + 65{,}376) / 2{,}043 = 134.5$$

1.3.1.1.2 *Set of buildings [A1_2]*

Description: Cf. individual building

Unit: kWh/(m² a)

$$EN_{I,t} = \frac{\sum_{i \in I} EN_{i,t} * Cap_i}{\sum_{i \in I} Cap_i}$$

$EN_{I,t}$	Final energy demand/consumption of set I of buildings based on annual data of year t [kWh/(m² a)]
$EN_{i,t}$	Final energy energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]
Cap_{i}	Floor area of building i [m²]

1.3.1.1.3 *Large-scale or building-integrated energy supply unit [A1_3]*

Description: The energy demand/consumption of a large-scale or building-integrated energy supply unit corresponds to the energy entering the energy supply unit (e.g. energy content of light oil, electricity, district heat). The energy demand is based on the calculated figures whereas the energy consumption is based on metered figures. To enable the comparability between energy supply units, the total energy demand is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In case of cogeneration the input is matched to the output using an exergy based approach. Thus, this indicator represents the reciprocal efficiency of the energy supply unit. This indicator is introduced here in analogy to the buildings and as calculation base/help for the calculation of other indicators. The indicator energy efficiency is described in chapter 1.5.2.

Unit: kWh_{in}/kWh_{out}

Exemplary application: This indicator can be used in order to assess the reciprocal energy efficiency of an energy supply unit, i.e. of a condensing boiler, a stove etc.

> **Note:** In the following, a **large-scale energy supply** unit encompasses in addition to the production plant as well the corresponding distribution, e.g. the district heating network and the domestic delivery station in case of district heating. The system boundaries on the output side of the **building-integrated energy supply unit** correspond to the interface to the primary heating circuit. Cf. Chapter 1.7.

$$EN_{s,EC,t} = \frac{\dfrac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'}(Out_{EC',s,t} * EX_{s,EC'})} * \sum_{EC'} In_{EC',s,t}}{Out_{EC,s,t}}$$

Note: The fraction in the numerator is "1" in case of non-cogeneration.

$EN_{s,EC,t}$	Energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]
$In_{EC,s,t}$	Input (>0) energy flow of energy carrier (or source) EC into energy supply unit s in year t [kWh/a]
$EX_{s,EC}$	Exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network

$$EN_{s,EC=heat,t=2008} = \frac{\frac{37{,}700{,}000 * 0.22}{37{,}700{,}000 * 0.22 + 6{,}015{,}701 * 1} * (7{,}098{,}745 + 40{,}238{,}413)}{37{,}700{,}000} = 0.73$$

$$EN_{s,EC=electricity,t=2008} = \frac{\frac{6{,}015{,}701 * 1}{37{,}700{,}000 * 0.22 + 6{,}015{,}701 * 1} * (7{,}098{,}745 + 40{,}238{,}413)}{6{,}015{,}701} = 3.31$$

Sub-formula 1: exergy factors

$EX_{s,EC=electricity,t} = 1$	$EX_{s,EC=heat,t} = 1 - \frac{T_{ambient}}{T_{heat}}$	$EX_{s,EC=cold,t} = 1 - \frac{T_{cold}}{T_{environment}}$	$EX_{s,EC=losses,t} = 0$

$EX_{s,EC}$ exergy factor for the output of energy carrier EC (type IO) from an energy supply unit s [kWh/kWh]

$T_{ambient}$ annual average ambient temperature [K]

T_{heat} annual average temperature of the output heat (type IO) [K]

T_{cold} annual average temperature of the output cold (type IO) [K]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network

$$EX_{s,EC=heat,t} = 1 - \frac{10 + 273.15}{90 + 273.15} = 0.22$$

Reference units for EC=heat/electricity/cold (type IO)

Note: Figures of the reference energy supply units are calculated in an analogous way to the demonstration energy supply units. The corresponding figures are flagged with s=REF instead of s.

1.3.1.1.4 *Set of large-scale units [A1_4]*

Description: Cf. large-scale or building-integrated energy supply unit

Unit: kWh_{in}/kWh_{out}

$$EN_{S,EC,t} = \frac{\sum_{s \in S} EN_{s,EC,t} * Out_{EC,s,t}}{\sum_{s \in S} Out_{EC,s,t}}$$

$EN_{S,EC,t}$ Energy demand/consumption by set S of large-scale units divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

$EN_{s,EC,t}$ Energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.3.1.2 Primary energy demand and consumption [A2]

References:

- DIN EN 15603:2008-07. (2008) Energy performance of buildings – Overall energy use and definition of energy ratings

Description: The primary energy demand/consumption of a building encompasses in addition to the final energy demand/consumption, the energy that is used within the supply chain of the used energy carriers. Therefore, this indicator considers as well differences in the energetic effort within the supply chain of different energy carriers, e.g. domestic gas versus electricity.

Individual buildings

Unit: kWh/(m² a)

Set of buildings

Unit: kWh/(m² a)

Large-scale or building-integrated energy supply units

Unit: kWh_{in}/kWh_{out}

1.3.1.2.1 *Individual building [A2_1]*

$$PEN_{i,t} = \sum_{EC} \sum_{AA=AA1}^{AA4} ((In_{EC,AA,i,t} * PEF_{EC}) + Cap_i * PEF_{[i]} / EL_{[i]}) / Cap_i$$

Note: The right part of the formula corresponds to embedded energy.

$PEN_{i,t}$	Primary energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]
$In_{EC,AA,i,t}$	input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]
PEF_{EC}	Primary energy factor for energy carrier EC [kWh/kWh]
$PEF_{[i]}$	Primary energy factor for a building of the same type as i [kWh/m²]
Cap_{i}	Floor area of building i [m²]
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]

Sub-formula: Primary energy factor in case of direct thermal energy

$$PEF_{EC=B5} = PEN_{S_A / S_{A,small,el.},EC=B5,t}$$

PEF_{EC}	Primary energy factor for energy carrier EC [kWh/kWh]
$PEN_{S,EC,t}$	Primary energy demand/consumption by set S of large-scale units divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

Reference building

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; Use of KEA non renewable excl. construction

$$PEN_{i_1,t=2010} = (96{,}139.5*0.15+20{,}544*0.15+33{,}384*2.56)/1{,}605 = 64.2$$

$$PEN_{i_1} = (89{,}880*0.15+20{,}062.5*0.15+40{,}125*2.56)/1{,}605 = 74.3$$

$$PEN_{i_1=REF} = (144{,}450*0.15+20{,}062.5*0.15+51{,}360*2.56)/1{,}605 = 97.3$$

$$PEN_{i_2} = (99{,}176*0.15+22137.5*0.15+44{,}275*2.56)/1{,}771 = 74.3$$

$$PEN_{i_2=REF} = (159{,}390*0.15+22137.5*0.15+56{,}672*2.56)/1{,}771 = 97.3$$

$$PEN_{i_3} = (114{,}408*0.15+25{,}537.5*0.15+51{,}075*2.56)/2{,}043 = 74.3$$

$$PEN_{i_3=REF} = (183{,}870*0.15+25{,}537.5*0.15+65{,}376*2.56)/2{,}043 = 97.3$$

1.3.1.2.2 *Set of buildings [A2_2]*

$$PEN_{I,t} = \frac{\sum_{i \in I} PEN_{i,t} * Cap_i}{\sum_{i \in I} Cap_i}$$

$PEN_{I,t}$ Primary energy demand/consumption set I of buildings based on annual data of year t [kWh/(m² a)]

$PEN_{i,t}$ Primary energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]

Cap_i Floor area of building i [m²]

1.3.1.2.3 *Large-scale or building-integrated energy supply unit [A2_3]*

$$PEN_{s,EC,t} = \frac{\frac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'} (Out_{EC',s,t} * EX_{s,EC'})} * PEN_{s,t}}{Out_{EC,s,t}}$$

$PEN_{s,EC,t}$ Primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

$PEN_{s,t}$ Primary energy demand/consumption by energy supply unit s in year t [kWh/a]

$EX_{s,EC}$ exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network; Use of KEA non-renewable excl. construction, assuming wood chips with 30% humidity

$$PEN_{s,EC=heat,t=2008} = \frac{\frac{37{,}700{,}000 * 0.22}{37{,}700{,}000 * 0.22 + 6{,}015{,}701 * 1} * 9{,}702{,}106}{37{,}700{,}000} = 0.15$$

$$PEN_{s,EC=electricity,t=2008} = \frac{\frac{6{,}015{,}701 * 1}{37{,}700{,}000 * 0.22 + 6{,}015{,}701 * 1} * 9{,}702{,}106}{6{,}015{,}701} = 0.68$$

Sub-formula 1: annual primary energy demand/consumption of the energy supply unit

$$PEN_{s,t} = \sum_{EC} (In_{EC,s,t} * PEF_{EC} + Cap_{s,EC} * PEF_{[s],EC} / EL_{[s]})$$

$PEN_{s,t}$ Primary energy demand/consumption by energy supply unit s in year t [kWh/a]

$In_{EC,s,t}$ input (>0) energy flow of energy carrier (or source) EC into energy supply unit s in year t [kWh/a]

PEF_{EC} primary energy factor for energy carrier EC [kWh/kWh]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

$EL_{[s]}$ Expected lifetime of an energy supply unit of the same type as s [a]

$PEF_{[s],EC}$ Primary energy factor for energy supply units of the same type as s; the primary energy factor is zero, if the output of energy carrier EC (type IO at the plant (!)) is not used as base unit [kWh/kW]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network; Use of KEA non-renewable excl. construction, assuming wood chips with 30% humidity

$$PEN_{s,t} = (7{,}098{,}745 * 1.14 + 40{,}238{,}413 * 0.04) + 0 = 9{,}702{,}106$$

Reference unit EC=heat/electricity/cold (type IO)

Note: Figures of the reference energy supply units are calculated in an analogous way to the demonstration energy supply units. The corresponding figures are flagged with s=REF instead of s.

1.3.1.2.4 *Set of large-scale units [A2_4]*

Description: Cf. large-scale or building-integrated energy supply unit

Unit: kWh_{in}/kWh_{out}

$$PEN_{S,EC,t} = \frac{\sum_{s \in S} PEN_{s,EC,t} * Out_{EC,s,t}}{\sum_{s \in S} Out_{EC,s,t}}$$

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$PEN_{S,EC,t}$ Primary energy demand/consumption by set S of large-scale units divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

$PEN_{s,EC,t}$ Primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.3.1.3 Greenhouse gas emissions (and first approximation for particulate matter, NO_X and SO_2) [A3-A5]

Material M corresponds to CO_2 or CO_2 equivalents (and as first approximation as well particulate matter, NO_x, SO_2).

References:

- DIN EN 15603:2008-07. (2008) Energy performance of buildings – Overall energy use and definition of energy ratings

1.3.1.3.1 *Individual building [A3_1-A5_1]*

Description: The greenhouse gas, particulate matter, NO_x and SO_2 emissions of a building correspond to the emissions that are caused by different areas of application (space heating, space cooling, domestic water heating, electrical appliances). In different variants of this indicator the emissions caused by the production of the building components are included or excluded. To enable the comparability between buildings, the emissions are related to the size of the building (e.g. gross floor area or net floor area, heated floor area) and the considered interval of time (e.g. year). The greenhouse gases are considered as t of CO_2 or CO_2 equivalents.

Unit: t/(m² a)

$$EM_{i,M,t} = \sum_{EC} \sum_{AA=AA1}^{AA4} (In_{EC,AA,i,t} * (EF_{EC,M,direct} + EF_{EC,M,indirect})) + Cap_i * EF_{[i],M} / EL_{[i]}) / Cap_i$$

Note: The right part of the formula corresponds to embedded emissions.

$EM_{i,M,t}$ Emissions of material M by building i based on annual data of year t [t/(m² a)]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$EF_{EC,M,direct}$ Direct emission factor for energy carrier EC regarding material M [t/kWh]

$EF_{EC,M,indirect}$ Indirect emission factor for energy carrier EC regarding material M [t/kWh]

Cap_{i} Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

$EF_{[i],M}$ (Indirect) emission factor regarding material M for the construction of a building of the same type as i [t/m²]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; Use of KEA non renewable excl. construction

$$EM_{i_1,M=CO2,t=2010} = (96{,}139.5*41 + 20{,}544*41 + 33{,}384*612)/1{,}605/10^6 = 15.7*10^{-3}$$

$$EM_{i_1,M=CO2} = (89{,}880*41 + 20{,}062.5*41 + 40{,}125*612)/1{,}605/10^6 = 18.1*10^{-3}$$

$$EM_{i_1=REF,M=CO2} = (144{,}450*41 + 20{,}062.5*41 + 51{,}360*612)/1{,}605/10^6 = 23.8*10^{-3}$$

$$EM_{i_2,M=CO2} = (99{,}176*41 + 22137.5*41 + 44{,}275*612)/1{,}771/10^6 = 18.1*10^{-3}$$

$$EM_{i_2=REF,M=CO2} = (159{,}390*41 + 22137.5*41 + 56{,}672*612)/1{,}771/10^6 = 23.8*10^{-3}$$

$$EM_{i_3,M=CO2} = (114{,}408*41 + 25{,}537.5*41 + 51{,}075*612)/2{,}043/10^6 = 18.1*10^{-3}$$

$$EM_{i_3=REF,M=CO2} = (183{,}870*41 + 25{,}537.5*41 + 65{,}376*612)/2{,}043/10^6 = 23.8*10^{-3}$$

Sub-formula 1: indirect emission factors (incl./excl. direct thermal energy)

$$EF_{EC,M,indirect} = EF_{EC,M,extraction-refinery/plant/end-of-grid} + EF_{M,transport} / LHV_{EC} * Dist_{EC,transport}$$

$EF_{EC,M,indirect}$ Indirect emission factor for energy carrier EC regarding material M [t/kWh]

$EF_{EC,M,extraction-refinery/plant/end-of-grid}$ Emission factor regarding material M for the production of energy carrier EC and all transports from extraction to the refinery, the production plant or the customer in case of grid-bound energy carriers [t/kWh]

$EF_{M,transport}$ Emission factor regarding material M for the transport mix [t/(t km)]

$Dist_{EC,transport}$ Transport distance for energy carrier EC from the refinery or the production plant to the average object in

	the corresponding CONCERTO area; The distance is zero in case of grid-bound energy carriers [km]
LHV_{EC}	Lower heating value of energy carrier EC; zero if not applicable [kWh/t]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; Excl. construction

$$EF_{EC=el.,M=CO2,indirect} = 170 * 3.6 / 1{,}000{,}000 = 612 / 1{,}000{,}000$$

Sub-formula 2: indirect emission factors in case of direct thermal energy (B5)

$$EF_{EC=B5,M,indirect} = EM_{S_A/S_{A,small,el.},M,EC=B5,t}$$

$EF_{EC,M,indirect}$	Indirect emission factor for energy carrier EC regarding material M [t/kWh]
$EM_{S,M,EC,t}$	Emissions of material M by set S of large-scale units for the production of the output of energy carrier EC (type IO) based on year t [t/kWh]

Reference building

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

1.3.1.3.2 *Set of buildings [A3_2-A5_2]*

Description: Cf. individual building

Unit: t/(m² a)

$$EM_{I,M,t} = \frac{\sum_{i \in I} EM_{i,M,t} * Cap_i}{\sum_{i \in I} Cap_i}$$

$EM_{I,M,t}$	Emissions of material M by set I of buildings based on annual data of year t [t/(m² a)]
$EM_{i,M,t}$	emissions of material M by building i based on annual data of year t [t/(m² a)]
Cap_i	Floor area of building i [m²]

1.3.1.3.3 *Large-scale or building-integrated energy supply unit [A3_3-A5_3]*

Description: The greenhouse gas, particulate matter, NO_x and SO_2 emissions of a large-scale or building-integrated energy supply unit correspond to the emissions that are caused by the energy output. In different variants of this indicator the emissions caused by the production of the energy supply unit components are included or excluded. To enable the comparability between energy supply units, the total energy demand is related to the energy output of the energy supply unit (e.g. electricity, heat, cold). In case of cogeneration the input is matched to the output using an exergy based approach.

Unit: t/kWh

$$EM_{s,M,EC,t} = \frac{\dfrac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'}(Out_{EC',s,t} * EX_{s,EC'})} * EM_{s,M,t}}{Out_{EC,s,t}}$$

$EM_{s,M,EC,t}$ emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t [t/kWh]

$EM_{s,M,t}$ emissions of material M by energy supply unit s in year t [t/kWh]

$EX_{s,EC}$ exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network

$$EM_{s,M=CO2,EC=heat,t=2008} = \frac{\dfrac{37{,}700{,}000 * 0.22}{37{,}700{,}000 * 0.22 + 6{,}015{,}701 * 1} * 2047}{37{,}700{,}000} = 41 g / kWh$$

$$EM_{s,M=CO2,EC=electricity,t=2008} = \frac{\dfrac{6{,}015{,}701 * 1}{37{,}700{,}000 * 0.22 + 6{,}015{,}701 * 1} * 2047}{6{,}015{,}701} = 189 g / kWh$$

<u>Sub-formula 1: total annual emissions of the energy supply unit</u>

$$EM_{s,M,t} = \sum_{EC}(In_{EC,s,t} * (EF_{EC,M,direct} + EF_{EC,M,indirect}) + Cap_{s,EC} * EF_{[s],M,EC} / EL_{[s]})$$

$EM_{s,M,t}$ emissions of material M by energy supply unit s in year t [t/a]

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$In_{EC,s,t}$ input (>0) energy flow of energy carrier (or source) EC into energy supply unit s in year t [kWh/a]

$EF_{EC,M,direct}$ direct emission factor for energy carrier EC regarding material M [t/kWh]

$EF_{EC,M,indirect}$ indirect emission factor for energy carrier EC regarding material M [t/kWh]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

$EL_{[s]}$ Expected lifetime of an energy supply unit of the same type as s [a]

$EF_{[s],M,EC}$ (indirect) emission factor regarding material M for energy supply units of the same type as s; the emission factor is zero, if the output of energy carrier EC (type IO at the plant (!)) is not used as base unit [t/kW]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network; Use of KEA non-renewable excl. construction, assuming wood chips with 30% humidity

$$EM_{s,M=CO2,t=2008} = (7{,}098{,}745 * (6.92 + 55.15) + 40{,}238{,}413 * (3.18 + 0)) * 3.6 / 1{,}000{,}000 = 2047$$

Sub-formula 2: indirect emission factors

$$EF_{EC,M,indirect} = EF_{EC,M,extraction-refinery/plant/end-of-grid} + EF_{M,transport} / LHV_{EC} * Dist_{EC,transport}$$

$EF_{EC,M,indirect}$ indirect emission factor for energy carrier EC regarding material M [t/kWh]

$EF_{EC,M,extraction-refinery/plant/end-of-grid}$ emission factor regarding material M for the production of energy carrier EC and all transports from extraction to the refinery, the production plant or the customer in case of grid-bound energy carriers [t/kWh]

$EF_{M,transport}$ emission factor regarding material M for the transport mix [t/(t km)]

$Dist_{EC,transport}$ transport distance for energy carrier EC from the refinery or the production plant to the average object in the corresponding CONCERTO area; The distance is zero in case of grid-bound energy carriers [km]

LHV_{EC} Lower heating value of energy carrier EC; zero if not applicable [kWh/t]

Example: Scharnhauser Park; s=Biomass cogeneration plant with ORC process and district heating network; Excl. construction, assuming wood chips with 30% humidity

$$EF_{EC=domesticgas,M=CO2,indirect} = 6.92 * 3.6 / 1{,}000{,}000$$

$$EF_{EC=wood\_chips\_30\%,M=CO2,indirect} = 3.18 * 3.6 / 1{,}000{,}000$$

Reference unit EC=heat/electricity/cold (type IO)

Note: Figures of the reference energy supply units are calculated in an analogous way to the demonstration energy supply units. The corresponding figures are flagged with s=REF instead of s.

1.3.1.3.1 *Set of large-scale units [A3_4-A5_4]*

Description: Cf. large-scale or building-integrated energy supply unit

Unit: t/kWh

$$EM_{S,M,EC,t} = \frac{\sum_{s \in S} EM_{s,M,EC,t} * Out_{EC,s,t}}{\sum_{s \in S} Out_{EC,s,t}}$$

$EM_{S,M,EC,t}$ Emissions of material M by set S of large-scale units for the production of the output of energy carrier EC (type IO) based on year t [t/kWh]

$EM_{s,M,EC,t}$ Emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t [t/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.3.2 Improvement of environmental performance with respect to a baseline [AΔ1- AΔ5]

Description: The improvement of the environmental performance of a building or an energy supply unit can be expressed by several indicators. This improvement has to be measured against a baseline (or a reference object). In case of refurbishments, the building before the refurbishment or the building after a non-energetic refurbishment is chosen. In case of new constructions a functionally comparable new constructed building according to the new national minimum requirements is chosen. In case of energy supply units the national average of energy supply units or a typical new system is chosen. The considered indicators encompass the categories final energy demand and consumption, primary energy demand and consumption, greenhouse gas emissions, particulate matter emissions as well as NO_X and SO_2 emissions.

Individual buildings

Unit: kWh/(m² a), t/(m² a), %

Set of buildings

Unit: kWh/(m² a), t/(m² a), %

Large-scale or building-integrated energy supply units

Unit: kWh_{in}/kWh_{out}, t/kWh, %

Set of large-scale units

Unit: kWh_{in}/kWh_{out}, t/kWh, %

1.3.2.1 (Final) energy demand and consumption [AΔ1]

1.3.2.1.1 *Individual building [AΔ1_1]*

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

$$\Delta EN_{i,REF,t} = EN_{i=REF,t*} - EN_{i,t}$$

$\Delta EN_{i,REF,t}$ Reduction (>0) in final energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$EN_{i,t}$ Final energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$\Delta EN_{i_1,REF,t=2010} = EN_{i_1=REF} - EN_{i_1,t=2010} = 134.5 - 93.5 = 41$$

$$\Delta EN_{i_1,REF} = EN_{i_1=REF} - EN_{i_1} = 134.5 - 93.5 = 41$$

$$\Delta EN_{i_2,REF} = EN_{i_2=REF} - EN_{i_2} = 134.5 - 93.5 = 41$$

$$\Delta EN_{i_3,REF} = EN_{i_3=REF} - EN_{i_3} = 134.5 - 93.5 = 41$$

1.3.2.1.2 *Set of buildings [AΔ1_2]*

$$\Delta EN_{I,I_{REF},t} = \frac{\sum_{i \in I} \Delta EN_{i,REF,t} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\Delta EN_{I,I_{REF},t}$ Reduction (>0) in final energy demand/consumption of set I of buildings based on annual data of year t using set I_{REF} of reference buildings [kWh/(m² a)]

$\Delta EN_{i,REF,t}$ reduction (>0) in final energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

Cap_i Floor area of building i [m²]

1.3.2.1.3 *Large-scale or building-integrated energy supply unit [AΔ1_3]*

$$\Delta EN_{s,EC,t,REF} = EN_{s=REF,EC,t'}{}^{*} - EN_{s,EC,t}$$

$\Delta EN_{s,EC,t,REF}$ Reduction (>0) in energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$EN_{s,EC,t}$ Energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

1.3.2.1.4 *Set of large-scale units [AΔ1_4]*

$$\Delta EN_{S,EC,t,S_{REF}} = \frac{\sum_{s \in S} \Delta EN_{s,EC,t,REF}{}^{*} Out_{EC,s,t}}{\sum_{s \in S} Out_{EC,s,t}}$$

$\Delta EN_{S,EC,t,S_{REF}}$ Reduction (>0) in energy demand/consumption by set S of large-scale units s divided by the production of the output of energy carrier EC (type IO) based on year t compared to set S_{REF} of reference units [kWh/kWh]

$\Delta EN_{s,EC,t,REF}$ Reduction (>0) in energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.3.2.2 Primary energy demand and consumption [AΔ2]

1.3.2.2.1 *Individual building [AΔ2_1]*

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

$$\Delta PEN_{i,REF,t} = PEN_{i=REF,t^*} - PEN_{i,t}$$

$\Delta PEN_{i,REF,t}$ reduction (>0) in primary energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$PEN_{i,t}$ Primary energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$\Delta PEN_{i_1,REF,t=2010} = PEN_{i_1=REF} - PEN_{i_1,t=2010} = 97.3 - 64.2 = 33.1$$

$$\Delta PEN_{i_1,REF} = PEN_{i_1=REF} - PEN_{i_1} = 97.3 - 74.3 = 23$$

$$\Delta PEN_{i_2,REF} = PEN_{i_2=REF} - PEN_{i_2} = 97.3 - 74.3 = 23$$

$$\Delta PEN_{i_3,REF} = PEN_{i_3=REF} - PEN_{i_3} = 97.3 - 74.3 = 23$$

1.3.2.2.2 *Set of buildings[AΔ2_2]*

Description: Cf. individual building

$$\Delta PEN_{I,I_{REF},t} = \frac{\sum_{i \in I} \Delta PEN_{i,REF,t} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\Delta PEN_{I,I_{REF},t}$ Reduction (>0) in primary energy demand/consumption of set I of buildings based on annual data of year t using set I_{REF} of reference buildings [kWh/(m² a)]

$\Delta PEN_{i,REF,t}$ Reduction (>0) in primary energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

Cap_i Floor area of building i [m²]

1.3.2.2.3 *Large-scale or building-integrated energy supply unit [AΔ2_3]*

$$\Delta PEN_{s,EC,t,REF} = PEN_{s=REF,EC,t*} - PEN_{s,EC,t}$$

$\Delta PEN_{s,EC,t,REF}$ reduction (>0) in primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$PEN_{s,EC,t}$ Primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

1.3.2.2.4 *Set of large-scale units [AΔ2_4]*

$$\Delta PEN_{S,EC,t,S_{REF}} = \frac{\sum_{s \in S} \Delta PEN_{s,EC,t,REF} * Out_{EC,s,t}}{\sum_{s \in S} Out_{EC,s,t}}$$

$\Delta PEN_{S,EC,t,S_{REF}}$ Reduction (>0) in primary energy demand/consumption by set S of large-scale units s divided by the production of the output of energy carrier EC (type IO) based on year t compared to set S_{REF} of reference units [kWh/kWh]

$\Delta PEN_{s,EC,t,REF}$ Reduction (>0) in primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.3.2.3 Greenhouse gas emissions (and first approximation for particulate matter, NO_X and SO_2) [AΔ3-AΔ5]

References:

- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.

1.3.2.3.1 *Individual building [AΔ3_1-AΔ5_1]*

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

$$\Delta EM_{i,M,REF,t} = EM_{i=REF,M,t^*} - EM_{i,M,t}$$

$\Delta EM_{i,M,REF,t}$ reduction (>0) in emissions of material M by building i based on annual data of year t using reference building REF of the same type as i [t/(m² a)]

$EM_{i,M,t}$ emissions of material M by building i based on annual data of year t [t/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$\Delta EM_{i_1,M=CO2,REF,t=2010} = EM_{i_1=REF,M=CO2} - EM_{i_1,M=CO2,t=2010} = (23.8-15.7)*10^{-3} = 8.1*10^{-3}$$

$$\Delta EM_{i_1,M=CO2,REF} = EM_{i_1=REF,M=CO2} - EM_{i_1,M=CO2} = (23.8-18.1)*10^{-3} = 5.7*10^{-3}$$

$$\Delta EM_{i_2,M=CO2,REF} = EM_{i_2=REF,M=CO2} - EM_{i_2,M=CO2} = (23.8-18.1)*10^{-3} = 5.7*10^{-3}$$

$$\Delta EM_{i_3,M=CO2,REF} = EM_{i_3=REF,M=CO2} - EM_{i_3,M=CO2} = (23.8-18.1)*10^{-3} = 5.7*10^{-3}$$

1.3.2.3.2 *Set of buildings [AΔ3_2-AΔ5_2]*

$$\Delta EM_{I,I_{REF},M,t} = \frac{\sum_{i\in I} \Delta EM_{i,REF,t} * Cap_i}{\sum_{i\in I} Cap_i}$$

$\Delta EM_{I,I_{REF},M,t}$ Reduction (>0) in emissions of material M by set I of buildings based on annual data of year t using set I_{REF} of reference buildings [t/(m² a)]

$\Delta EM_{i,M,REF,t}$ Reduction (>0) in emissions of material M by building i based on annual data of year t using reference building REF of the same type as i [t/(m² a)]

Cap_i Floor area of building i [m²]

1.3.2.3.3 *Large-scale or building-integrated energy supply unit [AΔ3_3-AΔ5_3]*

$$\Delta EM_{s,M,EC,t,REF} = EM_{s=REF,M,EC,t^*} - EM_{s,M,EC,t}$$

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$\Delta EM_{s,M,EC,t,REF}$ reduction (>0) in emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [t/kWh]

$EM_{s,M,EC,t}$ emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t [t/kWh]

1.3.2.3.4 *Set of large-scale units [AΔ3_4-AΔ5_4]*

$$\Delta EM_{S,M,EC,t,S_{REF}} = \frac{\sum_{s \in S} \Delta EM_{s,M,EC,t,REF} * Out_{EC,s,t}}{\sum_{s \in S} Out_{EC,s,t}}$$

$\Delta EM_{S,M,EC,t,S_{REF}}$ Reduction (>0) in emissions of material M by set S of large-scale units for the production of the output of energy carrier EC (type IO) based on year t compared to set S_{REF} of reference units [t/kWh]

$\Delta EM_{s,M,EC,t,REF}$ Reduction (>0) in emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [t/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.4 Economic Indicators [BA1-BA2, BB1-BB3, BC1-BC5, BD1-BD3, BE1-BE4, CA1-CA7, CB1-CB5, CC1-CC10, CD1-CD6]

References:

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1.4.1 Investments, CONCERTO grants and other grants [BA1-BA2]

1.4.1.1 Investments [BA1]

References:

- European Committee of Construction Economists. (2008). CEEC Code of Measurement for Cost Planning.
- DIN 276-1:2008-12. (2008). Code DIN 276-1:2008-12 Building Costs - Part 1 Building Construction.
- VDI 2067 – Part 1: (2000) Economic efficiency of building installations - Fundamentals and economic calculation Economic efficiency of building installations.

1.4.1.1.1 *Individual buildings [BA1_1]*

Description: The investment in a new constructed building is defined as cumulated payments until the initial operation of the building. The investment in the refurbishment of a new building is defined as cumulated payments until the initial operation of the building after the refurbishment. A major problem is the completeness of the included components. In case of new constructions, construction payments, design and incidental payments as well as land and finance payments can be included. In case of refurbishments payments for energy efficiency measures, building-integrated renewable energy measures as well as non-energetic measures can be included. In order to enable the comparability between buildings, the same components have to be included.

Therefore, the components included can be specified in detail in the data collection sheets. Furthermore, the investments are related to the size of the building (e.g. gross floor area or net floor area, heated floor area) in order to improve the comparability.

Unit: €, €/m²

$$\bar{I}_{i,t_1} = \frac{I_{i,t_1}}{Cap_i}$$

$\bar{I}_{i,t_1}$	Specific investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€/m²]
I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]
Cap_i	Floor area of building i [m²]

Refurbishment

I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]

New construction

I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]

Reference building

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$I_{i_1,t_1=2005} = 1{,}000{,}000$$

$$I_{i_1=REF,t_1=2005} = 969{,}161$$

$$I_{i_2,t_1=2005} = 1{,}950{,}236$$

$$I_{i_2=REF,t_1=2005} = 1{,}913{,}272$$

$$I_{i_3,t_1=2005} = 2{,}249{,}764$$

$$I_{i_3=REF,t_1=2005} = 2{,}212{,}771$$

1.4.1.1.2 *Set of buildings [BA1_2]*

Description: Cf. individual buildings

Unit: €, €/m²

$$I_{I,t_1} = \sum_{i \in I} I_{i,t_1}$$

I_{I,t_1}	Investment for set I of buildings; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]
I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]

$$\bar{I}_{I,t_1} = \frac{\sum_{i \in I} I_{i,t_1}}{\sum_{i \in I} Cap_i}$$

$\bar{I}_{I,t_1}$	Specific investment for set I of buildings; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€/m²]
I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]
Cap_i	Floor area of building i [m²]

1.4.1.1.3 *Large-scale or building-integrated energy supply unit [BA1_3]*

Description: The investment in an energy supply unit is defined as cumulated payments until the initial operation of the energy supply unit. A major problem is the completeness of the included components. In case of large-scale energy supply units, among others delivery payments (incl. packaging and insurance), labour payments for fitting (incl. insurace and start-up), construction payments (incl. building, foundation, ...), payments for lot of land, payments for monitoring equipment (e.g. meters), planning payments, payments for approval procedure, payments for resource storage, payments for connection to district heating system can be included. In order to enable the comparability between energy supply units, the same components have to be included. Therefore, the components included can be specified in detail in the data collection sheets. Furthermore, investments are related to the maximum energy output of the energy supply unit (e.g. electrical capacity, heating capacity, cooling capacity) in order to improve the comparability.

Unit: €/kW (installed or peak)

Note: In the following, a **large-scale energy supply** unit encompasses in addition to the production plant as well the corresponding distribution, e.g. the district heating network and the domestic delivery station in case of district heating. The system boundaries on the output side of the **building-integrated energy supply unit** correspond to the interface to the primary heating circuit.

For a deeper analysis the corresponding distribution can be excluded from the consideration.

$$\bar{I}_{s,EC,t_1} = \frac{I_{s,t_1}}{Cap_{s,EC}}$$

$\bar{I}_{s,EC,t_1}$ Specific investment for energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)); construction in year t_1; investment is discounted to year t_1 [€/kW]

I_{s,t_1} Investment for energy supply unit s; construction in year t_1; investment is discounted to year t_1 [€]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

Large-scale energy supply units

I_{s,t_1} Investment for energy supply unit s (incl. the corresponding distribution); construction in year t_1; investment is discounted to year t_1 [€]

In case of district heating/cooling the investments for the "plant", the district heating/cooling network (excl. delivery stations) and the domestic delivery stations are determined separately and summed up.

Building-integrated energy supply units in case of *new constructions*

I_{s,t_1} Investment for energy supply unit s; construction in year t_1; investment is discounted to year t_1 [€]

Building-integrated energy supply units in case of *refurbishments*

I_{s,t_1} Investment for energy supply unit s; construction in year t_1; investment is discounted to year t_1 [€]

Reference unit EC=heat/electricity/cold (type IO)

Note: Figures of the reference energy supply units are calculated in an analogous way to the demonstration energy supply units. The corresponding figures are flagged with s=REF instead of s.

1.4.1.1.4 *Set of large-scale units [BA1_4]*

Description: Cf. large-scale or building-integrated energy supply unit
Unit: €/kW (installed or peak)

$$I_{S,t_1} = \sum_{s \in S} I_{s,t_1}$$

I_{S,t_1} Investment for set S of large-scale units; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]

I_{s,t_1} Investment for energy supply unit s; construction in year t_1; investment is discounted to year t_1 [€]

$$\bar{I}_{S,EC,t_1} = \frac{\sum_{s \in I} I_{s,t_1}}{\sum_{s \in S} Cap_{s,EC}}$$

$\bar{I}_{S,EC,t_1}$ Specific investment for set S of large-scale units regarding the output of energy carrier EC (type IO at the plant (!)); construction in year t_1; investment is discounted to year t_1 [€/kW]

I_{s,t_1} Investment for energy supply unit s; construction in year t_1; investment is discounted to year t_1 [€]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

1.4.1.2 Grants (CONCERTO and other grants) [BA2]

Description: The (here: investment-related) grant is defined as the part of the investment that is granted by a grant provider.

Individual buildings

Unit: €/m², %

Set of buildings

Unit: €/m², %

Large-scale or building-integrated energy supply units

Unit: €/kW, %

Set of large-scale units

Unit: €/kW, %

1.4.1.2.1 *Individual building [BA2_1]*

$$\overline{IG}_{i,t_1} = \frac{IG_{i,t_1}}{Cap_i}$$

$\overline{IG}_{i,t_1}$	Specific investment grants for building i discounted to year t_1 [€/m²]
IG_{i,t_1}	Investment grants for building i discounted to year t_1 [€]
Cap_i	Floor area of building i [m²]

$$IG_{i,t_1} = CIG_{i,t_1} + OIG_{i,t_1}$$

IG_{i,t_1}	Investment grants for building i discounted to year t_1 [€]
CIG_{i,t_1}	CONCERTO investment grants for building i discounted to year t_1 [€]
OIG_{i,t_1}	Other investment grants for building i discounted to year t_1 [€]
t_1	year of construction start of building i [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$IG_{i_1,t_1=2005} = 10{,}794$$

$$IG_{i_2,t_1=2005} = 12{,}937$$

$$IG_{i_3,t_1=2005} = 12{,}947$$

1.4.1.2.2 *Set of buildings [BA2_2]*

$$\overline{IG}_{i,t_1} = \frac{IG_{i,t_1}}{\sum_{i \in I} Cap_i}$$

$\overline{IG}_{I,t_1}$	Specific investment grants for set I of buildings discounted to year t_1 [€/m²]
IG_{I,t_1}	Investment grants for set I of buildings discounted to year t_1 [€]
Cap_i	Floor area of building i [m²]

$$IG_{i,t_1} = \sum_{i \in I} IG_{i,t_1}$$

IG_{I,t_1}	Investment grants for set I of buildings discounted to year t_1 [€]
IG_{i,t_1}	Investment grants for building i discounted to year t_1 [€]
t_1	Year of construction start of building i [-]

1.4.1.2.3 *Large-scale or building-integrated energy supply unit [BA2_3]*

$$\overline{IG}_{s,EC,t_1} = \frac{IG_{s,t_1}}{Cap_{s,EC}}$$

$\overline{IG}_{s,EC,t_1}$	Specific investment grants for energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) discounted to year t_1 [€/kW]
IG_{s,t_1}	Investment grants for energy supply unit s discounted to year t_1 [€]
$Cap_{s,EC}$	Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

$$IG_{s,t_1} = CIG_{s,t_1} + OIG_{s,t_1}$$

IG_{s,t_1}	Investment grants for energy supply unit s discounted to year t_1 [€]
CIG_{s,t_1}	CONCERTO investment grants for energy supply unit s discounted to year t_1 [€]
OIG_{s,t_1}	Other investment grants for energy supply unit s discounted to year t_1 [€]
t_1	year of construction start of energy supply unit s [-]

1.4.1.2.1 *Set of large-scale units [BA2_4]*

$$\overline{IG}_{S,EC,t_1} = \frac{IG_{S,t_1}}{\sum_{s \in S} Cap_{s,EC}}$$

$\overline{IG}_{S,EC,t_1}$ Specific investment grants for set S of large-scale units regarding the output of energy carrier EC (type IO at the plant (!)) discounted to year t_1 [€/kW]

IG_{S,t_1} Investment grants for set I of large-scale units discounted to year t_1 [€]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

$$IG_{S,t_1} = \sum_{s \in S} IG_{s,t_1}$$

IG_{S,t_1} Investment grants for set I of large-scale units discounted to year t_1 [€]

IG_{s,t_1} Investment grants for energy supply unit s discounted to year t_1 [€]

1.4.2 Total annual costs, sum of discounted total annual costs and annuity [BB1-BB5]

References:

- VDI 2067 – Part 1. (2000) Economic efficiency of building installations - Fundamentals and economic calculation Economic efficiency of building installations.
- VDI 6025. (1996) Economic calculations for capital goods and plants.
- DIN EN 15459:2007. Energy performance of buildings – Economic evaluation procedure for energy systems in buildings.
- DIN 18960:2008-02. (2008). User costs of buildings.

Relation of cash-flows and costs: It is assumed that - apart from capital-related costs and revenues – revenues and costs coincide with cash-flows from a time perspective. Concerning capital-related costs and revenues it is assumed that investments and grants cause a single cash-flow at the beginning of the construction works. Other capital-related costs and revenues (e.g. repairs) coincide with cash-flows from a time perspective.

1.4.2.1 Total annual costs [BB1]

Description: The total annual costs are defined as sum of capital-related annual costs, requirement-related costs, operation-related costs and other costs. These costs (can) vary for each year. Capital-related costs encompass depreciation, interests and repairs caused by the investment. Requirement-related costs include power costs, auxiliary power costs, fuel costs, costs for operating resources and in some cases external costs. Operation-related costs include among other things the costs of using the installation and costs of servicing and inspection. Other costs include costs of insurance, general output, uncollected taxes etc. The total annual costs are related to the considered interval of time (year). **To make different objects comparable the same types of costs have to be included in the calculation.**

Unit: €/a

1.4.2.1.1 *Individual building [BB1_1]*

$$ATC_{i,t,t'} = ACRC_{i,t'} + ARRC_{i,t,t'} + AORC_{i,t,t'} + AOC_{i,t,t'} + AEC_{i,t,t'}$$

$ATC_{i,t,t'}$	Total annual costs of building i in year t' based on data of year t [€/a]
$ACRC_{i,t'}$	Annual capital-related costs of building i in year t' [€/a]
$ARRC_{i,t,t'}$	Annual requirement-related costs of building i in year t' based on energy flows of year t [€/a]
$AORC_{i,t,t'}$	Annual operation-related costs of building i in year t' based on data of year t [€/a]
$AOC_{i,t,t'}$	Annual other costs of building i in year t' based on data of year t [€/a]
$AEC_{i,t,t'}$	Annual external costs of building i in year t' based on data of year t [€/a]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$ATC_{i_1,t=2010,t'} = 61{,}000 + 16{,}180 = 77{,}180$$

$$ATC_{i_1,t'} = 61{,}000 + 17{,}326 = 78{,}326$$

$$ATC_{i_1=REF,t'} = 59{,}119 + 23{,}842 = 82{,}961$$

$$ATC_{i_2,t'} = 118.964 + 19{,}118 = 138{,}082$$

$$ATC_{i_2=REF,t'} = 116{,}710 + 26{,}308 = 143{,}018$$

$$ATC_{i_3,t'} = 137.236 + 22{,}054 = 152{,}290$$

$$ATC_{i_3=REF,t'} = 134{,}979 + 30{,}349 = 165{,}328$$

Reference building

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

1.4.2.1.2 *Set of buildings [BB1_2]*

$$ATC_{I,(t),t'} = \sum_{i \in I} ATC_{i,t,t'}$$

$ATC_{I,(t),t'}$ Total annual costs of set I of buildings in year t' based on data of year (t) [€/a]

$ATC_{i,t,t'}$ Total annual costs of building i in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.1.3 *Large-scale or building-integrated energy supply units [BB1_3]*

$$ATC_{s,t,t'} = ACRC_{s,t'} + ARRC_{s,t,t'} + AORC_{s,t,t'} + AOC_{s,t,t'} + AEC_{s,t,t'}$$

$ATC_{s,t,t'}$ Total annual costs of energy supply unit s in year t' based on data of year t [€/a]

$ACRC_{s,t'}$ Annual capital-related costs of energy supply unit s in year t' [€/a]

$ARRC_{s,t,t'}$ Annual requirement-related costs of energy supply unit s in year t' based on energy flows of year t [€/a]

$AORC_{s,t,t'}$ Annual operation-related costs of energy supply unit s in year t' based on data of year t [€/a]

$AOC_{s,t,t'}$ Annual other costs of energy supply unit s in year t' based on data of year t [€/a]

$AEC_{s,t,t'}$ Annual external costs of energy supply unit s in year t' based on data of year t [€/a]

Reference unit EC=heat/electricity/cold (type P)

Note: Figures of the reference energy supply units are calculated in an analogous way to the demonstration energy supply units. The corresponding figures are flagged with s=REF instead of s.

1.4.2.1.4 *Set of large-scale units [BB1_4]*

$$ATC_{S,(t),t'} = \sum_{s \in S} ATC_{s,t,t'}$$

$ATC_{S,(t),t'}$ Total annual costs of set S of energy supply units in year t' based on data of year (t) [€/a]

$ATC_{s,t,t'}$ Total annual costs of energy supply unit s in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.2 Sum of discounted total annual costs [BB2]

Description: The sum of discounted total annual costs is calculated over a period of time. The latter can be determined by the time of initial operation of the building (after the construction or after the refurbishment) or the energy supply unit and the calculated service life.

1.4.2.2.1 *Individual buildings [BB2_1]*

In order to enable the comparability between buildings, the sum of discounted total annual costs is related to the size of the building (e.g. gross floor area or net floor area, heated floor area).

Unit: €/m²

$$\overline{STC}_{i,t,t_0,t_1,t_2} = \frac{\sum_{t'=t_2}^{t_2+EL_{[i]}-1} \left(1 \big/ (1+r)^{t'-t_0} * ATC_{i,t,t'} \right)}{Cap_i}$$

$\overline{STC}_{i,t,t_0,t_1,t_2}$ Sum of discounted total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/m²]

$ATC_{i,t,t'}$ Total annual costs of building i in year t' based on data of year t [€/a]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

t_1 Year of construction start of building i

t_2 Year of construction end of building i

r Interest rate for calculations [-]

1.4.2.2.2 *Set of buildings [BB2_2]*

In order to enable the comparability between sets of buildings, the sum of discounted total annual costs is related to the size of the buildings (e.g. gross floor area or net floor area, heated floor area).

Unit: €/m²

$$\overline{STC}_{i,t,t_0,t_1,t_2} = \frac{\sum_{i \in I} \overline{STC}_{i,t,t_0,t_1,t_2} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\overline{STC}_{I,(t),t_0,(t_1),(t_2)}$ Sum of discounted total annual costs of building i based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 [€/m²]

$\overline{STC}_{i,t,t_0,t_1,t_2}$ Sum of discounted total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/m²]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.2.3 *Large-scale or building-integrated energy supply units [BB2_3]*

In order to enable the comparability between energy supply units, the sum of discounted total annual costs is related to the energy output of the energy supply unit (e.g. electricity, heat, cold).

Unit: €/kWh

$$\overline{STC}_{s,EC,t,t_0} = \frac{\frac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'} (Out_{EC',s,t} * EX_{s,EC'})} * STC_{s,t,t_0}}{EL_{[s]} * Out_{EC,s,t}}$$

$\overline{STC}_{s,EC,t,t_0}$: Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

STC_{s,t,t_0} Sum of discounted total annual costs of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

$EX_{s,EC}$ Exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Sub-formula:

Unit: €

$$STC_{s,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[s]}} (1/(1+r)^{t'-t_0} * ATC_{s,t,t'})$$

STC_{s,t,t_0} Sum of discounted total annual costs of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

$ATC_{s,t,t'}$ Total annual costs of energy supply unit s in year t' based on data of year t [€/a]

t_1 year of construction start of energy supply unit s

t_2 year of construction end of energy supply unit s

r Interest rate for calculations [-]

Reference unit EC=heat/electricity/cold (type P)

Note: Figures of the reference energy supply units are calculated in an analogous way to the demonstration energy supply units. The corresponding figures are flagged with s=REF instead of s.

1.4.2.2.4 *Set of large-scale units [BB2_4]*

In order to enable the comparability between sets of large-scale units, the sum of discounted total annual costs is related to the energy output of the energy supply unit (e.g. electricity, heat, cold).

Unit: €/kWh

$$\overline{STC}_{S,EC,(t),t_0} = \frac{\sum_{s\in S} \overline{STC}_{s,EC,t,t_0} * EL_{[s]} * Out_{EC,s,t}}{\sum_{s\in S} EL_{[s]} * Out_{EC,s,t}}$$

$\overline{STC}_{S,EC,(t),t_0}$ Sum of discounted total annual costs of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€/kWh]

$\overline{STC}_{s,EC,t,t_0}$: Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.3 Annuity of total annual costs [BB3]

Description: The annuity of the total annual costs is **defined here** as annuity that corresponds to the sum of discounted total annual costs. Thereby, sum of discounted total annual costs and annuity are based on the same period of time. Thus, the annuity represents the "average" of the total annual costs.

1.4.2.3.1 *Individual building [BB3_1]*

Unit: €/(m² a)

$$\overline{TC}_{i,t,t_0,t_1,t_2} = \frac{\sum_{t'=t_2}^{t_2+EL_{[i]}-1} \left(1/(1+r)^{t'-t_0} * ATC_{i,t,t'}\right)}{EL_{[i]} * Cap_i}$$

$\overline{TC}_{i,t,t_0,t_1,t_2}$ Annuity of total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/(m² a)]

$ATC_{i,t,t'}$ Total annual costs of building i in year t' based on data of year t [€/a]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

t_1 Year of construction start of building i

t_2 Year of construction end of building i

r Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$\overline{TC}_{i_1,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{\sum_{t'=2006}^{2045} (1/(1+0.05)^{t'-2005} * 77{,}180)}{40 * 1{,}605} = 20.63$$

$$\overline{TC}_{i_1,t_0=2005,t_1=2005,t_2=2006} = \frac{\sum_{t'=2006}^{2045} (1/(1+0.05)^{t'-2005} * 78{,}326)}{40 * 1{,}605} = 20.93$$

$$\overline{TC}_{i_1=REF,t_0=2005,t_1=2005,t_2=2006} = \frac{\sum_{t'=2006}^{2045} (1/(1+0.05)^{t'-2005} * 82.961)}{40 * 1{,}605} = 22.17$$

$$\overline{TC}_{i_2,t_0=2005,t_1=2007,t_2=2008} = \frac{\sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 138{,}082)}{40 * 1{,}771} = 30.34$$

$$\overline{TC}_{i_2=REF,t_0=2005,t_1=2007,t_2=2008} = \frac{\sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 143{,}018)}{40 * 1{,}771} = 31.42$$

$$\overline{TC}_{i_3,t_0=2005,t_1=2007,t_2=2008} = \frac{\sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 152{,}290)}{40 * \frac{\sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 165{,}328)}{40 * 2{,}043}} = 30.34$$

$$\overline{TC}_{i_3=REF,t_0=2005,t_1=2007,t_2=2008} = \frac{\sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 165{,}328)}{40 * 2{,}043} = 31.49$$

Reference building

Note: Figures of the reference buildings are calculated in an analogous way to the demonstration buildings. The corresponding figures are flagged with i=REF instead of i.

1.4.2.3.2 *Set of buildings [BB3_2]*

Unit: €/(m² a)

$$\overline{TC}_{I,(t).t_0,(t_1),(t_2)} = \frac{\sum_{i \in I} \overline{TC}_{i,t,t_0,t_1,t_2} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\overline{TC}_{I,(t).t_0,(t_1),(t_2)}$ Annuity of total annual costs of set I of buildings based on annual data of the year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 [€/(m² a)]

$\overline{TC}_{i,t,t_0,t_1,t_2}$ Annuity of total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/(m² a)]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.3.3 *Large-scale or building-integrated energy supply units [BB3_3]*

Unit: €/a

Not required as the interpretation of this figure would be difficult.

1.4.2.3.4 *Set of large-scale units [BB3_4]*

Unit: €/a

Not required as the interpretation of this figure would be difficult.

1.4.2.4 Capital-related annual costs [BC1]

"In this case, the investments in operational system parts and the associated components (see Table A1) are to be determined, e.g. from economic calculations or tender documents, and subdivided by system part into Tables A2 to A4, in order to be able to use the values listed there for the calculated service life and repair costs." [VDI 2067]

Examples: Installation components, e.g. heat generators, radiators, fans, driving motors etc., Structural installations, e.g. technical centres and chimneys, Sound- and heat-proofing measures, Connection costs, **Repairs** [VDI 2067]

1.4.2.4.1 *Individual building [BC1_1]*

$$ACRC_{i,t'} = I_{i,t_1} * ((1+r)^{t_2-t_1} * \frac{(1+r)^{EL_{[i]}} * r}{(1+r)^{EL_{[i]}} - 1} + d_{repair,t'} * f_{repair,[i]}); t' = t_2,...,t_2 + EL_{[i]}$$

$ACRC_{i,t'}$ Annual capital-related costs of building i in year t' [€/a]

I_{i,t_1} Investment for building i discounted to year t_1

t_1 Year of construction start of building i

t_2 Year of construction end of building i

$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]
$f_{repair,[i]}$	Factor for repairs as share of the investment per year [1/a]
$d_{repair,t'}$	Price-index for repair payments in year t' [-]; $d_{repair,t_0} = 1$
r	Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$ACRC_{i_1,t'} = 1{,}000{,}000 * ((1+0.05)^{2006-2005} * \frac{(1+0.05)^{40} * 0.05}{(1+0.05)^{40} - 1}) = 1{,}000{,}000 * 0.061 = 61{,}000$$

$$ACRC_{i_1=REF,t'} = 969{,}161 * 0.061 = 59{,}119$$

$$ACRC_{i_2,t'} = 1{,}959{,}236 * 0.061 = 118.964$$

$$ACRC_{i_2=REF,t'} = 1{,}913{,}272 * 0.061 = 116{,}710$$

$$ACRC_{i_3,t'} = 2{,}249{,}764 * 0.061 = 137.236$$

$$ACRC_{i_3=REF,t'} = 2{,}212{,}771 * 0.061 = 134.979$$

1.4.2.4.2 *Set of buildings [BC1_2]*

$$ACRC_{I,t'} = \sum_{i \in I} ACRC_{i,t'}$$

$ACRC_{I,t'}$	Annual capital-related costs of set I of buildings in year t' [€/a]
$ACRC_{i,t'}$	Annual capital-related costs of building i in year t' [€/a]

1.4.2.4.3 *Large-scale or building-integrated energy supply unit [BC1_3]*

$$ACRC_{s,t'} = I_{s,t_1} * ((1+i)^{t_2-t_1} * \frac{(1+i)^{EL_{[s]}} * i}{(1+i)^{EL_{[s]}} - 1} + d_{repair,t'} * f_{repair,[s]}); t' = t_2,...,t_2 + EL_{[s]}$$

$ACRC_{s,t'}$	Annual capital-related costs of energy supply unit s in year t' [€/a]
I_{s,t_1}	Investment for energy supply unit s discounted to year t_1
t_1	Year of construction start of energy supply unit s
t_2	Year of construction end of energy supply unit s
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]
$f_{repair,[s]}$	Factor for repairs as share of the investment per year [1/a]

$d_{repair,t'}$ Price-index for repair payments in year t' [-]; $d_{repair,t_0} = 1$

1.4.2.4.4 *Large-scale units [BC1_4]*

$$ACRC_{S,t'} = \sum_{s \in S} ACRC_{s,t'}$$

$ACRC_{S,t'}$ Annual capital-related costs of set S of energy supply units in year t' [€/a]

$ACRC_{s,t'}$ Annual capital-related costs of energy supply unit s in year t' [€/a]

1.4.2.5 Requirement-related costs (e.g. energy supply costs) [BC2]

Examples: Power costs (basic and kilowatt hour rates), Auxiliary power costs, Fuel costs (lubricants, additives, chemical etc.) [VDI 2067]

1.4.2.5.1 *Individual building [BC2_1]*

$$ARRC_{i,t,t'} = (\sum_{EC} \sum_{AA=AA1}^{AA4} (p_{EC,i,t} * In_{EC,AA,i,t}) + ANERRC_{i,t}) * \frac{d_{requirement,t'}}{d_{requirement,t}}$$

$ARRC_{i,t,t'}$ Annual requirement-related costs of building i in year t' based on energy flows of year t [€/a]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$p_{EC,i,t}$ Price of energy carrier (or source) EC (type IO) entering building i in year t [€/kWh]

$ANERRC_{i,t}$ Annual non-energy-requirement-related costs of building i in year t [€/a]

$d_{requirement,t'}$ Index for requirement(consumption)-related costs in year t' [-]; $d_{requirement,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$ARRC_{i_1,t=2010,t'} = (96{,}139.5 * 0.07 + 20{,}544 * 0.07 + 33{,}384 * 0.24) = 16{,}180$$

$$ARRC_{i_1,t'} = (89{,}880 * 0.07 + 20{,}062.5 * 0.07 + 40{,}125 * 0.24) = 17{,}326$$

$$ARRC_{i_1=REF,t'} = (144{,}450 * 0.07 + 20{,}062.5 * 0.07 + 51{,}360 * 0.24) = 23{,}842$$

$$ARRC_{i_2,t'} = (99{,}176 * 0.07 + 22137.5 * 0.07 + 44{,}275 * 0.24) = 19{,}118$$

$$ARRC_{i_2=REF,t'} = (159{,}390 * 0.07 + 22137.5 * 0.0.7 + 56{,}672 * 0.25) = 26{,}308$$

$$ARRC_{i_3,t'} = (114{,}408 * 0.07 + 25{,}537.5 * 0.07 + 51{,}075 * 0.24) = 22{,}054$$

$$ARRC_{i_3=REF,t'} = (183{,}870 * 0.07 + 25{,}537.5 * 0.07 + 65{,}376 * 0.24) = 30{,}349$$

1.4.2.5.2 *Set of buildings [BC2_2]*

$$ARRC_{I,(t),t'} = \sum_{i \in I} ARRC_{i,t,t'}$$

$ARRC_{I,(t),t'}$ Annual requirement-related costs of set I of buildings in year t' based on energy flows of year (t) [€/a]

$ARRC_{i,t,t'}$ Annual requirement-related costs of building i in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.5.3 *Large-scale or building-integrated energy supply unit [BC2_3]*

$$ARRC_{s,t,t'} = \left(\sum_{EC} (p_{EC,s,t} * In_{EC,s,t}) + ANERRC_{s,t}\right) * \frac{d_{requirement,t'}}{d_{requirement,t}}$$

$ARRC_{s,t,t'}$ Annual requirement-related costs of energy supply unit s in year t' based on energy flows of year t [€/a]

$In_{EC,s,t}$ Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy supply unit s in year t [kWh/a]

$p_{EC,s,t}$ Price of energy carrier (or source) EC (type IO) entering energy supply unit s in year t [€/kWh]

$ANERRC_{s,t}$ Annual non-energy-requirement-related costs of energy supply unit s in year t [€/a]

$d_{requirement,t'}$ Index for requirement(consumption)-related costs in year t' [-]; $d_{requirement,t_0} = 1$

1.4.2.5.4 *Set of large-scale units [BC2_4]*

$$ARRC_{S,(t),t'} = \sum_{s \in S} ARRC_{s,t,t'}$$

$ARRC_{S,(t),t'}$ Annual requirement-related costs of set S of energy supply units in year t' based on energy flows of year (t) [€/a]

$ARRC_{s,t,t'}$ Annual requirement-related costs of energy supply unit s in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.6 Operation-related costs (e.g. maintenance, staff) [BC3]

"The operation-related costs include among other things the costs of using the installation and costs of servicing and inspection, see also Table A1." [VDI 2067]
Examples: Operation, Cleaning, **Servicing**, Inspection [VDI 2067]

1.4.2.6.1 *Individual building [BC3_1]*

$$AORC_{i,t,t'} = AORC_{i,t} * \frac{d_{operation,t'}}{d_{operation,t}}$$

$AORC_{i,t,t'}$ Annual operation-related costs of building i in year t' based on data of year t [€/a]

$AORC_{i,t}$ Annual operation-related costs of building i in year t [€/a]

$d_{operation,t'}$ index for operation-related costs in year t' [-]; $d_{operation,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$AORC_{i,t,t'} = 0$$

1.4.2.6.2 *Set of buildings [BC3_2]*

$$AORC_{I,(t),t'} = \sum_{i \in I} AORC_{i,t,t'}$$

$AORC_{I,(t),t'}$ Annual operation-related costs of set I of buildings in year t' based on energy flows of year (t) [€/a]

$AORC_{i,t,t'}$ Annual operation-related costs of building i in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.6.3 *Large-scale or building-integrated energy supply unit [BC3_3]*

$$AORC_{s,t,t'} = AORC_{s,t} * \frac{d_{operation,t'}}{d_{operation,t}}$$

$AORC_{s,t,t'}$ Annual operation-related costs of energy supply unit s in year t' based on data of year t [€/a]

$AORC_{s,t}$ Annual operation-related costs of energy supply unit s in year t [€/a]

$d_{operation,t'}$ index for operation-related costs in year t' [-]; $d_{operation,t_0} = 1$

1.4.2.6.4 *Set of large-scale units [BC3_4]*

$$AORC_{S,(t),t'} = \sum_{s \in S} AORC_{s,t,t'}$$

$AORC_{I,(t),t'}$ Annual operation-related costs of set S of energy supply units in year t' based on energy flows of year (t) [€/a]

$AORC_{s,t,t'}$ Annual operation-related costs of energy supply unit s in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.7 Other Costs [BC4]

"These include costs of insurance, general output, uncollected taxes, shared administration costs and profits, in so far as these can be calculated in from the heat supplier, see also Table A1." [VDI 2067]

Examples: Insurance, Taxes, General effort, Shared administration costs, Profit and loss [VDI 2067]

1.4.2.7.1 *Individual building [BC4_1]*

$$AOC_{i,t,t'} = AOC_{i,t} * \frac{d_{other,t'}}{d_{other,t}}$$

$AOC_{i,t,t'}$ Annual other costs of building i in year t' based on data of year t [€/a]

$AOC_{i,t}$ Annual other costs of building i in year t [€/a]

$d_{other,t'}$ index for other costs in year t' [-]; $d_{other,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$AOC_{i,t,t'} = 0$$

1.4.2.7.2 *Set of buildings [BC4_2]*

$$AOC_{I,(t),t'} = \sum_{i \in I} AOC_{i,t,t'}$$

$AOC_{I,(t),t'}$	Annual other costs of set I of buildings in year t' based on energy flows of year (t) [€/a]
$AOC_{i,t,t'}$	Annual other costs of building i in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.7.3 *Large-scale or building-integrated energy supply unit [BC4_3]*

$$AOC_{s,t,t'} = AOC_{s,t} * \frac{d_{other,t'}}{d_{other,t}}$$

$AOC_{s,t,t'}$	Annual other costs of energy supply unit s in year t' based on data of year t [€/a]
$AOC_{s,t}$	Annual other costs of energy supply unit s in year t [€/a]
$d_{other,t'}$	index for other costs in year t' [-]; $d_{other,t_0} = 1$

1.4.2.7.4 *Set of large-scale units [BC4_4]*

$$AOC_{S,(t),t'} = \sum_{s \in S} AOC_{s,t,t'}$$

$AOC_{S,(t),t'}$	Annual other costs of set S of energy supply units in year t' based on energy flows of year (t) [€/a]
$AOC_{s,t,t'}$	Annual other costs of energy supply unit s in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.8 External costs [BC5]

References:

- Umweltbundesamt. (2007) Ökonomische Bewertung von Umweltschäden – Methodenkonvention zur Schätzung externer Umweltkosten.

1.4.2.8.1 *Individual building [BC5_1]*

$$AEC_{i,t,t'} = (EM_{i,M=CO_2equ.,t} * ex_{M=CO_2equ.,t'} + EM_{i,M=SO_2,t} * ex_{M=SO_2,t'} + EM_{i,M=NO_x,t} * ex_{M=NO_x,t'}$$
$$+ EM_{i,M=PM10,t} * ex_{M=PM10,t'} + EM_{i,M=PM2.5,t'} * ex_{M=PM2.5,t'}) * Cap_i$$

$AEC_{i,t,t'}$ Annual external costs of building i in year t' based on data of year t [€/a]

$EM_{i,M,t}$ Emissions of material M by building i based on annual data of year t [t/(m² a)]

$ex_{M,t'}$ External costs of emissions of material M in year t' [€/t]

Cap_i Floor area of building i [m²]

1.4.2.8.2 *Set of buildings [BC5_2]*

$$AEC_{I,(t),t'} = \sum_{i \in I} AEC_{i,t,t'}$$

$AEC_{I,(t),t'}$ Annual external costs of set I of buildings in year t' based on data of year (t) [€/a]

$AEC_{i,t,t'}$ Annual external costs of building i in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.2.8.3 *Large-scale or building-integrated energy supply unit [BC5_3]*

$$AEC_{s,t,t'} = EM_{s,M=CO_2equ.,t} * ex_{M=CO_2equ.,t'} + EM_{s,M=SO_2,t} * ex_{M=SO_2,t'} + EM_{s,M=NO_x,t} * ex_{M=NO_x,t'}$$
$$+ EM_{s,M=PM10,t} * ex_{M=PM10,t'} + EM_{s,M=PM2.5,t'} * ex_{M=PM2.5,t'}$$

$AEC_{s,t,t'}$ Annual external costs of energy supply unit s in year t' based on data of year t [€/a]

$EM_{s,M,t}$ Emissions of material M by energy supply unit s in year t [t/a]

$ex_{M,t'}$ External costs of emissions of material M in year t' [€/t]

1.4.2.8.4 *Set of large-scale units [BC5_4]*

$$AEC_{S,(t),t'} = \sum_{s \in S} AEC_{s,t,t'}$$

$AEC_{S,(t),t'}$ Annual external costs of set S of energy supply units in year t' based on data of year (t) [€/a]

$AEC_{s,t,t'}$ Annual external costs of energy supply unit s in year t' based on data of year t [€/a]

1.4.3 Total annual revenues, sum of discounted annual revenues and annuity [BD1-BD3]

References:

- VDI 2067 – Part 1. (2000) Economic efficiency of building installations - Fundamentals and economic calculation Economic efficiency of building installations.
- VDI 6025. (1996) Economic calculations for capital goods and plants.

Relation of cash-flows and revenues: It is assumed that - apart from capital-related costs and revenues – revenues and costs coincide with cash-flows from a time perspective. Concerning capital-related costs and revenues it is assumed that investments and grants cause a single cash-flow at the beginning of the construction works. Other capital-related costs and revenues (e.g. repairs) coincide with cash-flows from a time perspective.

1.4.3.1 Total annual revenues [BD1]

Description: The total annual revenues are defined as sum of capital-related revenues, requirement-related revenues, operation-related revenues and other revenues. These revenues (can) vary for each year. Capital-related revenues encompass temporally distributed investment-related grants. Requirement-related revenues include sales revenues and grants for electricity, heat, cold and other. Operation-related revenues and other revenues are in this context of minor importance. The total annual revenues are related to the considered interval of time (year).

Unit: €/a

The calculation procedure is not described here, as the interpretation of these non-aggregated total annual revenues is difficult and the total annual revenues are not required for the calculation of other indicators. Instead, the sum of discounted annual revenues is calculated directly without using the total annual revenues as intermediate step.

For the calculation of other indicators the total annual revenues are split into grant revenues, energy-sales revenues and non-grant-non-energy-sales revenues. For these revenues, the sum of discounted annual revenues and the annuity are calculated.

1.4.3.2 Sum of discounted annual revenues [BD2]

Description: The sum of discounted annual revenues is calculated over a period of time. The latter can be determined by the time of initial operation of the building (after the construction or after the refurbishment) or the energy supply unit and the calculated service life.

Unit: €, €/kWh

1.4.3.2.1 *Individual buildings [BD2_1]*

1.4.3.2.1.1 Total revenues [BD2_1_1]

$$STR_{i,t,t_0} = SER_{i,,el.,t,t_0} + SGR_{i,t,t_0,spec.} + SNGNER_{i,t,t_0}$$

STR_{i,t,t_0}	Sum of discounted total annual revenues of building i based on data of year t and with discount base in year t_0 [€]
$SER_{i,el.,t,t_0}$	Sum of discounted annual energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]
SGR_{i,t,t_0}	Sum of discounted annual grant revenues of building i over the expected-lifetime based on data of year t and with discount base in year t_0 [€]
$SNGNER_{i,t,t_0}$	Sum of discounted annual non-energy-sales non-grant revenues of building i based on data of year t and with discount base in year t_0 [€]

1.4.3.2.1.2 Grant revenues [BD2_1_2]

$$SGR_{i,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[i]}} (1/(1+r)^{t'-t_0} * (ACRR_{i,t'} + ARRGR_{i,t,t'}))$$

SGR_{i,t,t_0}	Sum of discounted annual grant revenues of building i over the expected-lifetime based on data of year t and with discount base in year t_0 [€]
$ACRR_{i,t'}$	Annual capital-related revenues of building i in year t' [€/a]
$ARRGR_{i,t,t'}$	Annual requirement-related grant revenues of building i in year t' based on energy flows of year t [€/a]
t_2	Year of construction end of building i
r	Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices; assumed interest rate of 5%

$$SGR_{i_1,t=2010,t_0=2005} = \sum_{t'=2006}^{2045} (1/(1+0.05)^{t'-2005} * 658) = 11{,}298$$

$$SGR_{i_1,t_0=2005} = \sum_{t'=2006}^{2045} (1/(1+0.05)^{t'-2005} * 658) = 11{,}298$$

$$SGR_{i_1=REF,t_0=2005} = 0$$

$$SGR_{i_2,t_0=2005} = \sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 658) = 12{,}282$$

$$SGR_{i_2=REF,t_0=2005} = 0$$

$$SGR_{i_3,t_0=2005} = \sum_{t'=2008}^{2047} (1/(1+0.05)^{t'-2005} * 658) = 12{,}292$$

$$SGR_{i_3=REF,t_0=2005} = 0$$

1.4.3.2.1.3 Non-grant non-energy-sales revenues [BD2_1_3]

$$SNGNER_{i,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[i]}} (1/(1+r)^{t'-t_0} * (ARRNGNER_{i,t,t'} + AORR_{i,t,t'} + AOR_{i,t,t'}))$$

$SNGNER_{i,t,t_0}$ Sum of discounted annual non-grant non-energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]

$ARRNGNER_{i,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of building i in year t′ based on energy flows of year t [€/a]

$AORR_{i,t,t'}$ Annual operation-related revenues of building i in year t′ based on data of year t [€/a]

$AOR_{i,t,t'}$ Annual other revenues of energy supply unit s in year t′ based on data of year t [€/a]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

t_2 Year of construction end of energy supply unit s

r Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; based on assumptions because of lacking data.

$$SNGNER_{i,t,t_0,NPV} = 0$$

1.4.3.2.1.4 Energy-sales revenues [BD2_1_4]

$$SER_{i,el.,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[i]}} (1/(1+r)^{t'-t_0} * ARRER_{i,t,t'})$$

$SER_{i,el.,t,t_0}$	Sum of discounted annual energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]
$ARRER_{i,t,t'}$	Annual requirement-related energy-sales revenues of building i in year t' based on energy flows of year t [€/a]
t_2	Year of construction end of energy supply unit s
r	Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; based on assumptions because of lacking data.

$$SER_{i,el.,t,t_0} = 0$$

1.4.3.2.2 *Set of buildings [BD2_2]*

1.4.3.2.2.1 Total revenues [BD2_2_1]

$$STR_{I,(t),t_0} = \sum_{i \in I} STR_{i,t,t_0}$$

$STR_{I,(t),t_0}$	Sum of discounted total annual revenues of set I of buildings based on data of year (t) and with discount base in year t_0 [€]
STR_{i,t,t_0}	Sum of discounted total annual revenues of building i based on data of year t and with discount base in year t_0 [€]

1.4.3.2.2.2 Grant revenues [BD2_2_2]

$$SGR_{I,(t),t_0} = \sum_{i \in I} SGR_{i,t,t_0}$$

$SGR_{I,(t),t_0}$	Sum of discounted annual grant revenues of set I of buildings over the expected-lifetime based on data of year (t) and with discount base in year t_0 [€]
SGR_{i,t,t_0}	Sum of discounted annual grant revenues of building i over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

1.4.3.2.2.3 Non-grant non-energy-sales revenues [BD2_2_3]

$$SNGNER_{I,(t),t_0} = \sum_{i \in I} SNGNER_{i,t,t_0}$$

$SNGNER_{I,(t),t_0}$ Sum of discounted annual non-grant non-energy-sales revenues of set I of buildings based on data of year (t) and with discount base in year t_0 [€]

$SNGNER_{i,t,t_0}$ Sum of discounted annual non-grant non-energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]

1.4.3.2.2.4 Energy-sales revenues [BD2_2_4]

$$SER_{I,el.,(t),t_0} = \sum_{i \in I} SER_{i,el.,t,t_0}$$

$SER_{I,el.,(t),t_0}$ Sum of discounted annual energy-sales revenues of set I of buildings based on data of year (t) and with discount base in year t_0 [€]

$SER_{i,el.,t,t_0}$ Sum of discounted annual energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]

1.4.3.2.3 *Large-scale or building-integrated energy supply units [BD2_3]*

In order to enable the comparability between energy supply units, the sum of discounted annual revenues is related to the energy output of the energy supply unit (e.g. electricity, heat, cold).

Unit: €/kWh

1.4.3.2.3.1 Total revenues [BD2_3_1]

$$\overline{STR}_{s,EC,t,t_0} = \overline{SER}_{s,EC,t,t_0} + \overline{SGR}_{s,EC,t,t_0} + \overline{SNGNER}_{s,EC,t,t_0}$$

$\overline{STR}_{s,EC,t,t_0}$ Sum of discounted total annual revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SER}_{s,EC,t,t_0}$ Sum of discounted energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SNGNER}_{s,EC,t,t_0}$ Total non-grant non-energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

1.4.3.2.3.2 Grant revenues [BD2_3_2]

$$\overline{SGR}_{s,EC,t,t_0} = \frac{\dfrac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'} (Out_{EC',s,t} * EX_{s,EC'})} * SGR_{s,t,t_0}}{EL_{[s]} * Out_{EC,s,t}}$$

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

SGR_{s,t,t_0} Sum of discounted grant revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

$EX_{s,EC}$ exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Sub-formula:

Unit: €

$$SGR_{s,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[s]}} \left(1 / (1+r)^{t'-t_0} * (ACRR_{s,t'} + ARRGR_{s,t,t'})\right)$$

SGR_{s,t,t_0} Sum of discounted grant revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

$ACRR_{s,t'}$ Annual capital-related revenues of energy supply unit s in year t' [€/a]

$ARRGR_{s,t,t'}$ Annual requirement-related grant revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

t_2 year of construction end of energy supply unit s

r Interest rate for calculations [-]

1.4.3.2.3.3 Non-grant non-energy-sales revenues [BD2_3_3]

$$\overline{SNGNER}_{s,EC,t,t_0} = \frac{\dfrac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'}(Out_{EC',s,t} * EX_{s,EC'})} * SNGNER_{s,t,t_0}}{EL_{[s]} * Out_{EC,s,t}}$$

$\overline{SNGNER}_{s,EC,t,t_0}$ Sum of discounted non-grant non-energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$SNGNER_{s,t,t_0}$ Sum of discounted non-grant non-energy-sales revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

$EX_{s,EC}$ exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Sub-formula:

Unit: €

$$SNGNER_{s,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[s]}} (1/(1+r))^{t'-t_0} * (ARRNGNER_{s,t,t'} + AORR_{s,t,t'} + AOR_{s,t,t'})$$

$SNGNER_{s,t,t_0}$ Sum of discounted non-grant non-energy-sales revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

$ARRNGNER_{s,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

$AORR_{s,t,t'}$ Annual operation-related revenues of energy supply unit s in year t' based on data of year t [€/a]

$AOR_{s,t,t'}$	Annual other revenues of energy supply unit s in year t' based on data of year t [€/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]
t_2	Year of construction end of energy supply unit s
r	Interest rate for calculations [-]

1.4.3.2.3.1 Energy-sales revenues [BD2_3_4]

$$\overline{SER}_{s,EC,t,t_0} = \frac{SER_{s,EC,t,t_0}}{EL_{[s]} * Out_{EC,s,t}}$$

$\overline{SER}_{s,EC,t,t_0}$	Sum of discounted energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]
SER_{s,EC,t,t_0}	Sum of discounted energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€]
$Out_{EC,s,t}$	output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]

<u>Sub-formula:</u>

Unit: €

$$SER_{s,EC,t,t_0} = \sum_{t'=t_2}^{t_2+EL_{[s]}} \left(1 \big/ (1+r)^{t'-t_0} * ARRER_{s,EC,t,t'} \right)$$

SER_{s,EC,t,t_0}	Sum of discounted energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€]
$ARRER_{s,EC,t,t'}$	Annual requirement-related energy-sales revenues of energy supply unit s regarding the production of the output of energy carrier EC (type IO) in year t' based on energy flows of year t [€/a]
t_2	Year of construction end of energy supply unit s
r	Interest rate for calculations [-]

1.4.3.2.4 *Set of large-scale units [BD2_4]*

In order to enable the comparability between buildings, the sum of discounted annual revenues is related to the energy output of the energy supply unit (e.g. electricity, heat, cold).

Unit: €/kWh

1.4.3.2.4.1 Total revenues [BD2_4_1]

$$STR_{S,EC,(t),t_0} = \frac{\sum_{s\in S} STR_{s,EC,t,t_0} * EL_{[s]} * Out_{EC,s,t}}{\sum_{s\in S} EL_{[s]} * Out_{EC,s,t}}$$

$STR_{S,EC,(t),t_0}$ Sum of discounted total annual revenues of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€/kWh]

STR_{s,EC,t,t_0} Sum of discounted total annual revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

1.4.3.2.4.2 Grant revenues [BD2_4_2]

$$\overline{SGR}_{S,EC,(t),t_0} = \frac{\sum_{s\in S} \overline{SGR}_{s,EC,t,t_0} * EL_{[s]} * Out_{EC,s,t}}{\sum_{s\in S} EL_{[s]} * Out_{EC,s,t}}$$

$\overline{SGR}_{S,EC,(t),t_0}$ Sum of discounted grant revenues of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€/kWh]

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Sub-formula:

Unit: €

$$SGR_{S,(t),t_0} = \sum_{s \in S} SGR_{s,t,t_0}$$

$SGR_{S,(t),t_0}$ Sum of discounted grant revenues of set S of energy supply units over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

SGR_{s,t,t_0} Sum of discounted grant revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

1.4.3.2.4.3 Non-grant non-energy-sales revenues [BD2_4_3]

$$\overline{SNGNER_{S,EC,(t),t_0}} = \frac{\sum_{s \in S} \overline{SNGNER_{s,EC,t,t_0}} * EL_{[s]} * Out_{EC,s,t}}{\sum_{s \in S} EL_{[s]} * Out_{EC,s,t}}$$

$\overline{SNGNER_{S,EC,(t),t_0}}$ Sum of discounted non-grant non-energy-sales revenues of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€/kWh]

$\overline{SNGNER_{s,EC,t,t_0}}$ Sum of discounted non-grant non-energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Sub-formula:

Unit: €

$$SNGNER_{S,(t),t_0} = \sum_{s \in S} SNGNER_{s,t,t_0}$$

$SNGNER_{S,(t),t_0}$ Sum of discounted non-grant non-energy-sales revenues of set S of energy supply units over the expected-lifetime based on data of year (t) and with discount base in year t_0 [€]

$SNGNER_{s,t,t_0}$ Sum of discounted non-grant non-energy-sales revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

1.4.3.2.4.4 Energy-sales revenues [BD2_4_4]

$$\overline{SER}_{S,EC,(t),t_0} = \frac{\sum_{s \in S} \overline{SER}_{s,EC,t,t_0} * EL_{[s]} * Out_{EC,s,t}}{\sum_{s \in S} EL_{[s]} * Out_{EC,s,t}}$$

$\overline{SER}_{S,EC,(t),t_0}$ Sum of discounted energy-sales revenues of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€/kWh]

$\overline{SER}_{s,EC,t,t_0}$ Sum of discounted energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Sub-formula:

Unit: €

$$SER_{S,EC,(t),t_0} = \sum_{s \in S} SER_{s,EC,t,t_0}$$

$SER_{S,EC,(t),t_0}$ Sum of discounted energy-sales revenues of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€]

SER_{s,EC,t,t_0} Sum of discounted energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€]

1.4.3.3 Annuity of annual revenues [BD3]

Description: The annuity of the annual revenues is defined as annuity that corresponds to the sum of discounted annual revenues. Thereby, sum of discounted annual revenues and annuity are based on the same period of time. Thus, the annuity represents the "average" of the annual revenues.

1.4.3.3.1 *Individual buildings [BD3_1]*

Unit: €/(m² a)

1.4.3.3.1.1 Total revenues [BD3_1_1]

$$\overline{TR}_{i,t,t_0} = \overline{TER}_{i,,el.,t,t_0} + \overline{TGR}_{i,t,t_0} + \overline{TNGNER}_{i,t,t_0}$$

$\overline{TR}_{i,t,t_0}$ Annuity of total annual revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

$\overline{TER}_{i,el.,t,t_0}$ Annuity of annual energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

$\overline{TGR}_{i,t,t_0}$ Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

$\overline{TNGNER}_{i,t,t_0}$ Annuity of annual non-grant non-energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$\overline{TR}_{i_1,t=2010,t_0=2005} = 0.18$$

$$\overline{TR}_{i_1,t_0=2005} = 0.18$$

$$\overline{TR}_{i_1=REF,t_0=2005} = 0$$

$$\overline{TR}_{i_2,t_0=2005} = 0.17$$

$$\overline{TR}_{i_2=REF,t_0=2005} = 0$$

$$\overline{TR}_{i_3,t_0=2005} = 0.15$$

$$\overline{TR}_{i_3=REF,t_0=2005} = 0$$

1.4.3.3.1.2 Grant revenues [BD3_1_2]

$$\overline{TGR}_{i,t,t_0} = \frac{SGR_{i,t,t_0}}{EL_{[i]} * Cap_i}$$

$\overline{TGR}_{i,t,t_0}$	Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]
SGR_{i,t,t_0}	Sum of discounted annual grant revenues of building i over the expected-lifetime based on data of year t and with discount base in year t_0 [€]
Cap_i	Floor area of building i [m²]
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$\overline{TGR}_{i_1,t=2010,t_0=2005,spec.} = \frac{11{,}298}{40 * 1{,}605} = 0.18$$

$$\overline{TGR}_{i_1,t_0=2005,spec.} = \frac{11{,}298}{40 * 1{,}605} = 0.18$$

$$\overline{TGR}_{i_1=REF,t_0=2005,spec.} = 0$$

$$\overline{TGR}_{i_2,t_0=2005,spec.} = \frac{12{,}282}{40 * 1{,}771} = 0.17$$

$$\overline{TGR}_{i_2=REF,t_0=2005,spec.} = 0$$

$$\overline{TGR}_{i_3,t_0=2005,spec.} = \frac{12{,}292}{40 * 2{,}043} = 0.15$$

$$\overline{TGR}_{i_3=REF,t_0=2005,spec.} = 0$$

1.4.3.3.1.3 Non-grant non-energy-sales revenues [BD3_1_3]

$$\overline{TNGNER}_{i,t,t_0} = \frac{SNGNER_{i,t,t_0}}{EL_{[i]} * Cap_i}$$

$\overline{TNGNER}_{i,t,t_0}$	Annuity of non-grant non-energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]
$SNGNER_{i,t,t_0}$	Sum of discounted annual non-grant non-energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$\overline{TNGNER}_{i,t,t_0} = 0$$

1.4.3.3.1.4 Energy-sales revenues [BD3_1_4]

$$\overline{TER}_{i,el.,t,t_0} = \frac{SER_{i,el.,t,t_0}}{EL_{[i]} * Cap_i}$$

$\overline{TER}_{i,el.,t,t_0}$ Total energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

$SER_{i,el.,t,t_0}$ Sum of discounted annual energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$TER_{i,el.,t,t_0} = 0$$

1.4.3.3.2 *Set of buildings [BD3_2]*

Unit: €/(m² a)

1.4.3.3.2.1 Total revenues [BD3_2_1]

$$\overline{TR}_{I,(t),t_0} = \frac{\sum_{i \in I} \overline{TR}_{i,t,t_0} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\overline{TR}_{I,(t),t_0}$ Annuity of total annual revenues of set i of buildings based on data of year (t) and with discount base in year t_0 [€/(m² a)]

$\overline{TR}_{i,t,t_0}$ Annuity of total annual revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.3.2.2 Grant revenues [BD3_2_2]

$$\overline{TGR}_{I,(t),t_0} = \frac{\sum_{i \in I} \overline{TGR}_{i,t,t_0} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\overline{TGR}_{I,(t),t_0}$ Annuity of annual grant revenues of set I of buildings based on data of year (t) and with discount base in year t_0 [€/(m² a)]

$\overline{TGR}_{i,t,t_0}$ Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.3.2.3 Non-grant non-energy-sales revenues [BD3_2_3]

$$\overline{TNGNER}_{I,(t),t_0} = \frac{\sum_{i \in I} \overline{TNGNER}_{i,t,t_0} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\overline{TNGNER}_{I,(t),t_0}$ Annuity of annual non-grant non-energy-sales revenues of set I of buildingsi based on data of year (t) and with discount base in year t_0 [€/(m² a)]

$\overline{TNGNER}_{i,t,t_0}$ Annuity of annual non-grant non-energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.3.2.4 Energy-sales revenues [BD3_2_4]

$$TER_{I,el.,(t),t_0} = \frac{\sum_{i \in I} \overline{TER}_{i,el.,t,t_0} * Cap_i}{\sum_{i \in I} Cap_i}$$

$\overline{TER}_{I,el.,(t),t_0}$ Annuity of annual energy-sales revenues of set I of buildings based on data of year (t) and with discount base in year t_0 [€/(m² a)]

$\overline{TER}_{i,el.,t,t_0}$	Annuity of annual energy-sales revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]
Cap_i	Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.3.3 *Large-scale or building-integrated energy supply units [BD3_3]*

Unit: €/a

Not required.

1.4.3.3.4 *Set of large-scale units [BD3_4]*

Unit: €/a

Not required.

1.4.3.4 Capital-related annual revenues [BE1]

1.4.3.4.1 *Individual building [BE1_1]*

$$ACRR_{i,t'} = IG_{i,t_1} * ((1+r)^{t_2-t_1} * \frac{(1+r)^{EL_{[i]}} * r}{(1+r)^{EL_{[i]}} - 1}); t' = t_2, \ldots, t_2 + EL_{[i]}$$

$ACRR_{i,t'}$	Annual capital-related revenues of building i in year t' [€/a]
IG_{i,t_1}	Investment grants for building i discounted to year t_1 [€]
t_1	Year of construction start of building i
t_2	Year of construction end of building i
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]
r	Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices, assumed interest rate of 5%, assumed lifetime of 40 years

$$ACRR_{i_1,t'} = 10{,}794 * ((1+0.05)^{2006-2005} * \frac{(1+0.05)^{40} * 0.05}{(1+0.05)^{40} - 1}) = 10{,}794 * 0.061 = 658$$

$$ACRR_{i_1=REF,t'} = 0$$

$$ACRR_{i_2,t'} = 12{,}937 * 0.061 = 789$$

$$ACRR_{i_2=REF,t'} = 0$$

$$ACRR_{i_3,t'} = 12{,}947 * 0.061 = 790$$

$$ACRR_{i_3=REF,t'} = 0$$

1.4.3.4.2 *Set of buildings [BE1_2]*

$$ACRR_{I,t'} = \sum_{i \in I} ACRR_{i,t'}$$

$ACRR_{I,t'}$ Annual capital-related revenues of set I of buildings in year t' [€/a]

$ACRR_{i,t'}$ Annual capital-related revenues of building i in year t' [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.4.3 *Large-scale or building-integrated energy supply unit [BE1_3]*

$$ACRR_{s,t'} = IG_{s,t_1} * ((1+i)^{t_2-t_1} * \frac{(1+i)^{EL_{[s]}} * i}{(1+i)^{EL_{[s]}} - 1}); t' = t_2, ..., t_2 + EL_{[s]}$$

$ACRR_{s,t'}$ Annual capital-related revenues of energy supply unit s in year t' [€/a]

IG_{s,t_1} Investment grants for energy supply unit s discounted to year t_1 [€]

t_1 Year of construction start of energy supply unit s

t_2 Year of construction end of energy supply unit s

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

1.4.3.4.4 *Set of large-scale units [BE1_4]*

$$ACRR_{S,t'} = \sum_{s \in S} ACRR_{s,t'}$$

$ACRR_{S,t'}$ Annual capital-related revenues of set S of energy supply units in year t' [€/a]

$ACRR_{s,t'}$ Annual capital-related revenues of energy supply unit s in year t' [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.5 Requirement-related revenues [BE2]

Examples: Sales-revenue and grants for electricity, heat, cold and other

1.4.3.5.1 *Annual requirement-related energy-sales revenues*

1.4.3.5.1.1 Individual building [BE2_1_1]

$$ARRER_{i,t,t'} = p_{el.,i,t,OUT} * Out_{el.,i,t} * \frac{e_{requirement,t'}}{e_{requirement,t}}$$

$ARRER_{i,t,t'}$ Annual requirement-related energy-sales revenues of building i in year t' based on energy flows of year t [€/a]

$p_{el.,i,t,OUT}$ Price of electricity (type IO) leaving building i in year t [€/kWh]

$Out_{el.,i,t}$ Electricity output (>0) flow of building i in year t [kWh/a]

$e_{requirement,t'}$ Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$

> **Example:** Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC
>
> $ARRER_{i,t,t'} = 0$

1.4.3.5.1.2 Set of buildings [BE2_1_2]

$$ARRER_{I,(t),t'} = \sum_{i \in I} ARRER_{i,t,t'}$$

$ARRER_{I,(t),t'}$ Annual requirement-related energy-sales revenues of set I of buildings in year t' based on energy flows of year (t) [€/a]

$ARRER_{i,t,t'}$ Annual requirement-related energy-sales revenues of building i in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.5.1.3 Large-scale or building-integrated energy supply unit [BE2_1_3]

$$ARRER_{s,EC,t,t'} = p_{EC,s,t,OUT} * Out_{EC,s,t} * \frac{e_{requirement,t'}}{e_{requirement,t}}$$

$ARRER_{s,EC,t,t'}$ Annual requirement-related energy-sales revenues of energy supply unit s regarding the production of the output of energy carrier EC (type IO) in year t' based on energy flows of year t [€/a]

$p_{EC,s,t,OUT}$ Price of energy carrier (or source) EC (type IO) leaving energy supply unit s in year t [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$e_{requirement,t'}$ Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$

1.4.3.5.1.4 Set of large-scale units [BE2_1_4]

$$ARRER_{S,EC,(t),t'} = \sum_{s \in S} ARRER_{s,EC,t,t'}$$

$ARRER_{S,EC,(t),t'}$ Annual requirement-related energy-sales revenues of set S of energy supply units regarding the production of the output of energy carrier EC (type IO) in year t' based on energy flows of year t [€/a]

$ARRER_{s,EC,t,t'}$ Annual requirement-related energy-sales revenues of energy supply unit s regarding the production of the output of energy carrier EC (type IO) in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.5.2 *Annual requirement-related grant revenues*

1.4.3.5.2.1 Individual building [BE2_2_1]

$$ARRGR_{s,t,t'} = g_{el.,i,t,OUT} * Out_{el.,i,t} * \frac{e_{requirement,t'}}{e_{requirement,t}}$$

$ARRGR_{i,t,t'}$ Annual requirement-related grant revenues of building i in year t' based on energy flows of year t [€/a]

$Out_{el.,i,t}$ Electricity output (>0) flow of building i in year t [kWh/a]

$g_{el.,i,t,OUT}$ Grants for electricity (type IO) leaving building i in year t [€/kWh]

$e_{requirement,t'}$ Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$ARRGR_{i,t,t'} = 0$$

1.4.3.5.2.2 Set of buildings [BE2_2_2]

$$ARRGR_{I,(t),t'} = \sum_{i \in I} ARRGR_{i,t,t'}$$

$ARRGR_{I,(t),t'}$ Annual requirement-related grant revenues of set I of buildings in year t' based on energy flows of year t [€/a]

$ARRGR_{i,t,t'}$ Annual requirement-related grant revenues of building i in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.5.2.3 Large-scale or building-integrated energy supply unit [BE2_2_3]

$$ARRGR_{s,t,t'} = (\sum_{EC} g_{EC,s,t,OUT} * Out_{EC,s,t}) * \frac{e_{requirement,t'}}{e_{requirement,t}}$$

$ARRGR_{s,t,t'}$ Annual requirement-related grant revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$g_{EC,s,t,OUT}$ Grants for energy carrier (or source) EC (type IO) leaving energy supply unit s in year t [€/kWh]

$e_{requirement,t'}$ Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$

1.4.3.5.2.4 Set of large-scale units [BE2_2_4]

$$ARRGR_{S,(t),t'} = \sum_{s \in S} ARRGR_{s,t,t'}$$

$ARRGR_{S,(t),t'}$ Annual requirement-related grant revenues of set S of energy supply units in year t' based on energy flows of year t [€/a]

$ARRGR_{s,t,t'}$ Annual requirement-related grant revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.5.3 *Annual requirement-related non-grant non-energy-sales revenues*

1.4.3.5.3.1 Individual building [BE2_3_1]

Note: *Possibility to consider rents from the point of view of the landlord*

$$ARRNGNER_{i,t,t'} = ARRNGNER_{i,t} * \frac{e_{requirement,t'}}{e_{requirement,t}}$$

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$ARRNGNER_{i,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of building i in year t' based on energy flows of year t [€/a]

$ARRNGNER_{i,t}$ Annual requirement-related non-grant non-energy-sales revenues of building i in year t [€/a]

$e_{requirement,t'}$ Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$ARRNGNER_{i,t,t'} = 0$$

1.4.3.5.3.2 Set of buildings [BE2_3_2]

$$ARRNGNER_{I,(t),t'} = \sum_{i \in I} ARRNGNER_{i,t,t'}$$

$ARRNGNER_{I,(t),t'}$ Annual requirement-related non-grant non-energy-sales revenues of set I of buildings in year t' based on energy flows of year (t) [€/a]

$ARRNGNER_{i,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of building i in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.5.3.3 Large-scale or building-integrated energy supply unit [BE2_3_3]

$$ARRNGNER_{s,t,t'} = ARRNGNER_{s,t} * \frac{e_{requirement,t'}}{e_{requirement,t}}$$

$ARRNGNER_{s,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

$ARRNGNER_{s,t}$ Annual requirement-related non-grant non-energy-sales revenues of energy supply unit s in year t [€/a]

$e_{requirement,t'}$ Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$

1.4.3.5.3.4 Set of large-scale units [BE2_3_4]

$$ARRNGNER_{S,(t),t'} = \sum_{s \in S} ARRNGNER_{s,t,t'}$$

$ARRNGNER_{S,(t),t'}$ Annual requirement-related non-grant non-energy-sales revenues of set S of energy supply units in year t' based on energy flows of year (t) [€/a]

$ARRNGNER_{s,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.1 (Operation-related revenues) [BE3]

1.4.3.1.1 *Individual building [BE3_1]*

$$AORR_{i,t,t'} = AORR_{i,t} * \frac{e_{operation,t'}}{e_{operation,t}}$$

$AORR_{i,t,t'}$ Annual operation-related revenues of building i in year t' based on data of year t [€/a]

$AORR_{i,t}$ Annual operation-related revenues of building i in year t [€/a]

$e_{operation,t'}$ Index for operation-related revenues in year t' [-]; $e_{operation,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$AORR_{i,t,t'} = 0$$

1.4.3.1.2 *Set of buildings [BE3_2]*

$$AORR_{I,(t),t'} = \sum_{i \in I} AORR_{i,t,t'}$$

$AORR_{I,(t),t'}$ Annual operation-related revenues of set I of buildings in year t' based on data of year (t) [€/a]

$AORR_{i,t,t'}$ Annual operation-related revenues of building i in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.1.3 *Large-scale or building-integrated energy supply unit [BE3_3]*

$$AORR_{s,t,t'} = AORR_{s,t} * \frac{e_{operation,t'}}{e_{operation,t}}$$

$AORR_{s,t,t'}$ Annual operation-related revenues of energy supply unit s in year t' based on data of year t [€/a]

$AORR_{s,t}$ Annual operation-related revenues of energy supply unit s in year t [€/a]

$e_{operation,t'}$ index for operation-related revenues in year t' [-]; $e_{operation,t_0} = 1$

1.4.3.1.4 *Set of large-scale units [BE3_4]*

$$AORR_{S,(t),t'} = \sum_{s \in S} AORR_{s,t,t'}$$

$AORR_{S,(t),t'}$ Annual operation-related revenues of set S of energy supply units in year t' based on data of year (t) [€/a]

$AORR_{s,t,t'}$ Annual operation-related revenues of energy supply unit s in year t' based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.2 (Other revenues) [BE4]

1.4.3.2.1 *Individual building [BE4_1]*

$$AOR_{i,t,t'} = AOR_{i,t} * \frac{e_{other,t'}}{e_{other,t}}$$

$AOR_{i,t,t'}$ Annual other revenues of building i in year t' based on data of year t [€/a]

$AOR_{i,t}$ Annual other revenues of building i in year t [€/a]

$e_{other,t'}$ index for other revenues in year t' [-]; $e_{other,t_0} = 1$

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC

$$AOR_{i,t,t'} = 0$$

1.4.3.2.2 *Set of buildings [BE4_2]*

$$AOR_{I,(t),t'} = \sum_{i \in I} AOR_{i,t,t'}$$

$AOR_{I,(t),t'}$ Annual other revenues of set I of buildings in year t’ based on data of year (t) [€/a]

$AOR_{i,t,t'}$ Annual other revenues of building i in year t’ based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.3.2.3 *Large-scale or building-integrated energy supply unit [BE4_3]*

$$AOR_{s,t,t'} = AOR_{s,t} * \frac{e_{other,t'}}{e_{other,t}}$$

$AOR_{s,t,t'}$ Annual other revenues of energy supply unit s in year t’ based on data of year t [€/a]

$AOR_{s,t}$ Annual other revenues of energy supply unit s in year t [€/a]

$e_{other,t'}$ index for other revenues in year t’ [-]; $e_{other,t_0} = 1$

1.4.3.2.4 *Set of large-scale units [BE4_4]*

$$AOR_{S,(t),t'} = \sum_{s \in S} AOR_{s,t,t'}$$

$AOR_{S,(t),t'}$ Annual other revenues of set S of energy supply units in year t’ based on data of year (t) [€/a]

$AOR_{s,t,t'}$ Annual other revenues of energy supply unit s in year t’ based on data of year t [€/a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4 Economic assessment of investments causing energy savings/production in comparison to a baseline [CA1-CA7, CB1-CB5, CC1-CC10, CD1-CD6]

(e.g. wall insulation that lowers heating energy consumption)

References:

- VDI 2067 – Part 1. (2000) Economic efficiency of building installations - Fundamentals and economic calculation Economic efficiency of building installations.

- DIN EN 15459:2007. Energy performance of buildings – Economic evaluation procedure for energy systems in buildings.
- VDI 6025. (1996) Economic calculations for capital goods and plants.
- DIN EN 15643-4:2010. (2010) Sustainability of construction works – Sustainability assessment of building – Part 4: Framework for the assessment of economic performance.

Description: The economic assessment of investments causing energy savings or energy production requires the definition of a baseline (or a reference object). The selection of reference objects is described in chapter 1.2.3. Additionally, in case of large-scale energy supply units or building-integrated electricity production systems "no investment", i.e. an alternative investment of the funds, can be chosen as special case.

The adequate economic assessment depends strongly on the concrete target groups. Therefore, different "points of view" are considered. A "point of view" determines

- the set of indicators and calculation procedures and
- the concrete components included in the costs and revenues that have been described in chapter 1.4.2 and 1.4.3.

In order to achieve a lean description of the indicator calculation procedures a two-step approach is used. Firstly, the points of view are clustered according to the adequate set of indicators and the calculation procedures. The indicator calculation procedures and thus the set of indicators are described for the point of view of

- owner-occupier, landlord, tenant and plant owner (cluster 1, chapter 1.4.4.1)
- national/local economy (cluster 2, chapter 1.4.4.2)
- national/local society (cluster 3, chapter 0)
- grant provider (cluster 4, chapter 1.4.4.4)

Especially in cluster 1, the concrete components included in costs and revenues differ between the target groups. Therefore, the target groups and the included components are specified in the corresponding chapter.

Relation of cash-flows and revenues/costs: It is assumed that - apart from capital-related costs and revenues – revenues and costs coincide with cash-flows from a time perspective. Concerning capital-related costs and revenues it is assumed that investments and grants cause a single cash-flow at the beginning of the construction works. Other capital-related costs and revenues (e.g. repairs) coincide with cash-flows from a time perspective. (Cf. CONCERTO Premium Economic Monitoring Guide)

1.4.4.1 Owner-occupier, landlord, tenant and plant owner (grants are no costs) [CA1-CA7]

The cost and revenue components included (or cash-flows) in economic assessments from the point of view of owner-occupier, landlord, tenant and plant owner are specified in Table 9.

Table 9: Included components of cost and revenue (or cash-flows) in economic assessments from the point of view of owner-occupier, landlord, tenant and plant owner; *: depends on concrete situation; **: Regarding revenues typology A or B is required in dependence on the indicators that shall be calculated

Considered costs and revenues from different points of view			Point of view			
			Owner-occupier	Landlord	Tenant	Plant owner
Costs	Capital-related	Depreciation and interest	X	X	-	X
		Repairs	X	X	-	X
	Requirement-related	Rent	-	-	X	-
		Energy	X	-	X	X
		External costs	-	-	-	-
		Other	X	X*		X
	Operation-related costs		X	X*		X
	Other costs		X	X*		X
Use of cost components as input for indicators	Energy production cost		X	-	-	X
	Energy production cost reduction		X	-	-	X
	Sum of discounted annual costs less revenues (net present value, internal rate of return and dynamic payback period using investments instead of depreciation and interest)		X	X	X	X
Revenues (typology A**)	Grant revenues	Investment-related	X	X	-	X
		Requirement-related	X	X	-	X
	Non-energy non-grant revenues	Rents	-	X	-	-
		Other	-	-	-	X

	Energy-sales revenues			X	X	-	X
Use of revenue components (typ. A**) as input for indicators	Energy production costs			X	-	-	X
	Energy production cost reduction			X	-	-	X
	Sum of discounted annual costs less revenues (net present value, internal rate of return and dynamic payback period using grants instead of investment-related grant revenues)			-	-	-	-
Revenues (typology B**)	Capital-related	Grants		X	X	-	X
	Requirement-related	Non-energy non-grant revenues	Rent	-	X	-	-
			Other	-	-	-	X
		Energy-sales		X	X	-	X
		Grants		X	X	-	X
	Operation-related			-	-	-	-
	Other			X	X	X	X
Use of revenue components (typ. B**) as input for indicators	Energy production cost			-	-	-	-
	Energy production cost reduction			-	-	-	-
	Sum of discounted annual costs less revenues (net present value, internal rate of return and dynamic payback period using grants instead of capital-related grants)			X	X	X	X

1.4.4.1.1 *Energy production costs [CA1]*

References:

- Panos, K. (2009), Praxisbuch Energiewirtschaft: Energieumwandlung, -transport und -beschaffung im liberalisierten Markt. Springer Berlin Heidelberg. ISBN: 978-3-540-78592-7, pp. 168-169.

1.4.4.1.1.1 Individual building [CA1_1]

Not applicable

1.4.4.1.1.2 Set of buildings [CA1_2]

Not applicable

1.4.4.1.1.3 Large-scale or building-integrated energy supply unit [CA1_3]

Description: The energy production costs are defined as sum of discounted total annual costs less sum of discounted total annual revenues except annual energy-sales revenues.

Unit: €/kWh

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	-	-	X

$$\overline{EPC}_{s,EC,t,t_0} = \overline{STC}_{s,EC,t,t_0} - \overline{SGR}_{s,EC,t,t_0} - \overline{SNGNER}_{s,EC,t,t_0}$$

$\overline{EPC}_{s,EC,t,t_0}$ Energy production costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{STC}_{s,EC,t,t_0}$ Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SNGNER}_{s,EC,t,t_0}$ Sum of discounted non-grant non-energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

1.4.4.1.1.4 Set of large-scale units [CA1_4]

Description: The energy production costs are defined as sum of discounted total annual costs less sum of discounted total annual revenues except annual energy-sales revenues.

Unit: €/kWh

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	-	-	-	X

$$\overline{EPC}_{S,EC,(t),t_0} = \frac{\sum_{s\in S} \overline{EPC}_{s,EC,t,t_0} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s\in S} Out_{EC,s,t} * EL_{[s]}}$$

$\overline{EPC}_{S,EC,(t),t_0}$ Energy production costs of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 [€/kWh]

$\overline{EPC}_{s,EC,t,t_0}$ Energy production costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.1.2 *Energy production cost reduction [CA2]*

1.4.4.1.2.1 Individual building [CA2_1]

Not applicable

1.4.4.1.2.2 Set of buildings [CA2_2]

Not applicable

1.4.4.1.2.3 Large-scale or building-integrated energy supply unit [CA2_3]

Description: The indicator energy production cost reduction compares the energy production costs of an energy supply unit with the energy production costs of a baseline (or reference unit).

Unit: €/kWh

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	-	-	X

$$\Delta EPC_{s,EC,t,t_0,REF,t^*} = \overline{EPC}_{s=REF,EC,t^*,t_0} - \overline{EPC}_{s,EC,t,t_0}$$

$\Delta EPC_{s,EC,t,t_0,REF,t^*}$	Reduction (>0) in energy production costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF based on data of year t* with discount base in t_0 [€/kWh]
$\overline{EPC}_{s,EC,t,t_0}$	Energy production costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

1.4.4.1.2.4 Set of large-scale units [CA2_4]

Description: The indicator energy production cost reduction compares the energy production costs of a set of energy supply units with the energy production costs of a baseline (or reference unit).

Unit: €/kWh

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	-	-	-	X

$$\overline{EPC}_{S,EC,(t),t_0} = \frac{\sum_{s \in S} (\overline{EPC}_{s=REF,EC,t^*,t_0} - \overline{EPC}_{s,EC,t,t_0})^* Out_{EC,s,t} {}^* EL_{[s]}}{\sum_{s \in S} Out_{EC,s,t} {}^* EL_{[s]}}$$

$\Delta EPC_{S,EC,(t),t_0,REF,t^*}$	Reduction (>0) in energy production costs of set S of energy supply units for the production of the output of energy carrier EC (type IO) based on year (t) compared to reference unit REF based on data of year t* with discount base in t_0 [€/kWh]
$\overline{EPC}_{s,EC,t,t_0}$	Energy production costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]
$Out_{EC,s,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]

1.4.4.1.3 *Net present value [CA3]*

References:

- VDI 6025. (1996) Economic calculations for capital goods and plants.

- Richter, Frank. (2011) Barwert von Cashflows und Residualgewinnen bei unsicheren Inflationserwartungen. ZDBID: 1086398-9. ISSN: 0341-2687. 63(5). 430-457.

Description: The net present value of an investment causing energy savings or energy production in comparison to a baseline is defined as the sum of the discounted annual incoming cash-flows related to the investment less the discounted annual outgoing cash-flows related to the investment less the discounted annual incoming cash-flows related to the baseline plus the discounted annual outgoing cash-flows related to the baseline over a period of time. The latter can be determined by the time of the investment and a planning horizon.

Unit: €

Relation of cash-flows and **costs:** It is assumed that - apart from capital-related costs and revenues – revenues and costs coincide with cash-flows from a time perspective. Concerning capital-related costs (e.g. deprecation, interests and repairs) and revenues, it is assumed that investments (instead of deprecation and interests) and grants cause a single cash-flow at the beginning of the construction works. Other capital-related costs (e.g. repairs) and revenues coincide with cash-flows from a time perspective.

Relation of net present value and **sum of discounted annual revenues less discounted annual costs:** Because of the assumption concerning cash-flows and costs and assuming a perfect capital market, the net present value and the sum of discounted annual revenues less discounted annual costs are identical. In the following, the net present value is favoured and formally desribed, since the dynamic payback period and the internal rate of return are based on the net present value.

1.4.4.1.3.1 Individual building [CA3_1]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	X	-

$$NPV_{i,REF,t,t_0,t_1,t_2} = (IG_{i,t_1} - I_{i,t_1}) * (1+r)^{t_0-t_1} - (IG_{i=REF,t_1} - I_{i=REF,t_1}) * (1+r)^{t_0-t_1}$$

$$- \sum_{t'=t_2}^{t_2+EL_{[i]}-1} 1/(1+r)^{t'-t_0} * (ARRER_{i=REF,t^*,t'} + ARRGR_{i=REF,t^*,t'} + ARRNGNER_{i=REF,t^*,t'} + AORR_{i=REF,t^*,t'} + AOR_{i=REF,t^*,t'})$$

$$+ \sum_{t'=t_2}^{t_2+EL_{[i]}-1} 1/(1+r)^{t'-t_0} * (ARRER_{i,t,t'} + ARRGR_{i,t,t'} + ARRNGNER_{i,t,t'} + AORR_{i,t,t'} + AOR_{i,t,t'})$$

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$$- \sum_{t'=t_2}^{t_2+EL_{[i]}-1} 1/(1+r)^{t'-t_0} * (I_{i,t_1} * d_{repair,t'} * f_{repair,[i]} + ARRC_{i,t,t'} + AORC_{i,t,t'} + AOC_{i,t,t'})$$

$$+ \sum_{t'=t_2}^{t_2+EL_{[i]}-1} 1/(1+r)^{t'-t_0} * (I_{i=REF,t_1} * d_{repair,t'} * f_{repair,[i]} + ARRC_{i=REF,t^*,t'} + AORC_{i=REF,t^*,t'} + AOC_{i=REF,t^*,t'})$$

$NPV_{i,REF,t,t_0,t_1,t_2}$	Net present value of investment in building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€]
IG_{i,t_1}	Investment grants for building i discounted to year t_1
I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]
$ARRER_{i,t,t'}$	Annual requirement-related energy-sales revenues of building i in year t' based on energy flows of year t [€/a]
$ARRGR_{i,t,t'}$	Annual requirement-related grant revenues of building i in year t' based on energy flows of year t [€/a]
$ARRNGNER_{i,t,t'}$	Annual requirement-related non-grant non-energy-sales revenues of building i in year t' based on energy flows of year t [€/a]
$AORR_{i,t,t'}$	Annual operation-related revenues of building i in year t' based on data of year t [€/a]
$AOR_{i,t,t'}$	Annual other revenues of building i in year t' based on data of year t [€/a]
$f_{repair,[i]}$	Factor for repairs as share of the investment per year [1/a]
$d_{repair,t'}$	Price-index for repair payments in year t' [-]; $d_{repair,t_0} = 1$
$ARRC_{i,t,t'}$	Annual requirement-related costs of building i in year t' based on energy flows of year t [€/a]
$AORC_{i,t,t'}$	Annual operation-related costs of building i in year t' based on data of year t [€/a]
$AOC_{i,t,t'}$	Annual other costs of building i in year t' based on data of year t [€/a]
t_1	Year of construction start of building i
t_2	Year of construction end of building i
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]
r	Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$NPV_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = (10{,}794 - 1{,}000{,}000)*(1.05)^0 - (0 - 969{,}161)*(1.05)^0$$
$$- \sum_{t'=2006}^{2045} 1/(1.05)^{t'-2005} * (16{,}180 - 23{,}842) = 111{,}428$$

$$NPV_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = (10{,}794 - 1{,}000{,}000)*(1.05)^0 - (0 - 969{,}161)*(1.05)^0$$
$$- \sum_{t'=2006}^{2045} 1/(1.05)^{t'-2005} * (17{,}326 - 23{,}842) = 91{,}764$$

$$NPV_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = (12{,}937 - 1{,}950{,}236)*(1.05)^{-2} - (0 - 1{,}913{,}272)*(1.05)^{-2}$$
$$- \sum_{t'=2008}^{2047} 1/(1.05)^{t'-2005} * (19{,}118 - 26{,}308) = 90{,}111$$

$$NPV_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = (12{,}947 - 2{,}249{,}764)*(1.05)^{-2} - (0 - 2{,}212{,}771)*(1.05)^{-2}$$
$$- \sum_{t'=2008}^{2047} 1/(1.05)^{t'-2005} * (22{,}054 - 30{,}349) = 107{,}291$$

1.4.4.1.3.2 Set of buildings [CA3_2]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	X	-

$$NPV_{I,I_{REF},(t),t_0,(t_1),(t_2)} = \sum_{i \in I} NPV_{i,REF,t,t_0,t_1,t_2}$$

$NPV_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Net present value of investment in set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [€]

$NPV_{i,REF,t,t_0,t_1,t_2}$ Net present value of investment in building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.1.3.3 Large-scale or building-integrated energy supply unit [CA3_3]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	-	X

$$NPV_{s,REF,EC,t,t_0} = NPV_{s,EC,t,t_0} - NPV_{s=REF,EC,t',t_0}$$

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NPV_{s,REF,EC,t,t_0} Net present value of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on annual data of year t with discount base in year t_0 using reference unit REF [€]

NPV_{s,EC,t,t_0} Net present value of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€]

Sub-formula:

$$NPV_{s,EC,t,t_0} = \frac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'}(Out_{EC',s,t} * EX_{s,EC'})} * (IG_{s,t_1} - I_{s,t_1}) * (1+r)^{t_0-t_1} + \sum_{t'=t_2}^{t_2+EL_{[s]}} 1/(1+r)^{t'-t_0} * ARRER_{s,EC,t,t'}$$

$$+ \frac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'}(Out_{EC',s,t} * EX_{s,EC'})} \sum_{t'=t_2}^{t_2+EL_{[s]}} 1/(1+r)^{t'-t_0} * (ARRGR_{s,t,t'} + ARRNGNER_{s,t,t'} + AORR_{s,t,t'} + AOR_{s,t,t'})$$

$$- \frac{Out_{EC,s,t} * EX_{s,EC}}{\sum_{EC'}(Out_{EC',s,t} * EX_{s,EC'})} \sum_{t'=t_2}^{t_2+EL_{[s]}} 1/(1+r)^{t'-t_0} * (I_{s,t_1} * d_{repair,t'} * f_{repair,[s]} + ARRC_{s,t,t'} + AORC_{s,t,t'} + AOC_{s,t,t'})$$

NPV_{s,EC,t,t_0} Net present value of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EX_{s,EC}$ Exergy factor for the output of energy carrier EC (type IO) from energy supply unit s [kWh/kWh]

IG_{s,t_1} Investment grants for energy supply unit s discounted to year t_1

I_{s,t_1} Investment for component s of a large-scale energy system; construction in year t_1; investment is discounted to year t_1 [€]

$ARRER_{s,EC,t,t'}$ Annual requirement-related energy-sales revenues of energy supply unit s regarding the production of the output of energy carrier EC (type IO) in year t' based on energy flows of year t [€/a]

$ARRGR_{s,t,t'}$ Annual requirement-related grant revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

$ARRNGNER_{s,t,t'}$ Annual requirement-related non-grant non-energy-sales revenues of energy supply unit s in year t' based on energy flows of year t [€/a]

$AORR_{s,t,t'}$	Annual operation-related revenues of energy supply unit s in year t' based on data of year t [€/a]
$AOR_{s,t,t'}$	Annual other revenues of energy supply unit s in year t' based on data of year t [€/a]
$ARRC_{s,t,t'}$	Annual requirement-related costs of energy supply unit s in year t' based on energy flows of year t [€/a]
$AORC_{s,t,t'}$	Annual operation-related costs of energy supply unit s in year t' based on data of year t [€/a]
$AOC_{s,t,t'}$	Annual other costs of energy supply unit s in year t' based on data of year t [€/a]
$f_{repair,[s]}$	Factor for repairs as share of the investment per year [1/a]
$d_{repair,t'}$	Price-index for repair payments in year t' [-]; $d_{repair,t_0} = 1$
t_1	Year of construction start of energy supply unit s
t_2	Year of construction end of energy supply unit s
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]
r	Interest rate for calculations [-]

1.4.4.1.3.4 Set of large-scale units [CA3_4]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	-	-

$$NPV_{S,REF,(t),t_0} = \sum_{i \in I} NPV_{s,REF,t,t_0}$$

$NPV_{S,REF,EC,(t),t_0}$	Net present value of investment in set S of energy supply units for the production of the output of energy carrier EC (type IO) based on annual data of year (t) with discount base in year t_0 using reference unit REF [€]
NPV_{s,REF,EC,t,t_0}	Net present value of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on annual data of year t with discount base in year t_0 using reference unit REF [€]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.1.4 *Internal rate of return [CA4]*

References:

- VDI 6025. (1996) Economic calculations for capital goods and plants.

Description: The internal rate of return of an investment causing energy savings or energy production in comparison to a baseline is defined as the interest rate that results into a net present value of zero.

Unit: -

1.4.4.1.4.1 Individual building [CA4_1]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	-	-

Determination of internal rate of return $r*_{i,REF,t,t_0,t_1,t_2} = r$ (variable) with

$NPV_{i,REF,t,t_0,t_1,t_2}(r) = 0$

$r*_{i,REF,t,t_0,t_1,t_2}$ Internal rate of return of investment in building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [-]

r Interest rate for calculations [-]; HERE VARIABLE

$NPV_{i,REF,t,t_0,t_1,t_2}$ Net present value of investment in building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$r*_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = 0.38$

$r*_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = 0.33$

$r*_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = 0.30$

$r*_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = 0.34$

1.4.4.1.4.2 Set of buildings [CA4_2]

	Point of view

	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	(X)	-

Determination of internal rate of return $r^*_{I,I_{REF},(t),t_0,(t_1),(t_2)} = r$ (variable) with

$NPV_{I,I_{REF},(t),t_0,(t_1),(t_2)}(r) = 0$

$r^*_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Internal rate of return of investment in set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [-]

r Interest rate for calculations [-]; HERE VARIABLE

$NPV_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Net present value of investment in set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [€]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.1.4.3 Large-scale or building-integrated energy supply unit [CA4_3]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	-	X

Determination of interest rate $r^*_{s,REF,EC,t,t_0} = r$ (variable) with

$NPV_{s,REF,EC,t,t_0}(r) = 0$

r^*_{s,REF,EC,t,t_0} Internal rate of return of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 using reference unit REF [-]

r Interest rate for calculations [-]; HERE VARIABLE

NPV_{s,REF,EC,t,t_0} Net present value of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on annual data of year t with discount base in year t_0 using reference unit REF [€]

1.4.4.1.4.4 Set of large-scale units [CA4_4]

	Point of view

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	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	-	-	-	X

Determination of interest rate $r*_{S,REF,EC,t,t_0} = r$ (variable) with

$NPV_{s,REF,EC,t,t_0}(r) = 0$

$r*_{S,REF,EC,(t),t_0}$ Internal rate of return of investment in set S of energy supply units for the production of the output of energy carrier EC (type IO) based on data of year (t) and with discount base in year t_0 using reference unit REF [-]

r Interest rate for calculations [-]; HERE VARIABLE

$NPV_{S,REF,EC,(t),t_0}$ Net present value of investment in set S of energy supply units for the production of the output of energy carrier EC (type IO) based on annual data of year (t) with discount base in year t_0 using reference unit REF [€]

1.4.4.1.5 *Dynamic Payback period [CA5]*

References:

- VDI 6025. (1996) Economic calculations for capital goods and plants.

Description: The dynamic payback period of an investment causing energy savings or energy production in comparison to a baseline is defined as the smallest planning horizon that causes a non-negative net present value.

Unit: a

1.4.4.1.5.1 Individual building [CA5_1]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	(X)	-

Min. payback period $PP_{i,REF,t,t_0,t_1,t_2} = EL_{[i]} \in N$ (variable) whereas

$NPV_{i,REF,t,t_0,t_1,t_2}(EL_{[i]}) \geq 0$

PP_{i,REF,t,t_0,t_1,t_2} Payback period of investment in building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [a]

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$NPV_{i,REF,t,t_0,t_1,t_2}$ Net present value of investment in building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€]

$EL_{[i]}$ expected lifetime of a building of the same type as i [a] ; HERE VARIABLE

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$PP_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = 3$$

$$PP_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = 4$$

$$PP_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = 4$$

$$PP_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = 4$$

1.4.4.1.5.2 Set of buildings [CA5_2]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	(X)	-

Min. payback period $PP_{I,I_{REF},(t),t_0,(t_1),(t_2)} = EL_I \in N$ (variable) whereas $NPV_{I,I_{REF},(t),t_0,(t_1),(t_2)}(EL_I) \geq 0$

$PP_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Payback period of investment in set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [a]

$NPV_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Net present value of investment in set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [€]

EL_I Expected lifetime of a set I of buildings and thus of each building $i \in I$ ($EL_{[i]} = EL_I$) [a]; HERE VARIABLE

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

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1.4.4.1.5.3 Large-scale or building-integrated energy supply unit [CA5_3]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	X	X	-	X

Min. payback period $PP_{s,REF,t,t_0} = EL_{[s]} \in N$ (variable) whereas $NPV_{s,REF,EC,t,t_0}(EL_{[s]}) \geq 0$

PP_{s,REF,t,t_0} Payback period of investment in energy supply unit s based on annual data of year t with discount base in year t_0 using reference unit REF [a]

NPV_{s,REF,EC,t,t_0} Net present value of investment in energy supply unit s for the production of the output of energy carrier EC (type IO) based on annual data of year t with discount base in year t_0 using reference unit REF [€]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]; HERE VARIABLE

1.4.4.1.5.4 Set of large-scale units [CA5_4]

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	-	-	-	X

Min. payback period $PP_{S,REF,t,t_0} = EL_S \in N$ (variable) whereas $NPV_{S,REF,EC,t,t_0}(EL_S) \geq 0$

$PP_{S,REF,(t),t_0}$ Payback period of investment in set S of energy supply units based on annual data of year (t) with discount base in year t_0 using reference unit REF [a]

$NPV_{S,REF,EC,(t),t_0}$ Net present value of investment in set S of energy supply units for the production of the output of energy carrier EC (type IO) based on annual data of year (t) with discount base in year t_0 using reference unit REF [€]

EL_S Expected lifetime of a set S of energy supply units and thus of each energy supply unit $s \in S$ ($EL_{[s]} = EL_S$) [a] ; HERE VARIABLE

1.4.4.1.6 *Achieved rents incl./excl. ancillary costs [CA6]*

Description: The achieved rents of a building or a set of buildings can be expressed including ancillary costs and excluding ancillary costs. In order to enable the comparability between buildings, the rent is related to the size of the building(s) (e.g. gross floor area or net floor area, heated floor area).

Unit: €/(m² a)

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	-	X	X (payed rent)	-

1.4.4.1.6.1 Individual buildings [CA6_1]

$AR_{i,t}$ Achieved rents incl./excl. ancillary costs of building i in year t [€/(m² a)]

1.4.4.1.6.2 Set of buildings [CA6_2]

$$AR_{I,(t)} = \frac{\sum_{i \in I} Cap_i * AR_{i,t}}{\sum_{i \in I} Cap_i}$$

$AR_{I,(t)}$ Achieved rents incl./excl. ancillary costs of a set I of buildings in year (t) [€/(m² a)]

$AR_{i,t}$ Achieved rents incl./excl. ancillary costs of building i in year t [€/(m² a)]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.1.6.3 Large-scale or building-integrated energy supply units [CA6_3]

Not applicable.

1.4.4.1.6.4 Set of large-scale units [CA6_4]

Not applicable.

1.4.4.1.7 *Achieved rent increase (excl. ancillary costs) [CA7]*

Description: The achieved rent increase of a (refurbished) building is defined as difference of the achieved rents after and before the refurbishment. Ancillary costs are excluded. In theory, this indicator can be calculated as well for new constructions, if the achievable rent for a functionally comparable new constructed building according to the new national minimum requirements is known. In order to enable the comparability between buildings, the value is related to the size of the building (e.g. gross floor area or net floor area, heated floor area).

Unit: €/(m² a)

	Point of view			
	Owner-occupier	Landlord	Tenant	Plant owner
Applicability of indicator	-	X	X	-

1.4.4.1.7.1 Individual buildings [CA7_1]

$$AR_{i,REF,t,t^*} = AR_{i,t} - AR_{i=REF,t^*}$$

AR_{i,REF,t,t_1,t_2} Achieved rent increase of building i in year t compared to reference building REF in year t* [€/(m² a)]

1.4.4.1.7.2 Set of buildings [CA7_2]

$$AR_{I,I_{REF},(t),(t_1),(t_2)} = \frac{\sum_{i \in I} Cap_i * AR_{i,REF,t,t_1,t_2}}{\sum_{i \in I} Cap_i}$$

$AR_{I,I_{REF},(t),(t_1),(t_2)}$ Achieved rent increase of set I of buildings in year (t) using set I_{REF} of reference buildings [€/(m² a)]

AR_{i,REF,t,t_1,t_2} Achieved rent increase of building i in year t compared to reference building REF in year t* [€/(m² a)]

Cap_i Floor area of building i [m²]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.1.7.3 Large-scale or building-integrated energy supply units [CA7_3]

Not applicable.

1.4.4.1.7.4 Set of large-scale units [CA7_4]

Not applicable.

1.4.4.2 National/local economy [CB1-CB5]

References:

- UBA (1995). Economic Evaluation of Measures for the Mitigation of CO_2 Emissions. UBA-FB 104 01 108 / 03.
- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.

The cost and revenue components included (or cash-flows) in economic assessments from the point of view of national/local economy, national/local society and grant provider are specified in Table 10.

Table 10: Included components of costs and revenues (or cash-flows) in economic assessments from the point of view of national/local economy, national/local society and grant provider; *: implicitly considered by no grants as revenues

Considered costs and revenues from different points of view			Point of view		
			National/local economy	National/local society	Grant provider
Costs	Capital-related	Depreciation and interest	X	X	-
		Repairs	X	X	-
		Grants	-*	-*	X
	Requirement-related	Rents	-	-	-
		Energy	X	X	-
		External costs	-	X	-
		Other	X	X	-
	Operation-related costs		X	X	-
	Other costs		X	X	-
Revenues	Grant revenues	Investment-related	-	-	-
		Requirement-related	-	-	-
	Non-energy non-	Rents	-	-	-

	grant revenues	Other	X	X	-
	Energy-sales revenues		-	-	-

Description of mitigation costs from different points of view: Mitigation costs compare the object of interest to a baseline (or a reference object). The considered indicators encompass the categories (final) energy demand and consumption, primary energy demand and consumption, greenhouse gas emissions, particulate matter emissions as well as NO_X and SO_2 emissions. Common characteristic is that the mitigation costs are determined as ratio of a difference of a sum of discounted costs and a difference of cumulated environmental performance (over a period of time). The difference of environmental performance represents the reduction in (final) energy demand and consumption, primary energy demand and consumption, greenhouse gas emissions, particulate matter emissions, NO_X emissions or SO_2 emissions over a period of time. The difference of a sum of discounted costs depends on the "point of view" and considers the costs less the corresponding revenues according to Table 10. The mitigation costs are defined for the **national/local economy, national/local society** and **grant providers.**

Unit: €/kWh, €/t

1.4.4.2.1 *Mitigation costs of (final) energy demand [CB1]*

References:

- UBA (1995). Economic Evaluation of Measures for the Mitigation of CO_2 Emissions. UBA-FB 104 01 108 / 03.
- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.

1.4.4.2.1.1 Individual building [CB1_1]

$$MCEN_{i,REF,t,t_0,t_1,t_2} = \frac{\overline{TC}_{i,t,t_0,t_1,t_2} - \overline{STC}_{s=REF,EC=el.,t^*,t_0} * \dfrac{Out_{el.,i,t}}{Cap_i} - \overline{TC}_{i=REF,t,t_0,t_1,t_2}}{\Delta EN_{i,REF,t}}$$

Note: Requirement-related costs must not be included in the annuity of the total costs. Therefore, they have to be set 0.

$MCEN_{i,REF,t,t_0,t_1,t_2}$ Mitigation costs of building i for final energy demand/consumption based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€/kWh]

$\overline{TC}_{i,t,t_0,t_1,t_2}$ Annuity of total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/(m² a)]

$\overline{STC}_{s,EC,t,t_0}$ Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{el.,i,t}$ Electricity output (>0) flow of building i in year t [kWh/a]

Cap_i Floor area of building i [m²]

$\Delta EN_{i,REF,t}$ Reduction (>0) in final energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$\overline{MCEN}_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{20.63-22.17}{41} = -0.038$$

$$\overline{MCEN}_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = \frac{20.93-22.17}{41} = -0.030$$

$$\overline{MCEN}_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{30.34-31.42}{41} = -0.029$$

$$\overline{MCEN}_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{30.34-31.49}{41} = -0.030$$

1.4.4.2.1.2 Set of buildings [CB1_2]

$$MCEN_{I,I_{REF},(t),t_0,(t_1),(t_2)} = \frac{\sum_{i\in I} MCEN_{i,REF,t,t_0,t_1,t_2} * \Delta EN_{i,REF,t} * EL_{[i]} * Cap_i}{\sum_{i\in I} \Delta EN_{i,REF,t} * EL_{[i]} * Cap_i}$$

$MCEN_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Mitigation costs of set I of buildings for final energy demand/consumption based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [€/kWh]

$MCEN_{i,REF,t,t_0,t_1,t_2}$ Mitigation costs of building i for final energy demand/consumption based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€/kWh]

$\Delta EN_{i,REF,t}$ Reduction (>0) in final energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.2.1.3 Large-scale or building-integrated energy supply unit [CB1_3]

$$MCEN_{s,EC,REF,t,t_0} = \frac{\overline{STC}_{s,EC,t,t_0} - \overline{SNGNER}_{s,EC,t,t_0} - \overline{STC}_{s=REF,EC,t^*,t_0}}{\Delta EN_{s,EC,t,REF}}$$

$MCEN_{s,EC,REF,t,t_0}$ Mitigation costs of an energy supply unit s for energy demand/consumption regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [€/kWh]

$\overline{STC}_{s,EC,t,t_0}$ Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SNGNER}_{s,EC,t,t_0}$ Total non-grant non-energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\Delta EN_{s,EC,t,REF}$ reduction (>0) in energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

1.4.4.2.1.4 Set of large-scale units [CB1_4]

$$MCEN_{S,EC,REF,(t),t_0} = \frac{\sum_{s \in S} MCEN_{s,EC,REF,t,t_0} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s \in S} Out_{EC,s,t} * EL_{[s]}}$$

$MCEN_{S,EC,REF,(t),t_0}$ Mitigation costs of set S of energy supply units for final energy demand/consumption regarding output of energy carrier EC (type IO) based on annual data of year (t) using reference unit REF with discount base in year t_0 [€/kWh]

$MCEN_{s,EC,REF,t,t_0}$ Mitigation costs of an energy supply unit s for energy demand/consumption regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.2.2 *Mitigation costs of primary energy demand [CB2]*

References:

- UBA (1995). Economic Evaluation of Measures for the Mitigation of CO_2 Emissions. UBA-FB 104 01 108 / 03.
- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.

1.4.4.2.2.1 Individual building [CB2_1]

$$MCPEN_{i,REF,t,t_0,t_1,t_2} = \frac{\overline{TC}_{i,t,t_0,t_1,t_2} - \overline{STC}_{s=REF,EC=el.,t^*,t_0} * \frac{Out_{el.,i,t}}{Cap_i} - \overline{TC}_{i=REF,t,t_0,t_1,t_2}}{\Delta PEN_{i,REF,t}}$$

Note: Requirement-related costs must not be included in the annuity of the total costs. Therefore, they have to be set 0.

$MCPEN_{i,REF,t,t_0,t_1,t_2}$ Mitigation costs of building i for primary energy demand/consumption based on annual data of year t, with

	construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€/t]
$\overline{TC}_{i,t,t_0,t_1,t_2}$	Annuity of total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/(m² a)]
$\overline{STC}_{s,EC,t,t_0}$	Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]
$Out_{el.,i,t}$	Electricity output (>0) flow of building i in year t [kWh/a]
Cap_i	Floor area of building i [m²]
$\Delta PEN_{i,REF,t}$	Reduction (>0) in primary energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$MCPEN_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{20.63-22.17}{33.1} = -0.047$$

$$MCPEN_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = \frac{20.93-22.17}{23} = -0.054$$

$$MCPEN_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{30.34-31.42}{23} = -0.051$$

$$MCPEN_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{30.34-31.49}{23} = -0.054$$

1.4.4.2.2.2 Set of buildings [CB2_2]

$$MCPEN_{I,I_{REF},(t),t_0,(t_1),(t_2)} = \frac{\sum_{i\in I} MCPEN_{i,REF,t,t_0,t_1,t_2} * \Delta PEN_{i,REF,t} * EL_{[i]} * Cap_i}{\sum_{i\in I} \Delta PEN_{i,REF,t} * EL_{[i]} * Cap_i}$$

$MCPEN_{I,I_{REF},(t),t_0,(t_1),(t_2)}$	Mitigation costs of set I of buildings for primary energy demand/consumption based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [€/kWh]

$MCPEN_{i,REF,t,t_0,t_1,t_2}$ Mitigation costs of building i for primary energy demand/consumption based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€/kWh]

$\Delta PEN_{i,REF,t}$ reduction (>0) in primary energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.2.2.3 Large-scale or building-integrated energy supply unit [CB2_3]

$$MCPEN_{s,EC,REF,t,t_0} = \frac{\overline{TC}_{s,EC,t,t_0} - \overline{TNGNER}_{s,EC,t,t_0} - \overline{TC}_{s=REF,EC,t^*,t_0}}{\Delta PEN_{s,EC,t,REF}}$$

$MCPEN_{s,EC,REF,t,t_0}$ Mitigation costs of an energy supply unit s for primary energy demand/consumption regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [€/kWh]

$\overline{STC}_{s,EC,t,t_0}$ Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SNGNER}_{s,EC,t,t_0}$ Total non-grant non-energy-sales revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\Delta PEN_{s,EC,t,REF}$ Reduction (>0) in primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

1.4.4.2.2.4 Set of large-scale units [CB2_4]

$$MCPEN_{S,EC,REF,(t),t_0} = \frac{\sum_{s \in S} MCPEN_{s,EC,REF,t,t_0} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s \in S} Out_{EC,s,t} * EL_{[s]}}$$

$MCPEN_{S,EC,REF,(t),t_0}$	Mitigation costs of set S of energy supply units for primary energy demand/consumption regarding output of energy carrier EC (type IO) based on annual data of year (t) using reference unit REF with discount base in year t_0 [€/kWh]
$MCPEN_{s,EC,REF,t,t_0}$	Mitigation costs of an energy supply unit s for primary energy demand/consumption regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [€/kWh]
$Out_{EC,s,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.2.3 *Mitigation Costs of greenhouse gas emissions (and first approximation for particulate matter, NO_X and SO_2) [CB3-CB5]*

References:

- UBA (1995). Economic Evaluation of Measures for the Mitigation of CO_2 Emissions. UBA-FB 104 01 108 / 03.
- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.

1.4.4.2.3.1 Individual building [CB3_1-CB5_1]

$$MCEM_{i,M,REF,t,t_0,t_1,t_2} = \frac{\overline{TC}_{i,t,t_0,t_1,t_2} - \overline{STC}_{s=REF,EC=el.,t^*,t_0} * \frac{Out_{el.,i,t}}{Cap_i} - \overline{TC}_{i=REF,t,t_0,t_1,t_2}}{\Delta EM_{i,M,REF,t}}$$

$MCEM_{i,M,REF,t,t_0,t_1,t_2}$ Mitigation costs of building i for emissions of material M based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€/t]

$\overline{TC}_{i,t,t_0,t_1,t_2}$ Annuity of total annual costs of building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/(m² a)]

$\overline{STC}_{s,EC,t,t_0}$ Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{el.,i,t}$ Electricity output (>0) flow of building i in year t [kWh/a]

Cap_i Floor area of building i [m²]

$\Delta EM_{i,M,REF,t}$ Reduction (>0) in emissions of material M by building i based on annual data of year t using reference building REF of the same type as i [t/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices, CO_2 mitigation costs

$$MCEM_{i_1,M=CO2,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{20.63-22.17}{8.1*10^{-3}} = -190$$

$$MCEM_{i_1,M=CO2,REF,t_0=2005,t_1=2005,t_2=2006} = \frac{20.93-22.17}{5.7*10^{-3}} = -218$$

$$MCEM_{i_2,M=CO2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{30.34-31.42}{5.7*10^{-3}} = -207$$

$$MCEM_{i_3,M=CO2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{30.34-31.49}{5.7*10^{-3}} = -219$$

1.4.4.2.3.1 Set of buildings [CB3_2-CB5_2]

$$MCEM_{I,I_{REF},M,(t),t_0,(t_1),(t_2)} = \frac{\sum_{i \in I} MCEM_{i,M,REF,t,t_0,t_1,t_2} * \Delta EM_{i,M,REF,t} * EL_{[i]} * Cap_i}{\sum_{i \in I} \Delta EM_{i,M,REF,t} * EL_{[i]} * Cap_i}$$

$MCEM_{I,I_{REF},M,(t),t_0,(t_1),(t_2)}$	Mitigation costs of set I of buildings for emissions of material M based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [€/kWh]
$MCEM_{i,M,REF,t,t_0,t_1,t_2}$	Mitigation costs of building i for emissions of material M based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [€/t]
$\Delta EM_{i,M,REF,t}$	reduction (>0) in emissions of material M by building i based on annual data of year t using reference building REF of the same type as i [t/(m² a)]
Cap_i	Floor area of building i [m²]
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.2.3.2 Large-scale or building-integrated energy supply unit [CB3_3-CB5_3]

$$MCEM_{s,M,EC,REF,t,t_0} = \frac{\overline{STC}_{s,EC,t,t_0} - \overline{STNGNER}_{s,EC,t,t_0} - \overline{STC}_{s=REF,EC,t^*,t_0}}{\Delta EM_{s,M,EC,t,REF}}$$

$MCEM_{s,M,EC,REF,t,t_0}$	Mitigation costs of an energy supply unit s for emissions of material M regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [€/t]
$\overline{STC}_{s,EC,t,t_0}$	Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$\overline{SNGNER}_{s,EC,t,t_0}$	Total non-grant non-energy-salesrevenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]
$\Delta EM_{s,M,EC,t,REF}$	Reduction (>0) in emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [t/kWh]

1.4.4.2.3.3 Set of large-scale units [CB3_4-CB5_4]

$$MCEM_{S,M,EC,REF,(t),t_0} = \frac{\sum_{s \in S} MCEM_{s,M,EC,REF,t,t_0} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s \in S} Out_{EC,s,t} * EL_{[s]}}$$

$MCEM_{S,M,EC,REF,(t),t_0}$	Mitigation costs of set S of energy supply units for emissions of material M regarding output of energy carrier EC (type IO) based on annual data of year (t) using reference unit REF with discount base in year t_0 [€/t]
$MCEM_{s,M,EC,REF,t,t_0}$	Mitigation costs of an energy supply unit s for emissions of material M regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [€/t]
$Out_{EC,s,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.3 National/local society [CC1-CC10]

References:

- UBA (1995). Economic Evaluation of Measures for the Mitigation of CO_2 Emissions. UBA-FB 104 01 108 / 03.
- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.

1.4.4.3.1 *Mitigation costs of (final) energy demand [CC1]*

Cf. chapter 1.4.4.2.1, but total costs include external costs (cf. chapter 1.4.2.1).

1.4.4.3.2 *Mitigation costs of primary energy demand [CC2]*

Cf. chapter 0, but total costs include external costs (cf. chapter 1.4.2.1).

1.4.4.3.3 *Mitigation Costs of greenhouse gas emissions (and first approximation for particulate matter, NO_X and SO_2) [CC3-CC5]*

Greenhouse gas emissions [CC3]

Cf. chapter 0, but total costs include external costs for particulate matter, NO_X and SO_2.

Particulate matter emissions [CC4]

Cf. chapter 0, but total costs include external costs for greenhouse gases, NO_X and SO_2 (cf. chapter 1.4.2.1).

NO_x emissions [CC5]

Cf. chapter 0, but total costs include external costs for greenhouse gases, particulate matter and SO_2 (cf. chapter 1.4.2.1).

SO_2 emissions [CC5]

Cf. chapter 0, but total costs include external costs for greenhouse gases, particulate matter and NO_X (cf. chapter 1.4.2.1).

1.4.4.3.1 *Stimulation of local economy [CC6-CC10]*

References:

- CONCERTO Plus. (2009) Socio-economic matrix ("SE_matrix_core_indicators_Nov09")

Description: The stimulation of the local economy can be expressed by several indicators from the point of view of the **national/local economy**.

1.4.4.3.1.1 Number of jobs created [CC6]

Description: This indicator is defined as number of jobs created in the course of the CONCERTO activities.

Unit: jobs, person-years

Individual buildings [CC6_1]

Not applicable

Set of buildings [CC6_2]

Not applicable

Large-scale or building-integrated energy supply units [CC6_3]

Not applicable

Set of large-scale units [CC6_4]

Not applicable

CONCERTO area [CC6_5]

NJC Number of jobs created in the CONCERTO area in course of the CONCERTO activities [jobs, person-years]

Note: This indicator sould be calculated based on the investments, but the methodology has not yet been defined.

1.4.4.3.1.2 Number of new businesses created [CC7]

Description: This indicator is defined as number of businesses created in the CONCERTO area in the course of the CONCERTO activities.

Unit: businesses

Individual buildings [CC7_1]

Not applicable

Set of buildings [CC7_2]

Not applicable

Large-scale or building-integrated energy supply units [CC7_3]

Not applicable

Set of large-scale units [CC7_4]

Not applicable

CONCERTO area [CC7_5]

NBC Number of new businesses created in the CONCERTO area in the course of the CONCERTO activities [businesses]

1.4.4.3.1.3 Number of trainings/person-days for trainings offered [CC8]

Description: This indicator is defined as number of trainings or person-days for trainings offered in course of the CONCERTO activities.

Unit: trainings, person-days

Individual buildings [CC8_1]

Not applicable

Set of buildings [CC8_2]

Not applicable

Large-scale or building-integrated energy supply units [CC8_3]

Not applicable

Set of large-scale units [CC8_4]

Not applicable

CONCERTO area [CC8_5]

NTO Number of trainings/person-days for trainings offered in the course of the CONCERTO activities [trainings, person-days]

1.4.4.3.1.4 Increase in real estate and flat value [CC9]

Description: This indicator is defined as the increase of real estate and flat value after the CONCERTO project compared to the situation before the CONCERTO project. The indicator can only be calculated if an evaluation of the buildings has been done before and after the implementation of the CONCERTO measures. Eventually, the values of the buildings should be discounted to the same base.

Unit: -

Individual buildings [CC9_1]

$$IRV_i = \frac{VB_{i,afterCONCERTO}}{VB_{i,beforeCONCERTO}}$$

IRV_i Increase in the value of building i after the CONCERTO project compared to the situation before the CONCERTO project [%]

$VB_{i,afterCONCERTO}$ Value of building i before the CONCERTO activities [€]

$VB_{i,beforeCONCERTO}$ Value of building i after the CONCERTO activities [€]

Set of buildings [CC9_2]

$$IRV = \frac{\sum_{i \in I} VB_{i,afterCONCERTO}}{\sum_{i \in I} VB_{i,beforeCONCERTO}}$$

IRV_I Increase in the value of the set I of buildings after the CONCERTO project compared to the situation before the CONCERTO project [%]

$VB_{i,afterCONCERTO}$ Value of building i before the CONCERTO activities [€]

$VB_{i,beforeCONCERTO}$ Value of building i after the CONCERTO activities [€]

Large-scale or building-integrated energy supply units [CC9_3]

Not applicable

Set of large-scale units [CC9_4]

Not applicable

CONCERTO area [CC9_5]

Cf. set of buildings

1.4.4.3.1.5 Changes in community demographics [CC10]

Description: This indicator is defined as increase of the number of inhabitants of the CONCERTO area compared to the situation before the CONCERTO project.

Unit: inhabitants

Individual buildings [CC10_1]

Not applicable

Set of buildings [CC10_2]

Not applicable

Large-scale or building-integrated energy supply units [CC10_3]

Not applicable

Set of large-scale units [CC10_4]

Not applicable

CONCERTO area [CC10_5]

CCD Changes in community demographics - neighbourhood growth, i.e. increase of the number of inhabitants of the CONCERTO area compared to the situation before the CONCERTO project [inhabitants]

1.4.4.4 Grant provider [CD1-CD6]

References:

- UBA. (1995) Economic Evaluation of Measures for the Mitigation of CO_2 Emissions. UBA-FB 104 01 108 / 03.
- Deutsches Institut für Urbanistik in Kooperation mit Institut für Energie- und Umweltforschung Heidelberg GmbH (ifeu) und Klima-Bündnis - Climate Alliance - Alianza del Clima e.V. (2011) Klimaschutz in Kommunen – Praxisleitfaden. Hrsg., Frankfurt/M. ISBN: 978-3-88118-496-0. pp. 302-303.
- KfW (STE Research Report). (2009) Gesamtwirtschaftliche CO2-Vermeidungskosten der energetischen Gebäudesanierung und Kosten der Förderung für den Bundeshaushalt im Rahmen des CO2-Gebäudesanierungsprogramms, pp. 37-38.

The costs or outgoing cash-flows of the grant provider correspond to revenues of other target groups. Therefore, grant revenues from the point of view of owner-occupiers, landlords and plant owners is used in order to determine the costs and outgoing cash-flows of the grant provider.

1.4.4.4.1 *Mitigation of (final) energy demand per grant [CD1]*

1.4.4.4.1.1 Individual building [CD1_1]

$$MGEN_{i,REF,t,t_0,t_1,t_2} = \frac{\Delta EN_{i,REF,t}}{\overline{\overline{TGR}}_{i,t,t_0}}$$

$MGEN_{i,REF,t,t_0,t_1,t_2}$ Mitigation of final energy demand/consumption per grant for a building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [kWh/€]

$\Delta EN_{i,REF,t}$ Reduction (>0) in final energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$\overline{TGR}_{i,t,t_0}$	Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$MGEN_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{41}{0.18} = 228$$

$$MGEN_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = \frac{41}{0.18} = 228$$

$$MGEN_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{41}{0.17} = 241$$

$$MGEN_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{41}{0.15} = 273$$

1.4.4.4.1.2 Set of buildings [CD1_2]

$$MGEN_{I,I_{REF},(t),t_0,(t_1),(t_2)} = \frac{\sum_{i \in I} \Delta EN_{i,REF,t} * Cap_i * EL_{[i]}}{\sum_{i \in I} \overline{TGR}_{i,t,t_0} * Cap_i * EL_{[i]}}$$

$MGEN_{I,I_{REF},(t),t_0,(t_1),(t_2)}$	Mitigation of final energy demand/consumption per grant for a set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [kWh /€]
$\Delta EN_{i,REF,t}$	Reduction (>0) in final energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]
$\overline{TGR}_{i,t,t_0}$	Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]
Cap_i	Floor area of building i [m²]
$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.4.1.3 Large-scale or building-integrated energy supply unit s [CD1_3]

$$MGEN_{s,EC,REF,t,t_0} = \frac{\Delta EN_{s,EC,t,REF}}{\overline{SGR}_{s,EC,t,t_0}}$$

$MGEN_{s,EC,REF,t,t_0}$ Mitigation of energy demand/consumption per grant for an energy supply unit s regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [kWh/€]

$\Delta EN_{s,EC,t,REF}$ Reduction (>0) in energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

1.4.4.4.1.4 Set of large-scale units [CD1_4]

$$MGEN_{S,EC,REF,(t),t_0} = \frac{\sum_{s \in S} \Delta EN_{s,EC,t,REF} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s \in S} \overline{SGR}_{s,EC,t,t_0} * Out_{EC,s,t} * EL_{[s]}}$$

$MGEN_{S,EC,REF,(t),t_0}$ Mitigation of energy demand/consumption per grant for a set S of energy supply units regarding output of energy carrier EC (type IO) based on year (t) using reference unit REF with discount base in year t_0 [kWh/€]

$\Delta EN_{s,EC,t,REF}$ Reduction (>0) in energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$EL_{[s]}$ Expected lifetime of energy supply units of the same type as s [a]

1.4.4.4.2 *Mitigation of primary energy demand per grant [CD2]*

1.4.4.4.2.1 Individual building [CD2_1]

$$MGPEN_{i,REF,t,t_0,t_1,t_2} = \frac{\Delta PEN_{i,REF,t}}{\overline{TGR}_{i,t,t_0}}$$

$MGPEN_{i,REF,t,t_0,t_1,t_2}$ Mitigation of primary energy demand/consumption per grant for a building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [kWh/€]

$\Delta PEN_{i,REF,t}$ Reduction (>0) in primary energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$\overline{TGR}_{i,t,t_0}$ Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$MGPEN_{i_1,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{33.1}{0.18} = 184$$

$$MGPEN_{i_1,REF,t_0=2005,t_1=2005,t_2=2006} = \frac{23}{0.18} = 128$$

$$MGPEN_{i_2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{23}{0.17} = 135$$

$$MGPEN_{i_3,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{23}{0.15} = 153$$

1.4.4.4.2.1 Set of buildings [CD2_2]

$$MGPEN_{I,I_{REF},(t),t_0,(t_1),(t_2)} = \frac{\sum_{i\in I} \Delta PEN_{i,REF,t} * Cap_i * EL_{[i]}}{\sum_{i\in I} \overline{TGR}_{i,t,t_0} * Cap_i * EL_{[i]}}$$

$MGPEN_{I,I_{REF},(t),t_0,(t_1),(t_2)}$ Mitigation of primary energy demand/consumption per grant for a set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [kWh/€]

CONCERTO is co-funded by the European Union under the Research Framework Programme

$\Delta PEN_{i,REF,t}$ Reduction (>0) in primary energy demand/consumption by building i based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$\overline{TGR}_{i,t,t_0}$ Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.4.2.2 Large-scale or building-integrated energy supply unit [CD2_3]

$$MGPEN_{s,EC,REF,t,t_0} = \frac{\Delta PEN_{s,EC,t,REF}}{\overline{SGR}_{s,EC,t,t_0}}$$

$MGPEN_{s,EC,REF,t,t_0}$ Mitigation of primary energy demand/consumption per grant for an energy supply unit s regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [kWh/€]

$\Delta PEN_{s,EC,t,REF}$ Reduction (>0) in primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]

$\overline{SGR}_{s,EC,t,t_0}$ Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

1.4.4.4.2.1 Set of large-scale units [CD2_4]

$$MGPEN_{S,EC,REF,(t),t_0} = \frac{\sum_{s \in S} \Delta PEN_{s,EC,t,REF} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s \in S} \overline{SGR}_{s,EC,t,t_0} * Out_{EC,s,t} * EL_{[s]}}$$

$MGPEN_{S,EC,REF,(t),t_0}$ Mitigation of primary energy demand/consumption per grant for a set S of energy supply units regarding output of energy carrier EC (type IO) based on year (t) using reference unit REF with discount base in year t_0 [kWh/€]

$\Delta PEN_{s,EC,t,REF}$	Reduction (>0) in primary energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [kWh/kWh]
$\overline{SGR}_{s,EC,t,t_0}$	Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]
$Out_{EC,s,t}$	output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]

1.4.4.4.3 *Mitigation of greenhouse gas emissions (and first approximation for particulate matter, NO_X and SO_2) per grant [CD3-CD5]*

1.4.4.4.3.1 Individual building [CD3_1-CD5_1]

$$MGEM_{i,M,REF,t,t_0,t_1,t_2} = \frac{\Delta EM_{i,M,REF,t}}{\overline{TGR}_{i,t,t_0}}$$

$MGEM_{i,M,REF,t,t_0,t_1,t_2}$	Mitigation of emissions of material M per grant for a building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 using reference building REF [t/€]
$\Delta EM_{i,M,REF,t}$	Reduction (>0) in emissions of material M by building i based on annual data of year t using reference building REF of the same type as i [t/(m² a)]
$\overline{TGR}_{i,t,t_0}$	Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$MGEM_{i_1,M=CO2,REF,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{8.1*10^{-3}}{0.18} = 0.045$$

$$MGEM_{i_1,M=CO2,REF,t_0=2005,t_1=2005,t_2=2006} = \frac{5.7*10^{-3}}{0.18} = 0.032$$

$$MGEM_{i_2,M=CO2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{5.7*10^{-3}}{0.17} = 0.034$$

$$MGEM_{i_3,M=CO2,REF,t_0=2005,t_1=2007,t_2=2008} = \frac{5.7*10^{-3}}{0.15} = 0.038$$

1.4.4.4.3.2 Set of buildings [CD3_2-CD5_2]

$$MGEM_{I,I_{REF},M,(t),t_0,(t_1),(t_2)} = \frac{\sum_{i \in I} \Delta EM_{i,M,REF,t} * Cap_i * EL_{[i]}}{\sum_{i \in I} \overline{TGR}_{i,t,t_0} * Cap_i * EL_{[i]}}$$

$MGEM_{I,I_{REF},M,(t),t_0,(t_1),(t_2)}$ Mitigation of emissions of material M per grant for a set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 using set I_{REF} of reference buildings [t/€]

$\Delta EM_{i,M,REF,t}$ Reduction (>0) in emissions of material M by building i based on annual data of year t using reference building REF of the same type as i [t/(m² a)]

$\overline{TGR}_{i,t,t_0}$ Annuity of annual grant revenues of building i based on data of year t and with discount base in year t_0 [€/(m² a)]

Cap_i Floor area of building i [m²]

$EL_{[i]}$ Expected lifetime of a building of the same type as i [a]

Note: (x), (t) etc. represent series of elements as in a set of objects, each object could have an individual parameter x or t (e.g. construction start)

1.4.4.4.3.3 Large-scale or building-integrated energy supply unit [CD3_3-CD5_3]

$$MGEM_{s,M,EC,REF,t,t_0} = \frac{\Delta EM_{s,M,EC,t,REF}}{\overline{SGR}_{s,EC,t,t_0}}$$

$MGEM_{s,M,EC,REF,t,t_0}$ Mitigation of emissions of material M per grant for an energy supply unit s regarding output of energy carrier EC (type IO) based on year t using reference unit REF with discount base in year t_0 [t/€]

$\Delta EM_{s,M,EC,t,REF}$	Reduction (>0) in emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [t/kWh]
$\overline{SGR}_{s,EC,t,t_0}$	Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]

1.4.4.4.3.4 Set of large-scale units [CD3_4-CD5_4]

$$MGEM_{S,EC,REF,(t),t_0} = \frac{\sum_{s \in S} \Delta EM_{s,M,EC,t,REF} * Out_{EC,s,t} * EL_{[s]}}{\sum_{s \in S} \overline{SGR}_{s,EC,t,t_0} * Out_{EC,s,t} * EL_{[s]}}$$

$MGEM_{S,EC,REF,(t),t_0}$	Mitigation of emissions of material M per grant for a set S of energy supply units regarding output of energy carrier EC (type IO) based on year (t) using reference unit REF with discount base in year t_0 [kWh/€]
$\Delta EM_{s,M,EC,t,REF}$	Reduction (>0) in emissions of material M by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t compared to reference unit REF [t/kWh]
$\overline{SGR}_{s,EC,t,t_0}$	Sum of discounted grant revenues of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]
$Out_{EC,s,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]
$EL_{[s]}$	Expected lifetime of energy supply units of the same type as s [a]

1.4.4.4.4 *Triggered investment per grant provided [CD6]*

Description: The triggered investment per grant provided is defined as ratio of the investment triggered in connection with grants and the sum of discounted investment-related and requirement-related grant cash-flows. This indicator corresponds to the point of view of the **grant provider**.

Unit: €/€

1.4.4.4.4.1 Individual building [CD6_1]

$$TIG_{i,t,t_0,t_1,t_2} = \frac{I_{i,t_1} * (1+r)^{t_0-t_1}}{TGR_{i,t,t_0}}$$

TIG_{i,t,t_0,t_1,t_2} Triggered investment per grant for building i based on annual data of year t, with construction start in t_1, construction end in year t_2 and discount base in year t_0 [€/€]

I_{i,t_1} Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]

TGR_{i,t,t_0} Net present value of total grant revenues of building i over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

r Interest rate for calculations [-]

Example: Scharnhauser Park; i_1=MFH-PC; i_2=SFH-PC; i_3=RH-PC; constant energy prices

$$TIG_{i_1,t=2010,t_0=2005,t_1=2005,t_2=2006} = \frac{1{,}000{,}000}{11{,}298} = 89$$

$$TIG_{i_2,t_0=2005,t_1=2007,t_2=2008} = \frac{1{,}950{,}236}{12{,}282} = 159$$

$$TIG_{i_3,t_0=2005,t_1=2007,t_2=2008} = \frac{2{,}249{,}764}{12{,}292} = 183$$

1.4.4.4.4.2 Set of buildings [CD6_2]

$$TIG_{I,(t),t_0,(t_1),(t_2)} = \frac{\sum_{i\in I} I_{i,t_1} * (1+r)^{t_0-t_1}}{\sum_{i\in I} SGR_{i,t,t_0}}$$

$TIG_{I,(t),t_0,(t_1),(t_2)}$ Triggered investment per grant for set I of buildings based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 [€/€]

I_{i,t_1} Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]

SGR_{i,t,t_0} Sum of discounted annual grant revenues of building i over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

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r Interest rate for calculations [-]

1.4.4.4.4.3 Large-scale or building-integrated energy supply unit [CD6_3]

$$TIG_{s,t,t_0} = \frac{I_{s,t_1} * (1+r)^{t_0 - t_1}}{SGR_{s,t,t_0}}$$

TIG_{s,t,t_0} Triggered investment per grant for component s of a large-scale energy system based on data of year t and with discount base in year t_0 [€/€]

I_{s,t_1} Investment for component s of a large-scale energy system; construction in year t_1; investment is discounted to year t_1 [€]

SGR_{s,t,t_0} Sum of discounted grant revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

r Interest rate for calculations [-]

1.4.4.4.4.4 Set of large-scale units [CD6_4]

$$TIG_{S,(t),t_0,(t_1),(t_2)} = \frac{\sum_{s \in S} I_{s,t_1} * (1+r)^{t_0 - t_1}}{\sum_{s \in S} SGR_{s,t,t_0}}$$

$TIG_{S,(t),t_0,(t_1),(t_2)}$ Triggered investment per grant for set S of energy supply units based on annual data of year (t), with construction start in (t_1), construction end in year (t_2) and discount base in year t_0 [€/€]

I_{s,t_1} Investment for component s of a large-scale energy system; construction in year t_1; investment is discounted to year t_1 [€]

SGR_{s,t,t_0} Sum of discounted grant revenues of energy supply unit s over the expected-lifetime based on data of year t and with discount base in year t_0 [€]

r Interest rate for calculations [-]

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1.5 Technical indicators [D1-D13]

1.5.1 Density of final energy demand (or consumption) [D1]

1.5.1.1 Individual buildings [D1_1]

Not applicable

1.5.1.2 Set of buildings [D1_2]

Description: The indicator is defined as ratio of final energy demand (for heating or cooling) of a cohesive set of buildings and a simple figure representing the effort that a district heating or cooling network operator would have in order to supply these buildings. For the latter the territory area or the number of buildings is chosen in order to represent the length of the network and the number of connections that are required.

Unit: kWh/(km² a), kWh/(building a)

$$DEN_{EC,I,t} = \frac{\sum_{AA=AA1}^{AA4} In_{EC,AA,I,t}}{Cap_I}$$

$DEN_{EC,I,t}$ Density of final energy demand/consumption of a set I of buildings in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$In_{EC,AA,I,t}$ Input (>0) energy flow into set I of buildings for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

Cap_I Area or number of set I of buildings I [km² territory area, buildings]

1.5.1.1 Large-scale or building-integrated energy supply units [D1_3]

Not applicable

1.5.1.2 Set of large-scale units [D1_4]

Not applicable

1.5.1.3 Concerto area [D1_5]

Cf. set of buildings

1.5.2 Efficiency of energy supply units [D2]

Description: The efficiency of an energy supply unit or a set of energy supply units can be determined as **maximum or** as **average** efficiency over a month or a year. The inverse of the average efficiency is already described in chapter 1.3.1.1.3. In order to determine the maximum efficiency within a period of time, a high temporal resolution is required.

Unit: kWh_{out}/kWh_{in}

1.5.2.1 Individual buildings [D2_1]

Not applicable

1.5.2.2 Set of buildings [D2_2]

Not applicable

1.5.2.3 Large-scale or building-integrated energy supply units

1.5.2.3.1 *Average efficiency [D2_1_3]*

$$Ef_{s,EC,t,avg} = \frac{1}{EN_{s,EC,t}}$$

$Ef_{s,EC,t,avg}$ (Average) energy output of energy carrier EC (type IO) by energy supply unit s per energy input (demand/consumption) based on year t [kWh/kWh]

$EN_{s,EC,t}$ Energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.2.3.2 *Maximum efficiency [D2_2_3]*

$$Ef_{s,EC,t,\max} = \max_{k=1,\ldots,K}\left(\frac{1}{EN_{s,EC,\Delta t_k}}\right)$$

$Ef_{s,EC,t,\max}$ Maximum energy output of energy carrier EC (type IO) by energy supply unit s per energy input (demand/consumption) based on a partition of year t [kWh/kWh]

$EN_{s,EC,t,\Delta t_k}$ Energy demand/consumption by energy supply unit s divided by the production of the output of energy carrier EC (type IO) based on Δt_k (k=1,…,K) as part of a partition of year t [kWh/kWh]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.2.4 Set of large-scale units

1.5.2.4.1 *Average efficiency [D2_1_4]*

$$Ef_{S,EC,t,avg} = \frac{1}{EN_{S,EC,t}}$$

$Ef_{s,EC,t,avg}$ (Average) energy output of energy carrier EC (type IO) by set S of energy supply units per energy input (demand/consumption) based on year t [kWh/kWh]

$EN_{S,EC,t}$ Energy demand/consumption by set S of large-scale units divided by the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.2.4.2 *Maximum efficiency [D2_2_4]*

$$Ef_{S,EC,t,\max} = \max_{k=1,\dots,K}\left(\frac{1}{EN_{S,EC,\Delta t_k}}\right)$$

$Ef_{S,EC,t,\max}$ Maximum energy output of energy carrier EC (type IO) by set S of energy supply units per energy input (demand/consumption) based on a partition of year t [kWh/kWh]

$EN_{S,EC,t,\Delta t_k}$ Energy demand/consumption by set S of energy supply units divided by the production of the output of energy carrier EC (type IO) based on Δt_k (k=1,…,K) as part of a partition of year t [kWh/kWh]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.2.5 Concerto area [D2_5]

Not applicable

1.5.3 Power of energy supply units in operation [D3]

Description: The power of an energy supply unit or a set of energy supply units in operation can be determined as **maximum** or as **average** power over a month or a year. The average power is defined as energy output of the energy supply over a period of time and the length of this period (month or year). In order to determine the maximum power within a period of time, a high temporal resolution is required. The average or maximum power in operation can be compared to the maximum capacity (design value) in order to determine the degree of utilization of the energy supply unit.

Unit: kW/kW

1.5.3.1 Individual buildings [D3_1]

Not applicable

1.5.3.2 Set of buildings [D3_1]

Not applicable

1.5.3.3 Large-scale or building-integrated energy supply units

1.5.3.3.1 *Average power [D3_1_3]*

$$Po_{s,EC,t,avg} = \frac{Out_{EC,s,t}}{8760 * Cap_{s,EC}}$$

$Po_{s,EC,t,avg}$ (Average) power of energy carrier EC (type IO) by energy supply unit s per energy input (demand/consumption) based on year t [kW/kW]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.3.3.2 *Maximum power [D3_2_3]*

$$Po_{s,EC,t,\max} = \max_{k=1,\dots,K}\left(\frac{Out_{EC,s,t,\Delta t_k}}{\Delta t_k * 8760 * Cap_{s,EC}}\right)$$

$Po_{s,EC,t,\max}$ Maximum power of energy carrier EC (type IO) by energy supply unit s per energy input (demand/consumption) based on a partition of year t [kW/kW]

$Out_{EC,s,t,\Delta t_k}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s based on Δt_k (k=1,…,K) as part of a partition of year t [kWh/a]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.3.4 Set of large-scale units

1.5.3.4.1 *Average power [D3_1_4]*

$$Po_{S,EC,t,avg} = \frac{\sum_{s \in S} Out_{EC,s,t}}{\sum_{s \in S} 8760 * Cap_{s,EC}}$$

$Po_{S,EC,t,avg}$ (Average) power of energy carrier EC (type IO) by set S of energy supply units per energy input (demand/consumption) based on year t [kW/kW]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.3.4.2 *Maximum power [D3_2_4]*

$$Po_{S,EC,t,\max} = \max_{k=1,\dots,K} \left(\frac{\sum_{s \in S} Out_{EC,s,t,\Delta t_k}}{\sum_{s \in S} \Delta t_k * 8760 * Cap_{s,EC}} \right)$$

$Po_{S,EC,t,\max}$ Maximum power of energy carrier EC (type IO) by set S of energy supply units per energy input (demand/consumption) based on a partition of year t [kW/kW]

$Out_{EC,s,t,\Delta t_k}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s based on Δt_k (k=1,…,K) as part of a partition of year t [kWh/a]

$Cap_{s,EC}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.3.5 Concerto area [D3_5]

Not applicable

1.5.4 Peak load and load profile of electricity demand [D4]

Description: The peak load and the load profile of the electricity demand require a high temporal resolution. The load profile describes the demand characteristics over time. The electricity supply has to be able to cover the peak load. The load profile gives information about the possibilities or potentials of storage, demand-side management and self-supply via photovoltaic etc.

Unit: kW

1.5.4.1 Individual buildings

1.5.4.1.1 *Load profile [D4_1_1]*

$$LP_{i,EC=electricity,t,\Delta t_k} = \frac{\sum_{AA=AA1}^{AA4} In_{EC,AA,i,\Delta t_k}}{\Delta t_k * 8760}$$

$LP_{i,EC=electricity,t,\Delta t_k}$ Load of building i regarding energy carrier EC=electricity (type IO) in Δt_k (k=1,…,K) as part of a partition of year t [kW]

$In_{EC,AA,i,t,\Delta t_k}$ Input (>0) energy flow into building i for application area AA in Δt_k (k=1,…,K) as part of a partition of year t regarding energy carrier (or source) EC (type B) [kWh/a]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.4.1.2 *Peak load [D4_2_1]*

$$LP_{i,EC=electricity,t,\max} = \max_{k=1,\dots,K}(LP_{i,EC=electricity,t,\Delta t_k})$$

$LP_{i,EC=electricity,t,\max}$ Peak load of building i regarding energy carrier EC (type IO) based on a partition of year t [kW]

$LP_{i,EC=electricity,t,\Delta t_k}$ Load of building i regarding energy carrier EC=electricity (type IO) in Δt_k (k=1,…,K) as part of a partition of year t [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.4.2 Set of buildings

1.5.4.2.1 *Load profile [D4_1_2]*

$$LP_{I,EC=electricity,t,\Delta t_k} = \frac{\sum_{AA=AA1}^{AA4} In_{EC,AA,I,\Delta t_k}}{\Delta t_k * 8760}$$

$LP_{I,EC=electricity,t,\Delta t_k}$ Load of set I of buildings regarding energy carrier EC=electricity (type IO) in Δt_k (k=1,…,K) as part of a partition of year t [kW]

$In_{EC,AA,I,t,\Delta t_k}$ Input (>0) energy flow into set I of buildings for application area AA in Δt_k (k=1,…,K) as part of a partition of year t regarding energy carrier (or source) EC (type B) [kWh/a]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.4.2.2 *Peak load [D4_2_2]*

$$LP_{I,EC=electricity,t,\max} = \max_{k=1,\dots,K}(LP_{I,EC=electricity,t,\Delta t_k})$$

$LP_{I,EC=electricity,t,\max}$ Peak load of a set I of buildings regarding energy carrier EC (type IO) based on a partition of year t [kW]

$LP_{I,EC=electricity,t,\Delta t_k}$ Load of set I of buildings regarding energy carrier EC=electricity (type IO) in Δt_k (k=1,…,K) as part of a partition of year t [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.4.3 Large-scale or building-integrated energy supply units [D4_3]

Not applicable

1.5.4.4 Set of large-scale units [D4_4]

Not applicable

1.5.4.5 Concerto area [D4_5]

Cf. set of buildings

1.5.5 Peak load and load profile of thermal (heat and cold) energy demand [D5]

Description: The peak load and the load profile of the thermal (heat and cold) energy demand require a high temporal resolution. The load profile describes the demand characteristics over time. The thermal energy supply has to be able to cover the peak load. The load profile gives information about the possibilities or potentials of storage as well as supply-side and demand-side management. The indicator can be calculated for the district heat/cold supply (case A) or for the application areas of heating and cooling (case B).

Unit: kW

1.5.5.1 Individual buildings

1.5.5.1.1 *District heat/cold supply (case A) [D5_1_1, D5_2_1]*

Cf. chapter 1.5.4 with EC=heat or EC=cold instead of EC=electricity

1.5.5.1.2 *Application areas of heating and cooling (case B)*

1.5.5.1.2.1 Load profile [D5_1_1]

$$LP_{i,AA,t,\Delta t_k} = \frac{\sum_{EC} In_{EC,AA,i,\Delta t_k}}{\Delta t_k * 8760}$$

$LP_{i,AA,t,\Delta t_k}$ Load of building i regarding application area AA in Δt_k (k=1,…,K) as part of a partition of year t [kW]

$In_{EC,AA,i,t,\Delta t_k}$ Input (>0) energy flow into building i for application area AA in Δt_k (k=1,…,K) as part of a partition of year t regarding energy carrier (or source) EC (type B) [kWh/a]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.5.1.2.2 Peak load [D5_2_1]

$$LP_{i,AA,t,\max} = \max_{k=1,\dots,K} (LP_{i,AA,t,\Delta t_k})$$

$LP_{i,AA,t,\max}$ Peak load of building i regarding application area AA based on a partition of year t [kW]

$LP_{i,AA,t,\Delta t_k}$ Load of building i regarding application area AA in Δt_k (k=1,…,K) as part of a partition of year t [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.5.2 Set of buildings

1.5.5.2.1 *District heat/cold supply (case A) [D5_1_2, D5_2_2]*

Cf. chapter 1.5.4 with EC=heat or EC=cold instead of EC=electricity

1.5.5.2.2 *Application areas of heating and cooling (case B)*

1.5.5.2.2.1 Load profile [D5_1_2]

$$LP_{I,AA,t,\Delta t_k} = \frac{\sum_{EC} In_{EC,AA,I,\Delta t_k}}{\Delta t_k * 8760}$$

$LP_{I,AA,t,\Delta t_k}$ Load of set I of buildings regarding application area AA in Δt_k (k=1,…,K) as part of a partition of year t [kW]

$In_{EC,AA,I,t,\Delta t_k}$ Input (>0) energy flow into set I of buildings for application area AA in Δt_k (k=1,…,K) as part of a partition of year t regarding energy carrier (or source) EC (type B) [kWh/a]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.5.2.2.2 Peak load [D5_2_2]

$$LP_{I,AA,t,\max} = \max_{k=1,\dots,K}(LP_{I,AA,t,\Delta t_k})$$

$LP_{I,AA,t,\max}$ Peak load of a set I of buildings regarding application area AA based on a partition of year t [kW]

$LP_{I,AA,t,\Delta t_k}$ Load of set I of buildings regarding application area AA in Δt_k (k=1,…,K) as part of a partition of year t [kW]

Note: The variables for partitions of a year t are not specified in detail. The unit of Δt_k (k=1,…,K) is a.

1.5.5.3 Large-scale or building-integrated energy supply units [D5_3]

Not applicable

1.5.5.4 Set of large-scale units [D5_4]

Not applicable

1.5.5.5 Concerto area [D5_5]

Cf. set of buildings

1.5.6 Degree of accordance with national laws and standards [D6]

1.5.6.1 Individual buildings

Description: The degree of accordance with national laws and standards is defined as ratio of final or primary energy demand/consumption of an individual building and of a functionally comparable building built according to the national minimum requirements. The concrete specification of the energy demand depends on the national legislation. This indicator can be used for new constructed and refurbished buildings. In case of refurbished buildings, it has to be kept in mind that the refurbished building is compared to the national minimum requirements for new constructions.

Unit: %

1.5.6.1.1 *Final energy demand [D6_1_1]*

$$DA_{i,REF,t,final} = EN_{i,t} / EN_{i=REF,t'}$$

$DA_{i,REF,t,final}$ Degree of building i's accordance with national laws and standards regarding total final energy based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$EN_{i,t}$ Final energy energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]

1.5.6.1.2 *Primary energy demand [D6_2_1]*

$$DA_{i,REF,t,primary} = PEN_{i,t} / PEN_{i=REF,t'}$$

$DA_{i,REF,t,primary}$ Degree of building i's accordance with national laws and standards regarding total primary energy based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]

$PEN_{i,t}$ Primary energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]

1.5.6.2 Set of buildings [D6_1_2, D6_2_2]

$$DA_{I,t,final/primary} = \frac{\sum_{i \in I} Cap_i * DA_{i,REF,t,final/primary}}{\sum_{i \in I} Cap_i}$$

$DA_{I,REF,t,final/primary}$	Degree of accordance of a set I of buildings with national laws and standards regarding total final/primary energy based on annual data of year t [kWh/(m² a)]
$DA_{i,REF,t,final/primary}$	Degree of building i's accordance with national laws and standards regarding total final/primary energy based on annual data of year t using reference building REF of the same type as i [kWh/(m² a)]
Cap_i	Floor area of building i [m²]

1.5.6.3 Large-scale or building-integrated energy supply units [D6_3]

Not applicable

1.5.6.4 Set of large-scale units [D6_4]

Not applicable

1.5.6.5 Concerto area [D6_5]

Cf. set of buildings

1.5.7 Degree of congruence of calculated annual final energy demand and monitored consumption [D7]

1.5.7.1 Individual buildings [D7_1]

Description: The degree of congruence of calculated final energy demand and monitored consumption is defined as the ratio of the final energy demand of a building and the final energy consumption of a building over a period of time (year).

Unit: %

$$DC_{i,t} = \frac{EN_{i,t,(demand)}}{EN_{i,t,(consumption)}}$$

$DC_{i,t}$	Degree of building i's congruence of calculated final energy demand and monitored consumption based on annual data of year t [kWh/(m² a)]

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$EN_{i,t}$ Final energy energy demand/consumption of building i based on annual data of year t [kWh/(m² a)]

1.5.7.2 Set of buildings [D7_2]

$$DC_{I,t} = \frac{\sum_{i \in I} Cap_i * DC_{i,t}}{\sum_{i \in I} Cap_i}$$

$DC_{I,t}$ Degree of congruence of a set I of buildings regarding calculated final energy demand and monitored consumption based on annual data of year t [kWh/(m² a)]

$DC_{i,t}$ Degree of building i's congruence of calculated final energy demand and monitored consumption based on annual data of year t [kWh/(m² a)]

Cap_i Floor area of building i [m²]

1.5.7.3 Large-scale or building-integrated energy supply units [D7_3]

Not applicable

1.5.7.4 Set of large-scale units [D7_4]

Not applicable

1.5.7.5 Concerto area [D7_5]

Cf. set of buildings

1.5.8 Degree of energetic self-supply [D8-D9]

Description: The degree of energetic self-supply is defined as ratio of locally produced energy and the local consumption over a period of time (year). The indicators are separately determined for thermal energy (heat or cold) and electricity. Furthermore, the quantity of locally produced energy can be interpreted as by renewable energy sources (RES) produced energy or by combined heat and power (CHP) plants produced energy. In case of the CONCERTO community, the sectors included in the consumption have to be defined.

Unit: kWh/kWh

1.5.8.1 Share of locally by renewable energy sources (RES) produced energy in the total energy consumption/demand (thermal energy and electricity) [D8]

1.5.8.1.1 *Individual buildings [D8_1]*

Assumptions:

- Electricity produced in building i is used in building i, if the electricity demand is sufficient
- Electricity produced within other buildings is not used in building i
- Imported electricity and direct thermal energy is not renewable

$$ESS_{AA,i,t,RES} = \frac{\sum_{EC} In_{EC,AA,i,t} * RES_{EC,i,t}}{\sum_{EC} In_{EC,AA,i,t}}$$

$ESS_{AA,i,t,RES}$ Share of renewable energy in energy consumption/demand of building i for application area AA in year t [kWh/kWh]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$RES_{EC,i,t}$ Share of renewable energy in energy carrier EC supplying building i in year t [kWh/kWh]

1.5.8.1.1.1 Share of renewable energy in oil (B1), gas (B2), coal (B3)

$$RES_{EC,i,t} = RES_{EC} = 0$$

$RES_{EC,i,t}$ Share of renewable energy in energy carrier EC=**B1, B2, B3** supplying building i in year t [kWh/kWh]

RES_{EC} Share of renewable energy in energy carrier EC [kWh/kWh]

1.5.8.1.1.2 Share of renewable energy in biomass (B4), other renewables: heat (B6), other renewables: electricity (B8)

$$RES_{EC,i,t} = RES_{EC} = 1$$

$RES_{EC,i,t}$ Share of renewable energy in energy carrier EC=**B4, B6, B7** supplying building i in year t [kWh/kWh]

RES_{EC} Share of renewable energy in energy carrier EC [kWh/kWh]

1.5.8.1.1.3 Share of renewable energy in electricity (B8)

$$RES_{EC=electricity,i,t} = \max\left(\frac{\sum_{s \in S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,i,t}},1\right) * \frac{\sum_{s \in S_i} Out_{EC=electricity,s,t} * RES_{s,t}}{\sum_{s \in S_i} Out_{EC=electricity,s,t}} +$$

$$\left(1 - \max\left(\frac{\sum_{s \in S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,i,t}},1\right)\right) * RES_{EC=electricity,S_A,t}$$

$RES_{EC=electricity,i,t}$ Share of renewable energy in energy carrier EC supplying building i in year t [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$RES_{EC=electricity,S,t}$ Share of renewable energy in energy carrier EC=electricity supplied by set S of large-scale units in year t [kWh/kWh]

$RES_{s,t}$ Share of renewable energy in output of energy supply unit s in year t [kWh/kWh]

Sub-formula 1:

$$RES_{s,t} = \frac{\sum_{EC/\{B8,B5\}} In_{EC,s,t} * RES_{EC}}{\sum_{EC} In_{EC,s,t}}$$

$RES_{s,t}$ Share of renewable energy in output of energy supply unit s in year t [kWh/kWh]

$In_{EC,s,t}$ Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy supply unit s in year t [kWh/a]

RES_{EC} Share of renewable energy in energy carrier EC [kWh/kWh]

Sub-formula 2:

Note: Here, the set of energy supply units **excludes the building-integrated** electricity production.

$$RES_{EC=electricity,S,t} = \frac{\sum_{EC/\{B5,B8\}} In*_{EC,EC'=electricity,S/S_{A,small.el.},I_A,t} * RES_{EC}}{\sum_{EC} In*_{EC,EC'=electricity,S/S_{A,small.el.},I_A,t}}$$

$RES_{EC=electricity,S,t}$ Share of renewable energy in energy carrier EC=electricity supplied by set S of large-scale units in year t [kWh/kWh]

$In^*_{EC,EC',S,I,t}$	**Local consumption based** input (>0) energy flow of energy carrier (or source) EC (type C) into set S of large-scale units supplying a set I of buildings for the production of energy carrier (or source) EC' (type B) in year t using **local electricity mix** [kWh/a]
RES_{EC}	Share of renewable energy in energy carrier EC [kWh/kWh]

1.5.8.1.1.4 Share of renewable energy in direct thermal energy (B5)

$$RES_{EC=directthermalenergy,i,t} = RES_{EC=directthermalenergy,S_A,t}$$

$RES_{EC=directthermalenergy,i,t}$	Share of renewable energy in energy carrier EC supplying building i in year t [kWh/kWh]
$RES_{EC=directthermalenergy,S,t}$	Share of renewable energy in energy carrier EC from set S of large-scale units in year t [kWh/kWh]

Sub-formula:

Note: Here, the set of energy supply units **excludes the building-integrated** direct thermal energy production.

$$RES_{EC'=directthermalenergy,S,t} = \frac{\sum_{EC/\{B5,B8\}} In^*_{EC,EC'=B5,S/S_{A,small.el.},I_A,t} * RES_{EC} + In^*_{EC=B8,EC'=B5,S/S_{A,small.el.},I_A,t} * RES_{EC=B8,S_A,t}}{\sum_{EC} In^*_{EC,EC'=B5,S/S_{A,small.el.},I_A,t}}$$

$RES_{EC'=directthermalenergy,S,t}$	Share of renewable energy in energy carrier EC from set S of large-scale units in year t [kWh/kWh]
$In^*_{EC,EC',S,I,t}$	**Local consumption based** input (>0) energy flow of energy carrier (or source) EC (type C) into set S of large-scale units supplying a set I of buildings for the production of energy carrier (or source) EC' (type B) in year t using **local electricity mix** [kWh/a]
RES_{EC}	Share of renewable energy in energy carrier EC [kWh/kWh]
$RES_{EC=electricity,S,t}$	Share of renewable energy in energy carrier EC=electricity supplied by set S of large-scale units in year t [kWh/kWh]

1.5.8.1.2 *Set of buildings [D8_2]*

Assumptions:

- Electricity produced in set I of buildings is used in set I of buildings, if the electricity demand is sufficient

- Electricity produced in other buildings is not used in set I of buildings
- Imported electricity and direct thermal energy is not renewable

$$ESS_{AA,I,t,RES} = \frac{\sum_{EC} In_{EC,AA,I,t} * RES_{EC,I,t}}{\sum_{EC} In_{EC,AA,I,t}}$$

$ESS_{AA,I,t,RES}$ Share of renewable energy in energy consumption/demand of set I of buildings for application area AA in year t [kWh/kWh]

$In_{EC,AA,I,t}$ Input (>0) energy flow into set I of buildings for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$RES_{EC,I,t}$ Share of renewable energy in energy carrier EC supplying set I of buildings in year t [kWh/kWh]

1.5.8.1.2.1 Share of renewable energy in oil (B1), gas (B2), coal (B3)

$$RES_{EC,I,t} = RES_{EC} = 0$$

$RES_{EC,I,t}$ Share of renewable energy in energy carrier EC supplying set I of buildings in year t [kWh/kWh]

RES_{EC} Share of renewable energy in energy carrier EC [kWh/kWh]

1.5.8.1.2.2 Share of renewable energy in biomass (B4), other renewables: heat (B6), other renewables: electricity (B8)

$$RES_{EC,I,t} = RES_{EC} = 1$$

$RES_{EC,I,t}$ Share of renewable energy in energy carrier EC supplying set I of buildings in year t [kWh/kWh]

RES_{EC} Share of renewable energy in energy carrier EC [kWh/kWh]

1.5.8.1.2.3 Share of renewable energy in electricity (B8)

$$RES_{EC=electricity,I,t} = \max\left(\frac{\sum_{s \in \bigcup_{i \in I} S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,I,t}}, 1\right) * \frac{\sum_{s \in \bigcup_{i \in I} S_i} Out_{EC=electricity,s,t} * RES_{s,t}}{\sum_{s \in \bigcup_{i \in I} S_i} Out_{EC=electricity,s,t}} +$$

$$(1 - \max\left(\frac{\sum_{s \in \bigcup_{i \in I} S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,I,t}}, 1\right)) * RES_{EC=electricity,S_A,t}$$

$RES_{EC=electricity,I,t}$ Share of renewable energy in energy carrier EC supplying set I of buildings in year t [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$RES_{EC=electricity,S,t}$ Share of renewable energy in energy carrier EC=electricity supplied by set S of large-scale units in year t [kWh/kWh]

$RES_{s,t}$ Share of renewable energy in output of energy supply unit s in year t [kWh/kWh]

1.5.8.1.2.4 Share of renewable energy in direct thermal energy (B5)

$$RES_{EC=directthermalenergy,I,t} = RES_{EC=directthermalenergy,S_A,t}$$

$RES_{EC=directthermalenergy,I,t}$ Share of renewable energy in energy carrier EC supplying building I in year t [kWh/kWh]

$RES_{EC=directthermalenergy,S,t}$ Share of renewable energy in energy carrier EC from set S of large-scale units in year t [kWh/kWh]

1.5.8.1.3 *Large-scale or building-integrated energy supply units [D8_3]*

Not applicable

1.5.8.1.4 *Set of large-scale units [D8_4]*

Not applicable

1.5.8.1.5 *Concerto area [D8_5]*

Cf. set of buildings

1.5.8.2 Share of locally by combined heat and power (CHP) plants produced energy in the total energy consumption/demand (thermal energy and electricity) [D9]

1.5.8.2.1 *Individual buildings [D9_1]*

Assumptions:

- If an energy carrier is used for space heating and electricity export, this energy carrier is used in CHP units only.

- Electricity produced in building i is used in building i, if the electricity demand is sufficient
- Electricity produced in other buildings is not used in buildings i
- Imported electricity and direct thermal energy is not produced via CHP

$$ESS_{AA,i,t,CHP} = \frac{\sum_{EC} In_{EC,AA,i,t} * CHP_{EC,i,t}}{\sum_{EC} In_{EC,AA,i,t}}$$

$ESS_{AA,i,t,CHP}$ Share of locally combined heat and power in energy consumption/demand of building i for application area AA in year t [kWh/kWh]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$CHP_{EC,i,t}$ Share of locally combined heat and power in energy carrier EC supplying building i in year t [kWh/kWh]

1.5.8.2.1.1 Share of locally combined heat and power in energy carrier EC=B1, B2, B3, B4, B6, B7 supplying building i

$$CHP_{EC,i,t} = \mathrm{sgn}(In_{EC,AA=AA1,i,t} * In_{EC,AA=AA5,i,t})$$

$CHP_{EC,i,t}$ Share of locally combined heat and power in energy carrier EC**=B1, B2, B3, B4, B6, B7** supplying building i in year t [kWh/kWh]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

1.5.8.2.1.2 Share of locally combined heat and power in electricity (B8)

$$CHP_{EC=electricity,i,t} = \min\left(\frac{\sum_{s\in S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,i,t}},1\right) * \frac{\sum_{s\in S_i} Out_{EC=electricity,s,t} * CHP_{s,t}}{\sum_{s\in S_i} Out_{EC=electricity,s,t}} +$$
$$(1-\min(\frac{\sum_{s\in S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,i,t}},1)) * CHP_{EC=electricity,S_A,t}$$

$CHP_{EC,i,t}$ Share of locally combined heat and power in energy carrier EC supplying building i in year t [kWh/kWh]

$CHP_{s,t}$ Share of locally combined heat and power by large-scale energy supply unit s in year t [kWh/kWh]

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$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$CHP_{EC=electricity,S,t}$ Share of locally combined heat and power in energy carrier EC by set S of large-scale units in year t [kWh/kWh]

Sub-formula 1:

Note: Here, the set of energy supply units **excludes the building-integrated** electricity production.

$$CHP_{EC=electricity,S,t} = \frac{\sum_{s \in S/S_{A,small,el.}} Out_{EC=electricity,s,t} * CHP_{s,t}}{\sum_{s \in S/S_{A,small,el.}} Out_{EC=electricity,s,t}}$$

$CHP_{EC=electricity,S,t}$ Share of locally combined heat and power in energy carrier EC=electricity by set S of large-scale units in year t [kWh/kWh]

$CHP_{s,t}$ Share of locally combined heat and power by large-scale energy supply unit s in year t [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit $s \in S/S_{A,small,el.}$ in year t [kWh/a]

Sub-formula 2:

$$CHP_{s,t} = \mathrm{sgn}(Out_{EC=electricity,s,t} * Out_{EC=directthermalenergy,s,t})$$

$CHP_{s,t}$ Share of locally combined heat and power by large-scale energy supply unit s in year t [kWh/kWh]

$Out_{EC,s,t}$ Output (>0) energy flow of energy carrier (or source) EC (type IO) from ene rgy supply unit s in year t [kWh/a]

1.5.8.2.1.3 Share of locally combined heat and power in direct thermal energy (B5)

$$CHP_{EC=directthermalenergy,i,t} = CHP_{EC=directthermalenergy,S_A,t}$$

$CHP_{EC,i,t}$ Share of locally combined heat and power in energy carrier EC supplying building i in year t [kWh/kWh]

$CHP_{EC,S,t}$ Share of locally combined heat and power in energy carrier EC by set S of large-scale units in year t [kWh/kWh]

Sub-formula:

Note: Here, the set of energy supply units **excludes the building-integrated** direct thermal energy production.

$$CHP_{EC=directthermalenergy,S,t} = \frac{\sum_{s\in S/S_{A,small,el.}} Out_{EC=directthermalenergy,s,t} * CHP_{s,t}}{\sum_{s\in S/S_{A,small,el.}} Out_{EC=directthermalenergy,s,t}}$$

$CHP_{EC=directthermalenergy,S,t}$ Share of locally combined heat and power in energy carrier EC=direct thermal energy by large-scale energy supply system S in year t [kWh/kWh]

$CHP_{s,t}$ Share of locally combined heat and power by large-scale energy supply unit s in year t [kWh/kWh]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

1.5.8.2.2 *Set of buildings [D9_2]*

Assumptions:

- If an energy carrier is used in a building for space heating and electricity export, this energy carrier is used in CHP units only.
- Electricity produced in set I of buildings is used in set I of buildings, if the electricity demand is sufficient
- Electricity produced in other buildings is not used in set I of buildings
- Imported electricity and direct thermal energy is not produced via CHP

$$ESS_{AA,I,t,CHP} = \frac{\sum_{i\in I}\sum_{EC/\{B8\}} In_{EC,AA,i,t} * CHP_{EC,i,t} + In_{EC=B8,AA,I,t} * CHP_{EC=B8,S_A,t}}{\sum_{i\in I}\sum_{EC} In_{EC,AA,i,t}}$$

$ESS_{AA,I,t,CHP}$ Share of combined heat and power in energy consumption/demand of set I of buildings for application area AA in year t [kWh/kWh]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$In_{EC,AA,i,t}$ Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$CHP_{EC,i,t}$ Share of combined heat and power in energy carrier EC supplying building i in year t [kWh/kWh]

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$CHP_{EC,S,t}$ Share of locally combined heat and power in energy carrier EC by large-scale energy supply system S in year t [kWh/kWh]

1.5.8.2.2.1 Share of locally combined heat and power in electricity (B8)

$$CHP_{EC=electricity,I,t} = \min\left(\frac{\sum_{s\in\bigcup_{i\in I} S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,I,t}},1\right) * \frac{\sum_{s\in\bigcup_{i\in I} S_i} Out_{EC=electricity,s,t} * CHP_{s,t}}{\sum_{s\in\bigcup_{i\in I} S_i} Out_{EC=electricity,s,t}} +$$

$$\left(1-\min\left(\frac{\sum_{s\in\bigcup_{i\in I} S_i} Out_{EC=electricity,s,t}}{\sum_{AA} In_{EC=electricity,AA,I,t}},1\right)\right) * CHP_{EC=electricity,S_A,t}$$

$CHP_{EC,i,t}$ Share of locally combined heat and power in energy carrier EC supplying set I of buildings in year t [kWh/kWh]

$CHP_{s,t}$ Share of locally combined heat and power by large-scale energy supply unit s in year t [kWh/kWh]

$In_{EC,AA,I,t}$ Input (>0) energy flow into set I of buildings for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]

$Out_{EC,s,t}$ output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]

$CHP_{EC=electricity,S,t}$ Share of locally combined heat and power in energy carrier EC by set S of large-scale units in year t [kWh/kWh]

1.5.8.2.3 *Large-scale or building-integrated energy supply units [D9_3]*

Not applicable

1.5.8.2.4 *Set of large-scale units [D9_4]*

Not applicable

1.5.8.2.5 *Concerto area [D9_5]*

Cf. set of buildings

1.5.9 Market share of technology in order to measure the degree of innovation [D10]

Description: The degree of innovation of a technical measure can be indicated by the share of this technology in the national market – e.g. the ratio of sold wood pellet stoves and sold heating systems within one country and year.

Unit: %

1.5.9.1 Individual buildings [D10_1]

Not applicable

1.5.9.2 Set of buildings [D10_2]

Not applicable

1.5.9.3 Large-scale or building-integrated energy supply units [D10_3]

$$MST_{s,t} = \frac{SV_{[s],t}}{SV_{[s]^*,t}} * 100$$

$MST_{s,t}$ Market share of energy supply unit s in from a demand-side perspective comparable energy supply units in year t [%]

$SV_{[s],t}$ Sales volume of energy supply units of the same types as s in year t [€]

$SV_{[s]^*,t}$ Sales volume of energy supply units of the same types as s (from a demand-side perspective in year t [€]

1.5.9.4 Set of large-scale units [D10_4]

Not applicable

1.5.9.5 Concerto area [D10_5]

Not applicable

1.5.10 Temporal predictability and controllability of energy supply [D11]

1.5.10.1 Individual buildings [D11_1]

Not applicable

1.5.10.2 Set of buildings [D11_2]

Not applicable

1.5.10.3 Large-scale or building-integrated energy supply units [D11_3]

Description: The temporal predictability and controllability of an energy supply unit or a set of energy supply units is measured using a qualitative scale. E.g. heat pumps have a better temporal predictability and controllability than wind turbines and photovoltaic.

Unit: Qualitative scale

$$TPC_s = TPC_{[s]}$$

TPC_s Temporal predictability and controllability of energy supply unit s [scale: 1,2,3]

$TPC_{[s]}$ Temporal predictability and controllability of energy supply units of the same type as s [scale: 1,2,3]

1.5.10.4 Set of large-scale units [D11_4]

Not applicable

1.5.10.5 Concerto area [D11_5]

Not applicable

1.5.11 Visibility of technology [D12]

1.5.11.1 Individual buildings [D12_1]

Not applicable

1.5.11.2 Sets of buildings [D12_2]

Not applicable

1.5.11.3 Large-scale or building-integrated energy supply units [D12_3]

Description: The visibility of an energy supply unit is measured using a qualitative scale. E.g. photovoltaic is more visible than a biomass boiler in the basement.

Unit: Qualitative scale

$$VT_s = VT_{[s]}$$

VT_s Visibility of energy supply unit s [scale: 1,2,3 (i.e. low/medium/high visibility)]

$VT_{[s]}$ Visibility of energy supply units of the same type as s [scale: 1,2,3 (i.e. low/medium/high visibility)]

1.5.11.4 Set of large-scale units [D12_4]

Not applicable

1.5.11.5 Concerto area [D12_5]

Not applicable

1.5.12 Further detailed technical data e.g. pressure, temperature, mass flows, pipe lengths etc. [D13]

Description: Further detailed technical data and derived indicators depend on the individual situation.

Unit: Not known

1.6 Indicators & gap analysis of implementation process [E1-E2]

This chapter encompasses a short (and therefore simplified) description of indicators of the implementation process related to the CONCERTO project.

Description: The indicators of the implementation process are calculated in order to characterize the progress of the implementation process of the CONCERTO project. The indicators are calculated separately for the new construction of buildings, the refurbishment of buildings, new low-carbon electrical energy supply as well as new low-carbon heating and cooling energy supply. Even more detailed differentiations are possible.

1.6.1 Target that was planned to be implemented until year n [E1]

Description: This indicator is defined as the quantitative target that should be implemented until a certain year.

Unit: m^2, kW

1.6.1.1 Individual buildings [E1_1]

$Cap_{i,t,t'}$ Floor area of building i that was planned in year t to be implemented in year t' [m²]

1.6.1.2 Set of buildings [E1_2]

$$Cap_{I,t,t'} = \sum_{i \in I} Cap_{i,t,t'}$$

$Cap_{I,t,t'}$ Floor area of set I of buildings that was planned in year t to be implemented in year t' [m²]

$Cap_{i,t,t'}$ Floor area of building i that was planned in year t to be implemented in year t' [m²]

1.6.1.3 Large-scale or building-integrated energy supply units [E1_3]

$Cap_{s,EC,t,t'}$ Capacity of energy supply unit s regarding the output of energ y carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' [kW]

1.6.1.4 Set of large-scale or units [E1_4]

$$Cap_{S,EC,t,t'} = \sum_{s \in S} Cap_{s,EC,t,t'}$$

$Cap_{S,EC,t,t'}$ Capacity of set S of energy supply units regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' [kW]

$Cap_{s,EC,t,t'}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' [kW]

1.6.1.5 Concerto area [E1_5]

Cf. set of large-scale units and set of buildings

1.6.2 Fraction of the target that was implemented until year n [E2]

Description: This indicator is defined as the ratio of the quantity that has been implemented until a certain year and the quantitative target that should have been implemented until a certain year. Thematic descriptions related to the gap between target and implemented fraction can supplement the indicator values with textual information. This information includes barriers in case of underachievement of the target, measures taken in order to deal with the barriers, lessons learnt from barriers and measures taken in order to deal with them, links to related documents of CONCERTO projects and links to thematic contact persons of the CONCERTO project.

Unit: m², kW

1.6.2.1 Individual buildings [E2_1]

$$FT_{i,t,t'} = \frac{Cap_{i,t',t'}}{Cap_{i,t,t'}}$$

$FT_{i,t,t'}$ Fraction of the floor area of building i planned in year t to be implemented in year t’ that has been implemented in year t’ [m²]

$Cap_{i,t,t'}$ Floor area of building i that was planned in year t to be implemented in year t’ [m²]

1.6.2.2 Set of buildings [E2_2]

$$FT_{I,t,t'} = \frac{Cap_{I,t',t'}}{Cap_{I,t,t'}}$$

$FT_{I,t,t'}$ Fraction of the floor area of set I of buildings planned in year t to be implemented in year t’ that has been implemented in year t’ [m²]

$Cap_{I,t,t'}$ Floor area of set I of buildings that was planned in year t to be implemented in year t’ [m²]

1.6.2.3 Large-scale or building-integrated energy supply units [E2_3]

$$FT_{s,EC,t,t'} = \frac{Cap_{s,EC,t',t'}}{Cap_{s,EC,t,t'}}$$

$FT_{s,EC,t,t'}$ Fraction of the capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t’ that has been implemented in year t’ [kW]

$Cap_{s,EC,t,t'}$ Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' [kW]

1.6.2.4 Set of large-scale units [E2_4]

$$FT_{S,EC,t,t'} = \frac{Cap_{S,EC,t',t'}}{Cap_{S,EC,t,t'}}$$

$FT_{s,EC,t,t'}$ Fraction of the capacity of set S of energy supply units regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' that has been implemented in year t' [kW]

$Cap_{S,EC,t,t'}$ Capacity of set S of energy supply units regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' [kW]

1.6.2.5 Concerto area [E2_5]

Cf. set of large-scale units and set of buildings

1.7 Required data with link to the CONCERTO Premium data collection sheets

The data that is required for the indicator calculation is provided in Table 11 (general data), Table 12 (building data) and Table 13 (energy supply unit data). In these tables, a link to the CONCERTO Premium data collections sheets is provided as well. The general information flow from the CONCERTO Premium data collection sheets to the calculated indicators is shown in Figure 3 together with an example for the calculation of the final energy demand of a new building.

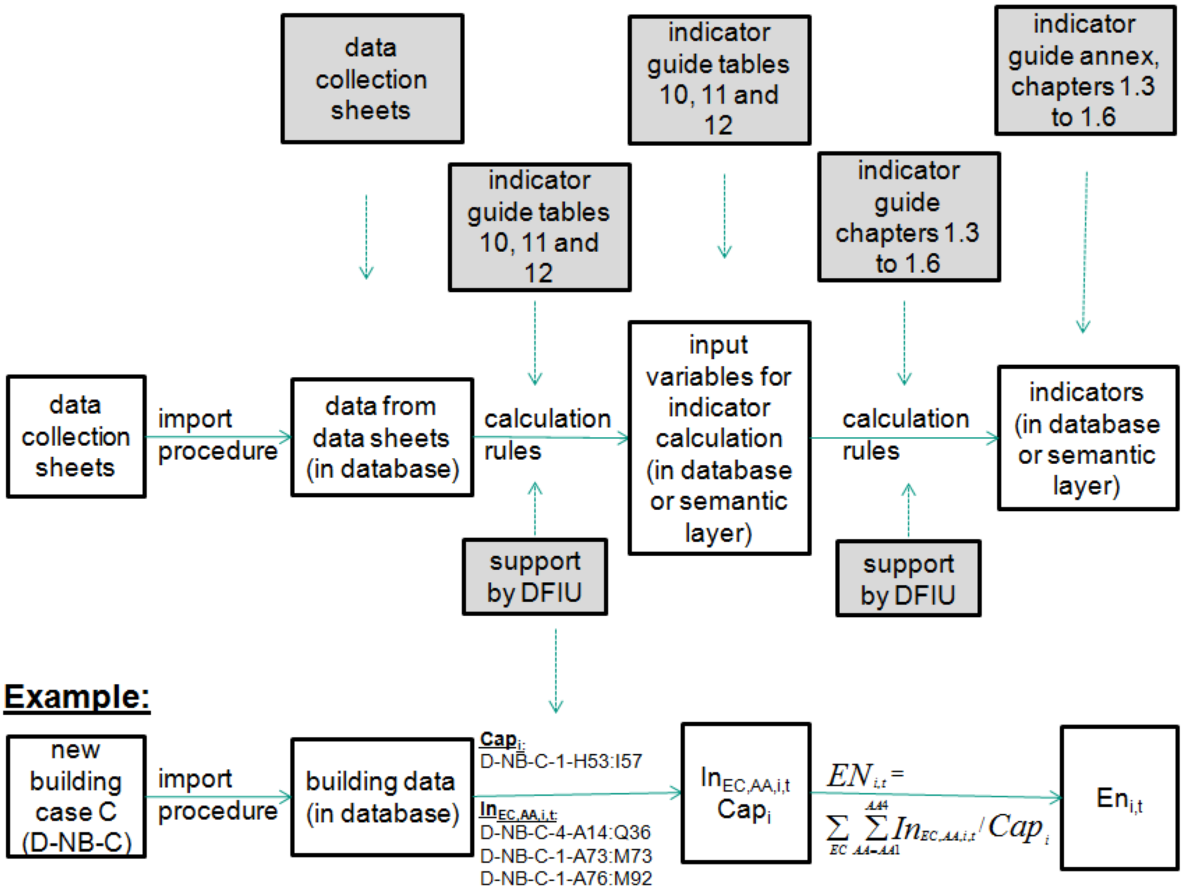

Figure 3: General information flow from the CONCERTO Premium data collection sheets to the calculated indicators

The CONCERTO Premium data collection sheets are imported into the CONCERTO Premium database. In this database the data structure corresponds strongly to the data structure of the data collection sheets. Based on this data structure the input variables for the indicator calculation are derived using the references and rules provided in Table 11, Table 12 and Table 13. Afterwards, the indicators can be calculated based on the indicator calculation procedures that are described in this document.

Table 11: Required general data with link to the CONCERTO Premium data collection sheets

Specificity	Type of data	Required data	Description	Data aggregation level: European/National	CONCERTO area/community	Demonstration object	Reference object	Data reference to data collection sheets
European / National data / CONCERTO area data	Diverse data	t_0	Year of discount base [a]	X				- (specified by user, default: 2005)
		r	Interest rate for calculations [-]	X				A-1-E31:E32 (OR, one for buildings and building-integrated energy supply units, one for large-scale energy supply units)
		$EF_{M,transport}$	Emission factor regarding material M for the transport mix [t/(t km)]	X				A-1-E37:E43 (one value per M)
	Energy Carrier data	$EF_{EC,M,direct}$	Direct emission factor for energy carrier EC regarding material M [t/kWh]	X	X			"0" if not requested. **Priority 1:** CA-2-G17:G38 (one value per EC-M=CO2-combination) **Priority 2 (if required for an EC-M-combination):** B-2-G47:G68 (one value per EC-M=CO2-combination) **Priority 3 (if required for an EC-M-combination):** A-1-F60:F171 (one value per EC-M-combination)
		$EF_{EC,M,indirect}$	Indirect emission factor for energy carrier EC regarding material M [t/kWh]		X			"0" if not requested. **Priority 1:** CALCULATED (cf. chapter 1.3.1.3) **Priority 2 (if required for an EC-M-combination):** CA-2-H17:H38 (one value per EC-M=CO2-combination) AND [CA-2-G11:G14 OR CA-2-I11:I14] (OR, two values per EC-M=CO2-combination, selection by user, idea: first value for reference buildings, second value for demonstration bulidings) **Priority 3 (if required for an EC-M-combination):** **B-2-G29:G43** (one value per EC-M=CO2-combination) AND **B-2-H47:H68** (one value per EC-M=CO2-combination)
		$EF_{EC,M,extract}$	Emission factor regarding material M for the production of energy carrier EC and all transports from extraction to the refinery, the production plant or the customer in case of grid-bound energy carriers [t/kWh]	X				A-1-F176:F320 (one value per EC-M-combination)
		LHV_{EC}	Lower heating value of energy carrier EC; zero if not applicable [kWh/t]	X	X	X	X	"1" if not requested. **Priority 1 (use values of community energy systems or building-integrated energy systems, exemplary reference**

								to large-scale CHP): E-CES-2-1-F142:I142 (OR, first one if energy demand is used, the others are used if the energy consumption of the corresponding monitoring period (G123:I124) is used) for EC in F56 AND F148:I148 (analogously) for EC in F58. **Priority 2 (if required for an EC):** CA-2-I17:I38 (one value per EC) **Priority 3 (if required for an EC):** B-2-I47:I68 (one value per EC) **Priority 4 (if required for an EC):** A-1-F326:F341 (one value per EC)
		PEF_{EC}	Primary energy factor for energy carrier EC [kWh/kWh]	X	X	X	X	"0" if not requested. **Priority 1:** CALCULATED (cf. Chapter 1.3.1.2) **Priority 2 (use values of community energy systems or building-integrated energy systems, exemplary reference to large-scale CHP):** E-CES-2-1-F130:I130 (OR, first one if energy demand is used, the others are used if the energy consumption of the corresponding monitoring period (G123:I124) is used) for EC in F56 (IF biomass) and for EC in F58 (IF biomass). **Priority 3 (if required for an EC):** B-2-F29:F68 (one value per EC) **Priority 4 (if required for an EC):** A-1-F346:F365 (one value per EC) OR [selected by user] A-1-F371:F390 (one value per EC)
		$Dist_{EC,transpo}$	Transport distance for energy carrier EC from the refinery or the production plant to the average object in the corresponding CONCERTO area; The distance is zero in case of grid-bound energy carriers [km]		X	X	X	"0" if not requested. **Priority 1 (use values of community energy systems or building-integrated energy systems, exemplary reference to large-scale CHP):** E-CES-2-1-F128:I128 (OR, first one if energy demand is used, the others are used if the energy consumption of the corresponding monitoring period (G123:I124) is used) for EC in F56 (IF biomass) and for EC in F58 (IF biomass). **Priority 2 (if required for an EC):** CA-2-P17:P38 (one value per EC) **Priority 3 (if required for an EC):** B-2-P47:P68 (one value per EC)
	Building type data	$PEF_{[i]}$	Primary energy factor for a building of the same type as i [kWh/m²]	X				A-1-E474:F486 (two per building type [i], OR, selected by user) OR [selected by user] A-1-E491:F503 (two per building type [i], OR, selected by user)

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		$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]	X				A-1-E508:F520 (two per building type [i], OR, selected by user)
		$EF_{[i],M}$	(Indirect) emission factor regarding material M for the construction of a building of the same type as i [t/m²]	X				A-1-E525:F615 (two per building type [i], OR, selected by user)
		$f_{repair,[i]}$	Factor for repairs as share of the investment per year [1/a]	X				A-1-E620:E632 (one per building type [i])
	Plant type data	$EF_{[s],M,EC}$	(Indirect) emission factor regarding material M for energy supply units of the same type as s; the emission factor is zero, if the output of energy carrier EC (type IO at the plant (!)) is not used as base unit [t/kW]	X				A-1-G777:H1077 (two(sometimes four) per [s]-M-combination, OR, selected by user (in some cases two)) (perhaps the units of the storages and the biogas plant should be changed) **RULES:** The ouput energy carrier EC (biomass IO4(each type), heat IO5a, cold IO5b, electricity IO8a) has to be written manually in the code. The match should be clear. In case of cogeneration both values (one should be zero) are stored.
		$PEF_{[s],EC}$	Primary energy factor for energy supply units of the same type as s; the primary energy factor is zero, if the output of energy carrier EC (type IO at the plant (!)) is not used as base unit [kWh/kW]	X				A-1-F640:G682 (two values) OR [slection by user] A-1-F687:G729 (two values) (perhaps the units of the storages and the biogas plant should be changed) **RULES:** The ouput energy carrier EC (biomass IO4(each type), heat IO5a, cold IO5b, electricity IO8a) has to be written manually in the code. The match should be clear. In case of cogeneration both values (one should be zero) are stored.
		$EL_{[s]}$	Expected lifetime of an energy supply unit of the same type as s [a]	X				A-1-F734:G772 (two per plant type [s], OR, selected by user)
		$f_{repair,[s]}$	Factor for repairs as share of the investment per year [1/a]	X				A-1-F1082:F1120 (two per plant type [s], OR, selected by user)
		$SV_{[s],t}$	Sales volume of energy supply units of the same type as s [€]	X				A-1-F1125:G1163 (one per [s]-year combination; this value is set for the other years as well)
		$SV_{[s]*,t}$	Sales volume of energy supply units of the same type as s (from a demand-side perspective) [€]	X				A-1-F1168:G1171 (one per [s]*-year combination; this value is set for the other years as well)
		$TPC_{[s]}$	Temporal predictability and controllability of energy supply units of the same type as s [scale: 1,2,3]	X				A-1-F1176:G1214 (one per [s])
		$VT_{[s]}$	Visibility of energy supply units of the same type as s [scale: 1,2,3]	X				A-1-F1219:G1257 (one per [s])
	Indices	$d_{repair,t'}$	Price-index for repair payments in year t' [-]; $d_{repair,t_0}=1$	X				A-1-B1267:B1322 (one per year)
		$d_{requirement,t'}$	Index for requirement(consumption)-related costs in year t' [-]; $d_{requirement,t_0}=1$	X				A-1-C1267:C1322 (one per year)
		$d_{operation,t'}$	Index for operation-related costs in year t' [-]; $d_{operation,t_0}=1$	X				A-1-D1267:D1322 (one per year)
		$d_{other,t'}$	Index for other costs in year t' [-]; $d_{other,t_0}=1$	X				A-1-E1267:E1322 (one per year)
		$e_{requirement,t'}$	Index for requirement-related revenues in year t'	X				A-1-F1267:F1322 (one per year)

			[-]; $e_{requirement,t_0} = 1$					
		$e_{operation,t'}$	Index for operation-related revenues in year t' [-]; $e_{operation,t_0} = 1$	X				A-1-G1267:G1322 (one per year)
		$e_{other,t'}$	Index for other revenues in year t' [-]; $e_{other,t_0} = 1$	X				A-1-H1267:H1322 (one per year)
	External costs	$ex_{M,t'}$	External costs of emissions of material M in year t' [€/t]	X				A-1-B1333:H1388 (one per M-year-combination)
European to CONCERTO area data	General concerto area data	NJC	Number of jobs created in the CONCERTO area in course of the CONCERTO activities [jobs, person-years]		X			-
		CCD	Changes in community demographics - neighbourhood growth, i.e. increase of the number of inhabitants of the CONCERTO area compared to the situation before the CONCERTO project [inhabitants]		X			CA-1-B287 (text, concrete selection of one value by user based on text)
		NTO	Number of trainings/person-days for trainings offered in course of the CONCERTO activities [trainings, person-days]		X			CA-1-B277 (text, concrete selection of one value by user based on text)
		NBC	Number of new businesses created in the CONCERTO area in course of the CONCERTO activities [businesses]		X			CA-1-B297 (text, concrete selection of one value by user based on text)
Currently neglected data	Set of buildings data	Cap_I	Area or numer of set I of buildings [km² territory area, buildings]					-
	Energy demand unit	$In_{EC,c,t}$	Input (>0) energy flow of energy carrier (or source) EC (type IO) into energy demand unit c in year t [kWh/a]					-
		$Out_{EC,c,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy demand unit c in year t [kWh/a]					-

For each building, two cases are distinguished with respect to the data collection: The total investment based approach (TC) and the additional cost approach (AC). Cf. CONCERTO Premium Economic Monitoring Guide for details. Both approaches should be applicable in the database in dependance on the data availability and the selection of the user [in a first step: OR, selected by user]. The majority of the input variables do not differ between the two approaches (cf. Table 12).

Table 12: Required building data with link to the CONCERTO Premium data collection sheets (Point of view of owner-occupier regarding economic data)

Specifi	Type of data	Required data	Description	Data aggregation level	Demonstration object (data reference to	Reference object (data reference to data

				European7National	CONCERTO	Demonstration object	Reference object		
Building data	Base data	i	ID of demonstration object			X	X	AC, TC: Combination of D-NB-1-C7, E7, F7, G7, I7 AC-RB, TC-RB: Combination of D-RB-1-C16, E16, F16, G16, I16	AC-NB: is demonstration object TC-NB: Combination of D-REF-1-C15, E15, F15, G15, I15 AC-RB, TC-RB: is demonstration object
		REF	ID of corresponding reference object			X		AC-NB: i TC-NB: Combination of D-NB-1-C7, E7, F7, **G-24** AC-RB, TC-RB: i	-
		Cap_i	Floor area of building i [m²]			X	X	AC, TC: D-NB-1-H53:I57 (OR, selected by user) AC, TC: D-RB-1-J72:K76 (OR, selected by user)	AC: D-NB-1-H53:I57 (OR, as reference object) TC: D-REF-1-H37:I41 (OR, as reference object) AC, TC: D-RB-1-H72:I76 (OR, as reference object)
		t_1	Year of construction start of building i			X		AC, TC: D-RB-1-G36 (perhaps change required) AC, TC: D-NB-1-G20	
		t_2	Year of construction end of building i			X		AC, TC: D-NB-1-G21 AC, TC: D-RB -1-G36	
		$Cap_{i,t,t'}$	Floor area of building i that was planned in year t to be implemented in year t' [m²]			X		-(to be supplemented)	
		[i]	Building type			X	X	AC, TC: D-NB-1-G44 AND G45 AND G49 AND G14; AC, TC: D-RB-1-G61 AND G63 AND G67 AND G23;	AC-NB, TC-NB: D-REF-1-G28 AND G29 AND G33 AND G22; AC, TC: D-RB-1-G61 AND G63 AND G67 AND G23;
								RULES for AC-NB,TC-NB (in other cases analogically) IF G44==residential IF G49==1 IF G45==detached "Detached one-family house" ELSE "Semi-detached one-family house" END ELSE "Apartment building" END ELSE %non-residential "Others" (Concrete selection by user based on text in G14) END	
	Energy flows	$In_{EC,AA,i,t}$	Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]			X	X	(rules required → collaboration IMI/DFIU) Energy demand	(rules required → collaboration IMI/DFIU)

		$Out_{el.,i,t}$	Electricity output (>0) flow of building i in year t [kWh/a]			X	X	(without time index): AC, TC: D-NB-1-A74:M74 AND D-NB-1-A77:M93 AC, TC: D-RB-1-A101:M101 AND D-RB--1-A120:M136 Energy consumption (with time index): AC, TC: D-NB-5-A14:Q36 AC, TC: D-RB-6-A14:Q35	Energy demand (without time index): AC: D-NB-1-A73:M73 AND D-NB-1-A77:M93 TC: D-REF-1-A56:M71 AND D-REF-1-A126:M144 AC, TC: D-RB-1-A100:M100 OR D-RB-1-A102:M102 (special case, selected by user) AND D-RB-1-A105:M120 Energy consumption (with time index): AC, TC: D-RB-A/C-5-A14:Q35
	Economic data – investments and investment grants	I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€] (The data cannot be referenced sufficiently. A flexibility in order to exclude elements from the total investment sum has to be offered. The concrete selection depends on the data availability regarding the individual demonstration projects)			X	X	TC: D-NB-2-J11 OR M11 (selected by user) AC: D-NB-3-J14 OR J15 (selected by user) TC: D-RB-2-J11 OR M11 (selected by user, interpretation difficult) AC: D-RB-2-J14 or J15 (selected by user)	TC-NB: D-REF-2-M10 AC-NB: "0" TC-RB: "0" (should be increased by non-energetic parts, but neglected in the first step) AC-RB: "0"
		CIG_{i,t_1}	CONCERTO investment grants for building i discounted to year t_1			X	X	AC, TC: D-NB-3-L14 OR L15 (selected by user) AC, TC: D-RB-3-L14 OR L15 (selected by user)	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"
		OIG_{i,t_1}	Other investment grants for building i discounted to year t_1			X	X	AC, TC: D-NB-3-M14 OR M15 (selected by user) AC, TC: D-RB-3-M14 OR M15 (selected by user)	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"
	Value analysis data	$VB_{i,afterCONCERTO}$	Value of building i before the CONCERTO activities [€]			X		AC-NB, TC-NB: - AC-RB, TC-RB: - D-RB-1-I56:J56 (only question if a valuation has been done → additional boolean variable required)	-
		$VB_{i,beforeCONCERTO}$	Value of building i after the CONCERTO activities [€]				X	-	AC-NB, TC-NB: - AC-RB, TC-RB: - D-RB-1-G56:H56 (only question if a valuation has been done → additional boolean variable required)
	Economic data – annual costs	$ANERRC$	Annual non-energy-requirement-related costs of building i in year t [€/a]			X	X	AC, TC: NB-5-sum(K48:57)-sum(H48:57) AC, TC: NB-6-sum(K48:55)-sum(H48:55)	AC-NB, TC-NB: "0" (perhaps change required) AC, TC: NB-5-sum(K51:58)-sum(H51:58)
		$AORC_{i,t}$	Annual operation-related costs of building i in year t [€/a]			X	X	AC, TC: NB-5-sum(J61, 63, 64, 66, 67) AC, TC: RB-6-sum(J59, 61, 62, 64, 65)	AC-NB, TC-NB: "0" (perhaps change required) AC, TC: RB-5-sum(J62, 64, 65, 67, 68)

		$AOC_{i,t}$	Annual other costs of building i in year t [€/a]			X	X	AC, TC: NB-5-sum(J68,69) AC, TC: RB-6-sum(J66,67)	AC-NB, TC-NB: "0" (perhaps change required) AC, TC: RB-5-sum(J69,70)
		$p_{EC,i,t}$	Price of energy carrier (or source) EC (type IO) entering building i in year t [€/kWh]		X	X	X	**Priority 1:** AC, TC: NB-5-D48:57 (one value per EC) AC, TC: RB-6-D48:55 (one value per EC) **Priority 2 (if required for an EC):** AC-NB, TC-NB, AC-RB, TC-RB: CA-2-M11:M38 (one value per EC, in case of district heating average) **Priority 3 (if required for an EC):** AC-NB, TC-NB, AC-RB, TC-RB: B-2-M29:M68	**Priority 1:** AC, TC: NB-5-D48:57 (one value per EC) AC, TC: RB-5-D51:58 (one value per EC) **Priority 22 (if required for an EC):** AC-NB, TC-NB, AC-RB, TC-RB: CA-2-M11:M38 (one value per EC, in case of district heating average) **Priority 32 (if required for an EC):** AC-NB, TC-NB, AC-RB, TC-RB: B-2-M29:M68
	Economic data – annual revenues	$ARRNGNER$	Annual requirement-related non-grant non-energy-salesrevenues of building i in year t [€/a]			X	X	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"
		$AORR_{i,t}$	Annual operation-related revenues of building i in year t [€/a]			X	X	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"
		$AOR_{i,t}$	Annual other revenues of building i in year t [€/a]			X	X	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"	AC-NB, TC-NB: "0" AC-RB, TC-RB: "0"
		$p_{el.,i,t,OUT}$	Price of electricity (type IO) leaving building i in year t [€/kWh]			X	X	AC, TC: NB-5-D74 AC, TC: RB-6-D72	AC, TC: NB-5-D74 AC, TC: RB-5-D75
		$g_{el.,i,t,OUT}$	Grants for electricity (type IO) leaving building i in year t [€/kWh]			X	X	AC, TC: NB-5-F74 AC, TC: RB-6-F72	AC, TC: "0" AC, TC: RB-5-F75
	Rents	$AR_{i,t}$	Achieved rents incl./excl. ancillary costs of building i in year t [€/(m² a)]			X	X	AC, TC: D-NB-5-D/E77 OR D/E78 (selected by user) AC, TC: D-RB-6-D/E75 OR D/E76 (selected by user)	AC-NB, TC-NB: B-1-D282:D284 (OR, one value, selected by user) AC, TC: D-RB-5-D/E78 OR D/E79 (selected by user)

The reference object of an energy supply unit depends on the output energy (carrier). Therefore, heat (H), cold (C) and electricity are distinguished. In case of electrictity two reference approaches exist, i.e. EA (typical technology) and EB (national/European mix). For building-integrated energy supply units that do not use renewable energy or cogeneration there will be no data collection sheet. Therefore, the data has to be extracted from the corresponding building data sheet (cf. Table 13).

If a large-scale plant produces heat or cold it is connected to a district heating or cooling network. In this case, the input variables for the indicator calculation have to be stored in two cases, D1 and D2:

- D1: The district heating/cooling network does not influence the input variables of the large-scale energy plant

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- D2: The input variables of the large-scale energy plant are changed based on the input variables of the district heating/cooling network. E.g., the investement and costs are increased due to investements of the network and the energy output is decreased due to the losses of the network.

Ususally type D2 is used within this guide. D1 is used only for chapters 1.2.2.4, 1.2.2.5, and 1.5.8. In order to enable the determination of the input variables in case D2, the determination of the input variables of the district heating/cooling network and the share of these input variables allocated to each large-scale plant is issued as well in Table 13.

References between district heating/cooling network and plants have to be specified manually if more than one district heating/cooling network exists in the CONCERTO area that is connected to demonstration objects. References between district heating/cooling network and demonstration buildings are specified using a reference-ID (referencing on the district heating/cooling network) provided by the builiding data collection sheets. But in a first step, an average district heating/cooling mix of the CONCERTO area is used for calculation and thus, this reference ID is neglected.

Table 13: Required plant data with link to the CONCERTO Premium data collection sheets

Specificity	Type of data	Required data	Description	Data aggregation level: European7National	CONCERTO area/community	Demonstration object	Reference object	Demonstration object (data referencne to data collection sheets): Example for E-CES2 (CHP)	Reference object (data reference to data collection sheets) Example for E-BIES6 (Other)	Building-integrated object without separate data collection sheet (data reference to data collection sheets)	District heating or cooling network (data reference to data collection sheets)	Change of plant data (demonstration object data) by district heating or cooling network data in case D2
Plant data	IDs	s	ID of object			X	X	Combination of D-E-CES2-1-C11, D11, E11, F11, H11	H, C, EA: Combination of D-E-BIES6-1-D11, H11 EB: Combination of Country and REF-EL_B	Combination of corresponding i and an internal ID of each building-integrated, i.e. 1-5 (for NB-1-A79:A83),1-4 (for RB-1-A123:A126), 1-4 (for RB-1-A107:A110), 1-6 (for REF-1-A58:A63)	Combination of D-E-CES4-1-C11, D11, E11, F11, H11	-
		REF	ID of corresponding reference object			X		One reference object per output EC: H: Combination of D-E-BIES6-1-	-	-	-	-

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								D11= CES2-1-D11 and E-BIES6-1-H11=**REF-HEAT** <u>C:</u> Combination of D- E-BIES6-1-D11= CES2-1-D11 and E-BIES6-1-H11=**REF-COLD** <u>EA:</u> Combination of E-BIES6-1-D11= CES2-1-D11 and E-BIES6-1-H11=**REF-EL_A** <u>EB:</u> Combination of CES2-1-D11 and **REF-EL_B**				
	Temperatures	$T_{ambient}$	Annual average ambient temperature [K]		X			-(selected by user, default: 10°C)		-	-(selected by user, default: 10°C)	-
		T_{heat}	Annual average temperature of the output heat (type IO) [K]			X	X	E-CES-2-1-F51	<u>H, C, EA:</u> In analogy to demonstration object <u>EB:</u> -	-	E-CES4-1-G40:42 [OR, user selection]	-
		T_{cold}	Annual average temperature of the output cold (type IO) [K]			X	X	-(not applicable in case of CHP)	<u>H, C, EA:</u> In analogy to demonstration object <u>EB:</u> -	-	E-CES4-1-G43:45[OR, user selection]	-
	Base data	$Cap_{s,EC}$	Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]			X	X	E-CES-2-1-F40:42 (for EC=heat, OR, selected by user) AND E-CES-2-1-F44:46 (for EC=electricity, OR, selected by user)	<u>H, C, EA:</u> In analogy to demonstration object <u>EB:</u> -	-	E-CES4-1-G47 (for EC=heat in case of district heating, for EC=cold in case of district cooling)	-
		t_1	Year of construction start of energy supply unit s			X	X	E-CES-2-1-F32	<u>H, C, EA:</u> In analogy to demonstration object <u>EB:</u> -	-	**Priority 1:** E-CES4-1-F31 **Priority 2:** E-CES4-1-F30	-
		t_2	Year of construction			X	X	E-CES-2-1-H32 OR	<u>H, C, EA:</u> In analogy to	-	**Priority 1:** E-	-

			end of energy supply unit s					(selected by user) E-CES-2-1-F33	demonstration object EB: -		CES4-1-J31 **Priority 2:** E-CES4-1-J30	
		[s]	Energy supply unit type			X	X	Cf. Table 14	Cf. Table 14	Cf. Table 14	Cf. Table 14	-
		[s]*	Energy supply unit type from a demand-side perspective			X	X	Cf. Table 14	Cf. Table 14	Cf. Table 14	Cf. Table 14	-
		$S_{A,large}$, $S_{A,spatial}$, $S_{A,temporal}$, $S_{A,small,el.}$, $S_{A,small,other}$	Sets of energy supply units			X	X	Cf. Table 14	Cf. Table 14	Cf. Table 14	Cf. Table 14	-
		$Cap_{s,EC,t,t'}$	Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) planned in year t to be implemented in year t' [kW]			X		-(to be supplemented)	-	-	-(to be supplemented)	-
	Energy flows	$In_{EC,s,t}$	Input (>0) energy flow of energy carrier (or source) EC into energy supply unit s in year t [kWh/a]			X	X	**Energy demand (without time index):** E-CES-2-1-F140, 146, 152, 153 for EC in F56, 58, 60, 62 (one value per EC) **Energy consumption (with time index):** E-CES-2-1-G/H/I140, 146, 152, 153 for EC in F56, 58, 60, 62 in the corresponding monitoring period (G123:I124) (one value per EC and t whereas t is specified by start and end of the period)	H, C, EA: In analogy to demonstration object EB: -	(rules required → collaboration IMI/DFIU) **Energy demand (without time index):** AC, TC: D-NB-1-A74:M74 AND D-NB-1-A77:M93 AC, TC: D-RB-1-A101:M101 AND D-RB-1-A120:M136 **Energy consumption (without time index):** AC, TC (AFTER): D-NB-5-A14:Q36 AC, TC: D-RB-6-A14:Q35 **Reference buildings:** **Energy demand (without time index):** AC: D-NB-1-A73:M73 AND D-NB-1-A77:M93	**Energy demand (without time index):** E-CES4-1-F126:127 (one value per EC) **Energy consumption (with time index):** E-CES4-1-G/H/I126:127 in the corresponding monitoring period (G119:I120) (one value per EC and t whereas t is specified by start and end of the period)	$IN_{EC=el.,s=plant,t}(NEW) = IN_{EC=el.,s=plant,t}(OLD) + (Out_{EC=heat/cold,s=plant,t} / IN_{EC=heat/cold,s=DH/DC,t})^{*} IN_{EC=el.,s=DH/DC,t}$

		$Out_{EC,s,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]			X	X	E-CES2-1-F156:I157 (one value per EC)	H, C, EA: In analogy to demonstration object EB: -	TC: D-REF-1-A56:M71 AND D-REF-1-A126:M144 AC, TC: D-RB-1-A100:M100 OR D-RB-1-A102:M102 (special case, selected by user) AND D-RB-1-A105:M120 **Energy consumption (without time index):** AC, TC: D-RB-A/C-5-A14:Q35	E-CES4-1-F128:I128 (one value per EC)	$Out_{EC=heat/cold,s=plant,t}$ (NEW)= $Out_{EC=heat/cold,s=plant,t}$ (OLD) * ($Out_{EC=heat/cold,s=DH/DC,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)
	Economic data – investments and investment grants	I_{s,t_1}	Investment for components of a large-scale energy system; construction in year t_1; investment is discounted to year t_1 [€]			X	X	E-CES-2-1-F69/70 (OR, selected by user)	H, C, EA: In analogy to demonstration object EB: -	-	E-CES4-1-F75/76 (OR, selected by user)	$I_{s=plant,t1}$(NEW)=$I_{s=plant,t1}$(OLD) + ($Out_{EC=heat/cold,s=plant,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)* $I_{s=DH/DC,t1}$
		CIG_{s,t_1}	CONCERTO investment grants for energy supply unit s discounted to year t_1			X	X	E-CES-2-1-F113/114 (OR, selected by user)	H, C, EA: In analogy to demonstration object EB: -	-	E-CES4-1-F110/111 (OR, selected by user)	$CIG_{s=plant,t1}$(NEW)=$CIG_{s=plant,t1}$(OLD) + ($Out_{EC=heat/cold,s=plant,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)* $CIG_{s=DH/DC,t1}$
		OIG_{s,t_1}	Other investment grants for energy supply unit s discounted to year t_1			X	X	E-CES-2-1-F115/116 (OR, selected by user)	H, C, EA: In analogy to demonstration object EB: -	-	E-CES4-1-F112/113 (OR, selected by user)	$OIG_{s=plant,t1}$(NEW)=$OIG_{s=plant,t1}$(OLD) + ($Out_{EC=heat/cold,s=plant,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)* $OIG_{s=DH/DC,t1}$
	Economic data – annual costs	$ANERR$	Annual non-energy-requirement-related costs of energy supply unit s in year t [€/a]			X	X	E-CES-2-1-F202:I204 (first value for energy demand, others for monitoring periods, i.e. one value per t)	H, C, EA: In analogy to demonstration object EB: -	-	E-CES4-1-F141:I141 (first value for energy demand, others for monitoring periods, i.e. one value per t)	$ANERRC_{s=plant,t}$(NEW)=$ANERRC_{s=plant,t}$(OLD) + ($Out_{EC=heat/cold,s=plant,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)* $ANERRC_{s=DH/DC,t}$
		$AOC_{s,t}$	Annual other costs of energy supply unit s in year t			X	X	E-CES-2-1-F204:I204 (first value for energy	H, C, EA: In analogy to demonstration object	-	E-CES4-1-F143:I143 (first value for	$AOC_{s=plant,t}$(NEW)=$AOC_{s=plant,t}$(OLD) + ($Out_{EC=heat/cold}$

			[€/a]					demand, others for monitoring periods, i.e. one value per t)	EB: -		energy demand, others for monitoring periods, i.e. one value per t)	$_{d,s=plant,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)* $AOC_{s=DH/DC,t}$
		$AORC_{s,t}$	Annual operation-related costs of energy supply unit s in year t [€/a]			X	X	E-CES-2-1-F203:I203 (first value for energy demand, others for monitoring periods, i.e. one value per t)	H, C, EA: In analogy to demonstration object EB: -	-	E-CES4-1-F142:I142 (first value for energy demand, others for monitoring periods, i.e. one value per t)	$AORC_{s=plant,t}$(NEW)=$AORC_{s=plant,t}$(OLD) + ($Out_{EC=heat/cold,s=plant,t}$ / $IN_{EC=heat/cold,s=DH/DC,t}$)* $AORC_{s=DH/DC,t}$
		$p_{EC,s,t}$	Price of energy carrier (or source) EC (type IO) entering energy supply unit s in year t [€/kWh]		X	X	X	**Priority 1:** E-CES-2-1-F197:I200 RULE: divided by corresponding input energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination) **Priority 2: (if required for an EC)** CA-2-N11:N38 (one value per EC for large-scale units in year CA-2-E11:E38) AND CA-2-M11:M38 (one value per EC for building-integrated energy supply units in year CA-2-E11:E38). If ambiguous for an EC then use average. **Priority 3: (if required for an EC)** B-2-N29:N68 (one value per EC for large-scale units in	H, C, EA: In analogy to demonstration object EB: -	-	Only for EC=electricity (Otherwise "0") **Priority 1:** E-CES-2-1-F140:I140 RULE: divided by corresponding input energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination) **Priority 2: (if required for an EC)** CA-2-N11 **Priority 3: (if required for an EC)** B-2-N29	If $p_{EC=el.,s=plant,t}$ has not been determined using priority 1 and $p_{EC=el.,s=DH/DC,t}$ has been determined using priority 1 use $p_{EC=el.,s=plant,t}$:= $p_{EC=el.,s=DH/DC,t}$

								year CA-2-E29:E68) B-2-M29:M68 (one value per EC for building-integrated energy supply units in year CA-2-E29:E68). If ambiguous for an EC then use average.					
	Economic data – annual revenues	$ARRNG$	Annual requirement-related non-grant non-energy-salesrevenues of energy supply unit s in year t [€/a]			X	X	E-CES2-1-F189:I189 (first value for energy demand, others for monitoring periods, i.e. one value per t)	H, C, EA: In analogy to demonstration object EB: -	-	"0"	-
		$AORR_{s,t}$	Annual operation-related revenues of energy supply unit s in year t [€/a]			X	X	"0"	H, C, EA: In analogy to demonstration object EB: -	-	"0"	-
		$AOR_{s,t}$	Annual other revenues of energy supply unit s in year t [€/a]			X	X	E-CES2-1-F190:I190 (first value for energy demand, others for monitoring periods, i.e. one value per t)	H, C, EA: In analogy to demonstration object EB: -	-	"0"	-
		$g_{EC,s,t,OUT}$	Grants for energy carrier (or source) EC (type IO) leaving energy supply unit s in year t [€/kWh]			X	X	**for electricity (IO8a):** E-CES2-1-F181:I181 RULE: divided by corresponding output energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination) **for heat (IO5a):** E-CES2-1-F186:I186 RULE: divided by	H, C, EA: In analogy to demonstration object EB: -	-	"0"	-

								corresponding output energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination)				
		$p_{EC,s,t,OUT}$	Price of energy carrier (or source) EC (type IO) leaving energy supply unit s in year t [€/kWh]			X	X	**for electricity (IO8a):** E-CES2-1-F1179:I179 RULE: divided by corresponding output energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination) **for heat (IO5a):** E-CES2-1-F184:I184 RULE: divided by corresponding output energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination)	H, C, EA: In analogy to demonstration object EB: -	-	**[network usage charges] for heat/cold (IO5a/b):** E-CES4-1-F136:I136 RULE: divided by corresponding output energy flows (first column for energy demand, others for monitoring periods, i.e. one value per t-EC combination)	$p_{EC=heat/cold,s=plant,t}$(NEW)= $p_{EC=heat/cold,s=plant,t}$(OLD) + $p_{EC=heat/cold,s=DH/DC,t}$
		$PEN_{s,EC,t}$	Primary energy demand/consumption by energy supply unit s for the production of the output of energy carrier EC (type IO) based on year t [kWh/kWh]	X			X	CALCULATED	H, C, EA: CALCULATED EB: A-1-F361 (one value for electricity IO8a) OR [selected by user] A-1-F386 (one value for electricity IO8a)	-	-	-
		$EM_{s,M,EC,t}$	emissions of material M by energy supply unit s for the production of	X			X	CALCULATED	H, C, EA: CALCULATED EB: A-1-F191, 212, 233, 254, 275, 295, 316 (one	-	-	-

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			the output of energy carrier EC (type IO) based on year t [t/kWh]						value per M for electricity IO8a)			
		$\overline{STC}_{s,EC,t,t}$	Sum of discounted total annual costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]	X			X	CALCULATED	H, C, EA: CALCULATED EB: A-1-F462 (one value for electricity IO8a)	-	-	-
		$\overline{EPC}_{s,EC,t,t}$	Energy production costs of energy supply unit s for the production of the output of energy carrier EC (type IO) based on data of year t and with discount base in year t_0 [€/kWh]	X			X	CALCULATED	H, C, EA: CALCULATED EB: A-1-F462 (one value for electricity IO8a)	-	-	-

Table 14: Matching of data collection sheets to energy supply unit types [s], [s]* and $S_{A,large}$, $S_{A,spatial}$, $S_{A,temporal}$, $S_{A,small,el.}$, $S_{A,small,other}$

Matching of data collection sheets in case of demonstration objects and reference objects	Matching of building-integrated energy supply units without separate data collection sheet	Energy supply unit types [s]			Energy supply unit types from a demand side perspective [s]*	$S_{A,large}$	$S_{A,small,el.}$	$S_{A,small,other}$	$S_{A,spatial}$	$S_{A,temporal}$
CES1.1	-	Large-scale energy systems	Heating	Heating plant using biomass	Space heating	X				
CES1.2 + user selection	-			Heating plant using geothermal source (with heat pump)	Space heating	X				
CES1.2 + user selection	-			Heating energy from geothermal source (without heat pump)	Space heating	X				
CES1.3	-			Solar thermal collectors	Space heating	X				
CES2	-		Cogeneration	Combined Heat and Power plant	Electricity	X				
CES3.1	-		Electricity	Photovoltaics	Electricity	X				
CES3.2	-			Wind power plants	Electricity	X				

CES3.3	-			Hydro power plants	Electricity	X				
CES7 + user selection (based on text in CES4-1-F24)	-		Cooling	Cooling energy from geothermal source	Cooling	X				
CES4 + CES4-1-G22=”district heating”	-		Spatial transformation - grids/networks	District heating network	Heating				X	
CES4 + CES4-1-G22=”district cooling”	-			District cooling network	Cooling				X	
Not included (for a possible extension)	-		Temporal transformation - storages	Electrical storages	-					X
CES5	-			Thermal storages	-					X
CES6	-		Biogas plant		-	X				
CES7 if not type specified above (Cooling)	-		Others		User selection	X				
BIES1.1 + BIES1.1-1-F24=”boiler”	NB-1-A79:A83= OR RB-1-A123:A126 OR RB-1-A107:A110 OR REF-1-A58:A63=”boiler”		Space heating and domestic hot water generation	Boiler	Heating			X		
BIES1.1 + BIES1.1-1-F24=”condensing boiler”	=”condensing boiler”			Condensing boiler	Heating			X		
cf. other	=“district heating (DH) network”			District heating (DH) transfer station	Heating			X		
BIES1.3 + BIES1.1-1-F24=”compression heat pump”	=”Compression heat pump”			Compression heat pump	Heating			X		
BIES1.3 + BIES1.1-1-F24=”absorption heat pump”	=”Absorption heat pump”			Absorption heat pump	Heating			X		
BIES1.3 + BIES1.1-1-F24=”adsorption heat pump”	=”Adsorption heat pump”			Adsorption heat pump	Heating			X		
BIES1.3 + BIES1.1-1-F23=”solar thermal collector (water)”	=“Solar thermal collectors“			Solar thermal collectors	Domestic water heating			X		
BIES1.3 + BIES1.1-1-F23=”solar air collector”	=“Solar air collectors”			Solar air collectors	Heating			X		
cf. other	=“Electrical heating system”			Electrical heating system	Heating			X		
cf. other	=“Night-storage heater”			Night-storage heater	Heating			X		
cf. other	=“Stove”			Stove	Heating			X		

cf. other	="Continuous flow water heater"			Continuous flow water heater	Domestic water heating			X		
cf. other	="Compression refrigeration machine"		Cooling	Compression refrigeration machine	Cooling			X		
BIES4 + BIES4-1-F22="adsorption"	="Adsorption chiller"			Adsorption chiller	Cooling			X		
BIES4 + BIES4-1-F22="absorption"	="Absorption chiller"			Absorption chiller	Cooling			X		
cf. other	="District cooling (DC) transfer station"			District cooling (DC) transfer station	Cooling			X		
BIES3	="Photovoltaic"		Electricity	Photovoltaic	Electricty		X			
cf. other	-			Connection to electricity grid	Electricty		X			
BIES2	="Micro CHP"		Cogeneration	Micro CHP	Heating		X			
BIES5	="Reversible heat pump for =heating and cooling"			Reversible heat pump for heating and cooling	Cooling			X		
cf. other	="Conventional HVAC system"			Conventional HVAC system	Cooling			X		
BIES6 + user selection	="if other, please specify"		Others		User selection		X (user selection)			

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1.8 Example: Scharnhauser Park, Ostfildern, POLYCITY

The Scharnhauser Park in Ostfildern, Germany, is one of three CONCERTO areas in the POLYCITY project. The energy demand side encompasses residential and non-residential buildings. The latter are a city hall, a youth centre, a sports hall and the ELEKTROR office building. The residential buildings encompass

- 10 new one family houses according to the POLYCITY standard (SFH-PC),
- 9 new one family houses according to a low energy standard (SFH-LE),
- 17 row houses according to the POLYCITY standard (RH-PC),
- 12 apartments according to POLYCITY standards and (MFH-PC) and
- 38 apartments according to a low energy standard (MFH-LE).

1.8.1 Residential buildings, Scharnhauser Park

Table 15: Exemplary data for residential buildings of the POLYCITY project in Ostfildern (many table entries are based on assumptions and therefore only for demonstration purposes)

				MFH-PC		SFH-PC		RH-PC	
Specificity	Type of data	Required data	Description	SWS (Siedlungswerk Stuttgart) building 1	Reference building	SWS building 2	Reference building	SWS building 3	Reference building
Building data	Base data	Cap_i	Floor area of building i [m²] (here: net floor area)	1 605		1 771		2 043	
		t_1	Year of construction start of building i	2005		2007		2007	
		t_2	Year of construction end of building i	2006		2008		2008	
		$Dist_{EC,transpo}$	Transport distance for energy carrier EC from the refinery or the production plant to the average object in the corresponding CONCERTO area; The distance is zero in case of grid-bound energy carriers [km]	0	0	0	0	0	0
	Energy flows	$In_{EC,AA,i,t}$	Input (>0) energy flow into building i for application area AA in year t regarding energy carrier (or source) EC (type B) [kWh/a]	Table 16		Table 17		Table 18	
		$Out_{el.,i,t}$	Electricity output (>0) flow of building i in year t [kWh/a]						
	Economic data – investments and investment grants	I_{i,t_1}	Investment for building i; construction start in year t_1; construction end in year t_2; investment is discounted to year t_1 [€]	1 000 000	969 161	1 950 236	1 913 272	2 249 764	2 212 771
		CIG_{i,t_1}	CONCERTO investment grants for building i discounted to year t_1	10 794	-	12 937	-	12 947	-
		OIG_{i,t_1}	Other investment grants for building i discounted to year t_1	0	0	0	0	0	0
	Economic data – annual costs	$ANERRC$	Annual non-energy-requirement-related costs of building i in year t [€/a]	0	0	0	0	0	0
		$AORC_{i,t}$	Annual operation-related costs of building i in year t [€/a]	0	0	0	0	0	0

		$AOC_{i,t}$	Annual other costs of building i in year t [€/a]	0	0	0	0	0	0
		$p_{EC,i,t}$	price of energy carrier (or source) EC (type IO) entering building i in year t [€/kWh]	0.0738 (gross)					
	Economic data – annual revenues	$ARRNGNER$	Annual requirement-related non-energy-sales non-grant revenues of building i in year t [€/a]	0	0	0	0	0	0
		$AORR_{i,t}$	Annual operation-related revenues of building i in year t [€/a]	0	0	0	0	0	0
		$AOR_{i,t}$	Annual other revenues of building i in year t [€/a]	0	0	0	0	0	0
		$p_{el.,i,t,OUT}$	Price of electricity (type IO) leaving building i in year t [€/kWh]	0	0	0	0	0	0
		$g_{el.,i,t,OUT}$	Grants for electricity (type IO) leaving building i in year t [€/kWh]	0	0	0	0	0	0

Table 16: Final energy consumption (t=2010) and demand of the residential building SWS Building 1 (Scharnhauser Park, Ostfildern, POLYCITY) as well as final energy demand of the reference building

$In_{EC,AA,i,t}$ [kWh/a]		Application area					$Out_{el.,i,t}$ [kWh/a]
		(AA1) space heating	(AA2) domestic water heating	(AA3) space cooling	(AA4) electrical appliances	(AA5) electricity export	
Entry of a building or export from CONCERTO area	(B1) oil	0	0	0	-	0	0
	(B2) gas	0	0	0	-	0	
	(B3) coal	0	0	0	-	0	
	(B4) biomass	0	0	0	-	0	
	(B5) direct thermal energy	96 139.5; 89 880.0; 144 450.9;	20 544.0; 20 062.5; 20 062.5;	0	-	-	
	(B6) other renewables: heat	0	0	0	-	-	
	(B7) other renewables: electricity	-	-	-	-	0	
	(B8) electricity	0	0	0	33 384; 40 125; 51 360	0	
	(B9) electricity for export out of the CONCERTO area	-	-	-	-	-	

Table 17: Final energy demand of the residential building SWS Building 2 (Scharnhauser Park, Ostfildern, POLYCITY) as well as final energy demand of the reference building

$In_{EC,AA,i,t}$ [kWh/a]		Application area					$Out_{el.,i,t}$ [kWh/a]
		(AA1) space heating	(AA2) domestic water heating	(AA3) space cooling	(AA4) electrical appliances	(AA5) electricity export	
Entry of a building or export from	(B1) oil	0	0	0	-	0	0
	(B2) gas	0	0	0	-	0	
	(B3) coal	0	0	0	-	0	
	(B4) biomass	0	0	0	-	0	
	(B5) direct thermal energy	99 176; 159 390	22 137.5; 22 137.5	0	-	-	
	(B6) other renewables: heat	0	0	0	-	-	
	(B7) other renewables: electricity	-	-	-	-	0	
	(B8) electricity	0	0	0	44 275;	0	

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					56 672		
	(B9) electricity for export out of the CONCERTO area	-	-	-	-	-	

Table 18: Final energy demand of the residential building SWS Building 3 (Scharnhauser Park, Ostfildern, POLYCITY) as well as final energy demand of the reference building

$In_{EC,AA,i,t}$ [kWh/a]		Application area					$Out_{el.,i,t}$ [kWh/a]
		(AA1) space heating	(AA2) domestic water heating	(AA3) space cooling	(AA4) electrical appliances	(AA5) electricity export	
Entry of a building or export from CONCERTO area	(B1) oil	0	0	0	-	0	0
	(B2) gas	0	0	0	-	0	
	(B3) coal	0	0	0	-	0	
	(B4) biomass	0	0	0	-	0	
	(B5) direct thermal energy	114 408; 183 870	25 537.5;	0	-	-	
	(B6) other renewables: heat	0	0	0	-	-	
	(B7) other renewables: electricity	-	-	-	-	0	
	(B8) electricity	0	0	0	51 075; 65 376	0	
	(B9) electricity for export out of the CONCERTO area	-	-	-	-	-	

1.8.2 Biomass cogeneration plant, district heating, Scharnhauser Park, Ostfildern, POLYCITY

Table 19: Exemplary data for the biomass cogeneration plant of the POLYCITY project in Ostfildern (many table entries are based on assumptions and therefore only for demonstration purposes)

Specificity	Type of data	Required data	Description	Biomass cogeneration plant, District heating, Scharnhauser Park	Source
European to plant data	Primary energy factors	PEF_{EC}	Primary energy factor for energy carrier EC [kWh/kWh]	Table 26	Mix of POLYCITY deliverables and assumptions
	Temperatures	$T_{ambient}$	Annual average ambient temperature [K]	10 °C	
		T_{heat}	Annual average temperature of the output heat (type IO) [K]	90 °C	
		T_{cold}	Annual average temperature of the output cold (type IO) [K]	-	
Plant data	Base data	$Cap_{s,EC}$	Capacity of energy supply unit s regarding the output of energy carrier EC (type IO at the plant (!)) [kW]	5 300 (biomass) + 18 000 (gas), 1 000 electricity	
		t_1	Year of construction start of energy supply unit s	2002	
		t_2	Year of construction end of energy supply unit s	2004	
		$Dist_{EC,transport}$	Transport distance for energy carrier EC from the refinery or the production plant to the average object in the corresponding CONCERTO area; The distance is zero	25 (wood chips 30%)	

			in case of grid-bound energy carriers [km]		
	Energy flows	$In_{EC,s,t}$	Input (>0) energy flow of energy carrier (or source) EC into energy supply unit s in year t [kWh/a]	Table 20	
		$Out_{EC,s,t}$	Output (>0) energy flow of energy carrier (or source) EC (type IO) from energy supply unit s in year t [kWh/a]		
	Economic data – investments and investment grants	I_{s,t_1}	Investment for component s of a large-scale energy system; construction in year t_1; investment is discounted to year t_1 [€]	11 774 522 (incl. DH system)	
		CIG_{s,t_1}	CONCERTO investment grants for energy supply unit s discounted to year t_1	96 082	
		OIG_{s,t_1}	Other investment grants for energy supply unit s discounted to year t_1	738 000	
	Economic data – annual costs	$ANERRC_{s,t}$	Annual non-energy-requirement-related costs of energy supply unit s in year t [€/a]	0	
		$AOC_{s,t}$	Annual other costs of energy supply unit s in year t [€/a]	0	
		$AORC_{s,t}$	Annual operation-related costs of energy supply unit s in year t [€/a]	0	
		$p_{EC,s,t}$	Price of energy carrier (or source) EC (type IO) entering energy supply unit s in year t [€/kWh]	0	
	Economic data – annual revenues	$ARRNGNER_{s,t}$	Annual requirement-related non-grant non-energy-sales revenues of energy supply unit s in year t [€/a]	0	
		$AORR_{s,t}$	Annual operation-related revenues of energy supply unit s in year t [€/a]	0	
		$AOR_{s,t}$	Annual other revenues of energy supply unit s in year t [€/a]	0	
		$g_{EC,s,t,OUT}$	Grants for energy carrier (or source) EC (type IO) leaving energy supply unit s in year t [€/kWh]	0	
		$p_{EC,s,t,OUT}$	Price of energy carrier (or source) EC (type IO) leaving energy supply unit s in year t [€/kWh]	0	

Table 20: Energy consumption (t=2008) of the biomass cogeneration plant of the POLYCITY project in Ostfildern (some table entries are based on assumptions and therefore only for demonstration purposes) [http://www.duh.de/uploads/media/6_Fink_291107_01.pdf]

$IN_{EC,s,t}$ [kWh/a]		Input or Output of a specific large-scale energy supply plant, a distribution unit or a building-integrated energy supply (electricity, heat, cold etc.) or demand unit (or of combinations)								
		(IO1) oil	(IO2) gas	(IO3) coal	(IO4) biomass	(IO5) direct thermal energy	(IO6) other renewables: heat	(IO7) other renewables: electricity	(IO8) electricity	(IO10) Losses
Biomass cogeneration plant, District heating, Scharnhauser Park (incl. district heating)	$In_{EC,s,t}$	-	7 098 745 (efficiency 100%)	-	40 238 413	-	-	-	-	-
	$Out_{EC,s,t}$	-	-	–	-	37 700 000	-	-	6 015 701	3 621 457 (91 efficiency %, no losses in district

										heating network)

1.8.3 General data

Table 21: Exemplary general data for the POLYCITY project in Ostfildern (many table entries are based on assumptions and therefore only for demonstration purposes)

Specificity	Type of data	Required data	Description	European/ German
European / National data	Diverse data	r	Interest rate for calculations [-]	0.05
		$EF_{M,transport}$	Emission factor regarding material M for the transport mix [t/(t km)]	Cf. Table 25
	Energy Carrier data	$EF_{EC,M,direct}$	Direct emission factor for energy carrier EC regarding material M [t/kWh]	Cf. Table 22
		$EF_{EC,M,extraction-}$	Emission factor regarding material M for the production of energy carrier EC and all transports from extraction to the refinery, the production plant or the customer in case of grid-bound energy carriers [t/kWh]	Cf. Table 23 and Table 24
		LHV_{EC}	Lower heating value of energy carrier EC; zero if not applicable [kWh/t]	0 (Not yet defined)
	Building type data	$PEF_{[i]}$	Primary energy factor for a building of the same type as i [kWh/m²]	0 (Not yet defined)
		$EL_{[i]}$	Expected lifetime of a building of the same type as i [a]	40
		$EF_{[i],M}$	(Indirect) emission factor regarding material M for the construction of a building of the same type as i [t/m²]	0 (Not yet defined)
		$f_{repair,[i]}$	Factor for repairs as share of the investment per year [1/a]	1
	Indices	$d_{repair,t'}$	Price-index for repair payments in year t' [-]; $d_{repair,t_0} = 1$	1
		$d_{requirement,t'}$	Index for requirement(consumption)-related costs in year t' [-]; $d_{requirement,t_0} = 1$	1
		$d_{operation,t'}$	Index for operation-related costs in year t' [-]; $d_{operation,t_0} = 1$	1
		$d_{other,t'}$	Index for other costs in year t' [-]; $d_{other,t_0} = 1$	1
		$e_{requirement,t'}$	Index for requirement-related revenues in year t' [-]; $e_{requirement,t_0} = 1$	1
		$e_{operation,t'}$	Index for operation-related revenues in year t' [-]; $e_{operation,t_0} = 1$	1
		$e_{other,t'}$	Index for other revenues in year t' [-]; $e_{other,t_0} = 1$	1
European to building data	Primary energy factors	PEF_{EC}	Primary energy factor for energy carrier EC [kWh/kWh]	Cf. Table 26

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1.9 Selected emission factors and primary energy factors

Table 22: Direct emission factor for energy carrier EC regarding material M [GEMIS]

EC				$EF_{EC,M,direct}$ M=CO_2											
Level1		Level 2		EU		Austria		Denmark, France		Germany		Netherlands		Spain	
				[t/TJ LHV]	Source	[t/TJ LHV]	Source	[t/TJ LHV]	Source	[t/TJ LHV]	Source	[t/TJ LHV]	Source	[t/TJ LHV]	Source
1	Oil	a	Light oil <10 mg S/kg	74.3782	Öl-leicht-DE	-	-	-	-	-	-	-	-	-	-
		b	Light oil >10 mg S/kg			-	-	-	-	-	-	-	-	-	-
		c	Heavy oil	78.7735	Öl-schwer-EU-2010	-	-	-	-	-	-	-	-	-	-
2	Gas	a	Domestic gas	-	-	55.1514	Erdgas-AT	57.2099	Erdgas-DK, Erdgas-FR	55.1514	Erdgas-DE	56.2234	Erdgas-NL	55.1514	Erdgas-ES 2010
		b	LPG	63.7488	Flüssiggas-DE-2010, Flüssiggas-ES-2010	-	-	-	-	63.7488	Flüssiggas-DE-2010	-	-	63.7488	Flüssiggas-ES-2010
3	Coal	a	Hard coal	97.2650	Steinkohle-EU-Import-mix	94.5977	Steinkohle-AT	-	-	93.5015	Steinkohle-DE-Brikett-2005	-	-	94.5977	Steinkohle-ES
		b	Lignite	-	-	104.630	Braunkohle-AT	-	-	98.3004	Braunkohle-DE-Briketts-rheinisch-2005	-	-	-	-
4	Biomass	a	Wood Chips, 30% humidity	-	-	-	-	-	-	103.293	Holz-DE-Wald-Hackschnitzel-2005	-	-	-	-
		B	Pellets	-	-	-	-	-	-	100.366	Holz-DE-Pellets-2005	-	-	-	-
		c1	Biogas (for gas pipeline)	-	-	-	-	-	-	56.2310	Biogas-aufbereitet-für-Gasnetz	-	-	-	-
		c2	Biogas (central)	-	-	-	-	-	-	84.6827	Biogas-zentral	-	-	-	-
		d	Local specification	-	-	-	-	-	-	-	-	-	-	-	-

Table 23: Emission factor regarding material M (CO_2, CO_2 equ.) for the production of energy carrier EC and all transports from extraction to the refinery, the production plant or the customer in case of grid-bound energy carriers; primary energy factor for energy carrier EC [GEMIS]

EC	Count	$EF_{EC,M,extraction-refinery/plant/end-of-grid}$ and PEF_{EC}

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Level 1		Level 2		ry	Incl. construction				Excl. construction				Remark	Source
					M=CO_2 [t/TJ LHV]	M=CO_2 equivalent [t/TJ LHV]	KEA non renewable [TJ/TJ LHV]	KEV non renewable [TJ/TJ LHV]	M=CO_2	M=CO_2 equivalent	KEA non renewable [TJ/TJ LHV]	KEV non renewable [TJ/TJ LHV]		
1	Oil	a + b	Light oil	AT	13.9781	14.7363	1.1627738	1.1627693	13.4758	14.1850	1.1579985	1.1579968	Excl. transport refinery to customer	Raffinerie\Öl-leicht-AT-2005
				DE	11.0973	11.7521	1.1426111	1.1426037	10.6228	11.2323	1.1380996	1.1380950		Raffinerie\Öl-leicht-DE-2005
				DK	8.54376	8.86455	1.1108726	1.1108444	8.23441	8.52488	1.1078728	1.1078540		Raffinerie\Öl-leicht-DK-2005
				ES	8.20306	8.68145	1.0949885	1.0949839	7.92449	8.37554	1.0922613	1.0922603		Raffinerie\Öl-leicht-ES-2005
				FR	5.43640	5.89448	1.0765922	1.0765885	5.09377	5.51838	1.0733119	1.0733101		Raffinerie\Öl-leicht-FR-2005
				NL	11.5754	12.2002	1.1372963	1.1372818	11.1700	11.7549	1.1334151	1.1334038		Raffinerie\Öl-leicht-NL-2005
		c	Heavy oil	AT	12.0180	12.7707	1.1372879	1.1372815	11.5183	12.2227	1.1325855	1.1325826		Raffinerie\Öl-schwer-AT-2005
				DE	9.90727	10.5874	1.1249536	1.1249462	9.43990	10.0717	1.1205141	1.1205095		Raffinerie\Öl-schwer-DE-2005
				DK	8.54367	8.88661	1.1108359	1.1108077	8.23441	8.54404	1.1078727	1.1078539		Raffinerie\Öl-schwer-DK-2005
				ES	11.4178	11.9924	1.1372600	1.1372530	11.1254	11.6686	1.1344122	1.1344105		Raffinerie\Öl-schwer-ES-2005
				FR	10.6161	11.1865	1.1431180	1.1431141	10.2520	10.7837	1.1396815	1.1396796		Raffinerie\Öl-schwer-FR-2005
				NL	11.5752	12.2475	1.1372704	1.1372559	11.1700	11.7991	1.1334151	1.1334038		Raffinerie\Öl-schwer-NL-2005
2	Gas	a	Domestic gas	AT	7.44236	17.0088	1.1874184	1.1873558	6.91628	16.4285	1.1822083	1.1822082	Incl. transport to customer	Pipeline\Gas-AT-2005-lokal
				DE	5.10954	12.5940	1.1195537	1.1195478	4.64344	12.0802	1.1152001	1.1151969		Pipeline\Gas-DE-2005-mix-lokal
				DK	0.98648986	5.13377	1.0202709	575.67731	0.65715461	4.77604	1.0174603	1.0174553		Pipeline\Gas-DK-2005-lokal
				ES	8.80727	15.1161	1.1634106	1.1633490	8.43578	14.7125	1.1602438	1.1602438		Pipeline\Gas-ES-2005-mix-lokal

				FR	5.60126	12.2345	1.1223738	1.1223107	5.14317	11.7298	1.1180806	1.1180797		Pipeline\Gas-FR-2005-lokal
				NL	1.47918	5.99058	1.0295540	1.0294889	1.18516	5.67036	1.0269867	1.0269831		Pipeline\Gas-NL-2005-lokal
		b	LPG	DE	7.62871	8.27445	1.0935226	1.0935101	7.17464	7.77711	1.0892559	1.0892467	Excl. transport plant to customer	Raffinerie\Flüssiggas-DE-2005
3	Coal	a	Hard coal	DE	3.62123	12.8215	1.0587971	1.0587402	3.53185	12.7270	1.0581160	1.0580649		Fabrik\Steinkohle-Brikett-DE-2005
		b	Lignite	DE	20.0261	21.7601	1.1894651	1.1894374	19.9626	21.6925	1.1889547	1.1889299		Fabrik\Braunkohle-Brikett-DE-rheinisch-2005
4	Biomass	a	Wood Chips, 30% humidity	DE	3.29753	3.37078	44.004	44.003	3.17666	3.23065	0.042579	0.042579		Fabrik\Holz-HS-Wald-grob
		B	Pellets	DE	2.73239	2.85115	0.040637	0.040594	2.62450	2.73256	0.039451	0.039414		Fabrik\Holz-Pellets-Holzwirtschaft-DE-2005
		c1	Biogas (for gas pipeline)	DE	23.9920	41.1063	0.34960	0.34738	23.0573	40.1033	0.34280	0.34077		Fermenter\Biogas-Mais-DE-2010-inkl-Aufbereitung
		c2	Biogas (central)	DE	15.0193	26.8365	0.21643	0.21489	14.1117	25.8464	0.20949	0.20814		Fermenter\Biogas-Mais-DE-2005
		d	Local specification		Local specification									
5	Direct thermal energy	a	Heat/district heat											
		b	Cold/district cold											
8	Electricity	a		AT	68.9113	75.0166	0.91395	0.91339	66.5529	72.5429	0.89878	0.89838	Excl. transport plant to customer	El-KW-Park-AT-2005
				DE	171.779	178.880	2.5680112	2.5652864	169.973	176.972	2.5550412	2.5525830		El-KW-Park-DE-2005
				DK	156.180	167.950	1.8046678	1.8006698	154.165	165.813	1.7886519	1.7858869		El-KW-Park-DK-2005
				ES	124.461	130.644	2.1919598	2.1910913	122.775	128.863	2.1797298	2.1794745		El-KW-Park-ES-2005
				FR	24.9994	26.4440	3.1649810	3.1647294	23.2550	24.6235	3.1544034	3.1541596		El-KW-Park-FR-2005
				EU-27	122.213	129.279	2.4645404	2.4630242	120.517	127.491	2.4523605	2.4509837		El-KW-Park-EU-27-2005

Table 24: Emission factor regarding material M (SO_2, NO_x, SO_2 equ.) for the production of energy carrier EC and all transports from extraction to the

refinery, the production plant or the customer in case of grid-bound energy carriers [GEMIS]

EC				Country	$EF_{EC,M,extraction-refinery/plant/end-of-grid}$							
Level 1		Level 2			Incl. construction			Excl. construction			Remark	Source
					M=SO_2 [kg/TJ LHV]	M=NO_x [kg/TJ LHV]	M=SO_2 equivalent [kg/TJ LHV]	M=SO_2 [kg/TJ LHV]	M=NO_x [kg/TJ LHV]	M=SO_2 equivalent [kg/TJ LHV]		
1	Oil	a + b	Light oil	AT	125.51077	40.111056	153.84977	124.75001	38.991871	152.30837	Excl. transport refinery to customer	Raffinerie\Öl-leicht-AT-2005
				DE	44.444417	27.097018	63.684580	43.720261	26.037923	62.221846		Raffinerie\Öl-leicht-DE-2005
				DK	63.489880	23.736897	80.131435	63.003331	23.050466	79.166192		Raffinerie\Öl-leicht-DK-2005
				ES	76.949821	36.732933	102.66251	76.509599	36.112877	101.78999		Raffinerie\Öl-leicht-ES-2005
				FR	40.504935	25.049715	58.149784	39.979994	24.287616	57.093363		Raffinerie\Öl-leicht-FR-2005
				NL	96.497622	37.670194	123.04824	95.873292	36.767204	121.79414		Raffinerie\Öl-leicht-NL-2005
		c	Heavy oil	AT	100.51770	36.627901	126.43719	99.773363	35.514793	124.91641		Raffinerie\Öl-schwer-AT-2005
				DE	41.471619	25.738777	59.76049	40.758618	24.695959	58.32024		Raffinerie\Öl-schwer-DE-2005
				DK	63.488427	23.736331	80.129581	63.003333	23.050462	79.166191		Raffinerie\Öl-schwer-DK-2005
				ES	109.75278	44.037315	140.56255	109.29531	43.386123	139.65108		Raffinerie\Öl-schwer-ES-2005
				FR	97.648244	35.504658	122.58497	97.092135	34.694862	121.46412		Raffinerie\Öl-schwer-FR-2005
				NL	96.495470	37.669545	123.04563	95.873290	36.767200	121.79414		Raffinerie\Öl-schwer-NL-2005

2	Gas	a	Domestic gas	AT	1.8350296	40.464391	30.105465	0.98999	39.286040	28.438609	Incl. transport to customer	Pipeline\Gas-AT-2005-lokal
				DE	1.3264717	25.693535	19.292236	0.63768	24.652112	17.876879		Pipeline\Gas-DE-2005-mix-lokal
				DK	0.57456	3.2053868	2.8188167	0.17888	2.4698562	1.9097016		Pipeline\Gas-DK-2005-lokal
				ES	2.0105517	51.548834	37.906768	1.5628596	50.719563	36.880204		Pipeline\Gas-ES-2005-mix-lokal
				FR	1.7687601	27.186229	20.741256	1.1045833	26.157161	19.359143		Pipeline\Gas-FR-2005-lokal
				NL	0.54506	6.0791327	4.8040090	0.17722	5.4186061	3.9751446		Pipeline\Gas-NL-2005-lokal
		b	LPG	DE	31.244382	23.128551	47.748583	30.566838	22.119609	46.367670	Excl. transport plant to customer	Raffinerie\Flüssiggas-DE-2005
3	Coal	a	Hard coal	DE	2.2292631	3.7279308	5.2725691	2.1412598	3.5317140	5.0472096		Fabrik\Steinkohle-Brikett-DE-2005
		b	Lignite	DE	9.7171783	12.827597	21.713880	9.6454967	12.687207	21.543829		Fabrik\Braunkohle-Brikett-DE-rheinisch-2005
4	Biomass	a	Wood Chips, 30% humidity	DE	4.9069629	36.689052	30.470164	4.6158503	36.417752	29.985991		Fabrik\Holz-HS-Wald-grob
		B	Pellets	DE	1.7996420	4.1306273	2.8701418	1.5911549	2.6243909	3.7505447		Fabrik\Holz-Pellets-Holzwirtschaft-DE-2005
		c 1	Biogas (for gas pipeline)	DE	24.158104	85.076148	280.02612	23.235027	82.836932	277.51756		Fermenter\Biogas-Mais-DE-2010-inkl-Aufbereitung
		c 2	Biogas (central)	DE	19.994237	74.885086	208.62188	18.991442	72.687444	206.05532		Fermenter\Biogas-Mais-DE-2005
		d	Local specification	Local specification								
5	Direct thermal energy	a	Heat/district heat									
		b	Cold/district cold									
8	Electricity	a		AT	35.753930	203.35440	180.67756	34.177069	198.20357	175.49832	Excl. transport plant to customer	El-KW-Park-AT-2005
				DE	104.62495	173.90217	247.23528	103.05062	169.96685	242.90196		El-KW-Park-DE-2005
				DK	158.00432	547.90333	556.51162	156.12684	543.39660	551.48855		El-KW-Park-DK-2005
				ES	266.10948	487.82939	608.40203	264.77035	484.10107	604.45843		El-KW-Park-ES-2005
				FR	55.41	71.65	108.43	54.44	67.85	104.80		El-KW-Park-FR-2005

					9641	0418	215	8507	2991	631		
				EU -27	225.8 1858	278.2 2352	428.87 605	224.4 4147	274.5 4642	424.92 741		El-KW-Park-EU-27-2005

Table 25: Emission factor regarding material M for the transport mix [GEMIS]

	$EF_{M,transport}$							
	M=CO_2 equivalent				M=CO_2			
	Excl. construction		Incl. construction		Excl. construction		Incl. construction	
	[g/ (t km)]	Source	[g/ (t km)]	Source	[g/ (t km)]	Source	[g/ (t km)]	Source
Germany	315.27	GEMIS, LKW 2005-Mix De	339.78	GEMIS, LKW 2005-Mix De	311.03	GEMIS, LKW 2005-Mix De	330.84	GEMIS, LKW 2005-Mix De

Table 26: Primary energy factor for energy carrier EC [GEMIS]

	Cumulated energy requirement – non-renewable (KEA)				Cumulated energy use – non-renewable (KEV)			
	Incl. energy related supply chain		Excl. energy related supply chain		Incl. energy related supply chain		Excl. energy related supply chain	
	[MJ/ (t km)]	Source	[MJ/ (t km)]	Source	[MJ/ (t km)]	Source	[MJ/ (t km)]	Source
Germany	4.4019	GEMIS, LKW 2005-Mix De	4.1637	GEMIS, LKW 2005-Mix De	4.4018	GEMIS, LKW 2005-Mix De	4.1637	GEMIS, LKW 2005-Mix De

1.10 Annex: Overview of covered indicators

Environmental indicators		**MD**	**TD**	**ID**
Achieved environmental performance	(Final) energy demand and consumption	X	X	A1
	Primary energy demand and consumption	X	X	A2
	Greenhouse gas emissions	X	X	A3
	Particulate matter emissions	X	X	A4
	NO_X and SO_2 emissions	X	X	A5
Improvement of environmental performance with respect to a	(Final) energy demand and consumption	X	X	A∆1
	Primary energy demand and consumption	X		A∆2
	Greenhouse gas emissions	X		A∆3
	Particulate matter emissions	X		A∆4

baseline	NO_X and SO_2 emissions	X		AΔ5

Economic indicators [and several IDs]			**MD**	**TD**	**ID**
Investments, CONCERTO grants and other grants		Investments	X	X	BA1
		Grants (CONCERTO and other grants)	X	X	BA2
Total annual costs **[BB1]**, sum of discounted annual costs **[BB2]** and annuity **[BB3]** (cf. VDI 2067)		Capital-related annual costs	X	X	BC1
		Requirement-related costs	X		BC2
		Operation-related costs	X		BC3
		Other Costs	X		BC4
		External costs	X		BC5
Total annual revenues **[BD1]** , sum of discounted annual revenues **[BD2]** and annuity **[BD3]**		Capital-related annual revenues	X	X	BE1
		Requirement-related revenues	X		BE2
		Operation-related revenues	X		BE3
		Other revenues	X		BE4
Economic assessment of investments causing energy savings/ production in comparison to a baseline	Economic assessment from the point of view of owner-occupier, land-lord, tenant and plant owner (grants are no costs)	Energy production costs	X	X	CA1
		Energy production cost reduction	X	X	CA2
		Net present value	X	X	CA3
		Internal rate of return	X	X	CA4
		Dynamic payback period	X	X	CA5
		Achieved rents incl./excl. ancillary costs	X	X	CA6
		Achieved rent increase (excl. ancillary costs)	X	X	CA7
	Economic assessment from the point of view of the national/local economy (grants are costs)	Mitigation costs of (final) energy demand	X	X	CB1
		Mitigation costs of primary energy demand	X		CB2
		Mitigation costs of greenhouse gas emissions	X		CB3
		Mitigation costs of particulate matter emissions	X		CB4
		Mitigation costs of NO_X and SO_2 emissions	X		CB5
	Economic assessment from the point of view of the national/local	Mitigation costs of (final) energy demand	X		CC1
		Mitigation costs of primary energy demand	X		CC2
		Mitigation costs of greenhouse gas emissions	X		CC3

	society (grants are costs, external costs are costs)	Mitigation costs of particulate matter emissions		X		CC4
		Mitigation costs of NO_X and SO_2 emissions		X		CC5
		Stimulation of local economy	Number of jobs created in course of the CONCERTO activities	X	X	CC6
			Number of new businesses created in the CONCERTO area	X	X	CC7
			Number of trainings/person-days for trainings offered in the CONCERTO project	X	X	CC8
			Increase in real estate and flats value	X	X	CC9
			Changes in community demographics - neighborhood growth	X	X	CC10
	Economic assessment from the point of of view of the grant provider	Mitigation of (final) energy demand per grant		X	X	CD1
		Mitigation of primary energy demand per grant		X		CD2
		Mitigation of greenhouse gas emissions per grant		X		CD3
		Mitigation of particulate matter emissions per grant		X		CD4
		Mitigation of NO_X and SO_2 emissions per grant		X		CD5
		Triggered investment per grant provided		X	X	CD6

Technical indicators	**MD**	**TD**	**ID**
Density of final energy demand (e.g. from the point of view of a district heating network operator, i.e. for space heat and domestic hot water)	X	X	D1

Maximum and annual/monthly efficiency of energy supply units		X	X	D2
Maximum and annual/monthly power of energy supply units		X	X	D3
Peak load and load profile of electricity demand		X	X	D4
Peak load and load profile of thermal (heat and cold) energy demand		X	X	D5
Degree of accordance with national laws and standards		X	X	D6
Degree of congruence of calculated annual final energy demand and monitored consumption		X	X	D7
Degree of energetic self-supply	Share of locally by combined heat and power (CHP) plants produced energy in the total energy consumption (thermal energy and electricity)	X	X	D8
	Share of locally by renewable energy sources (RES) produced energy in the total energy consumption (thermal energy and electricity)	X	X	D9
Market share of technology in order to measure the degree of innovation		X	X	D10
Temporal predictability and controllability of energy supply		X	X	D11
Visibility of technology		X	X	D12
Further detailed technical data e.g. pressure, temperature, mass flows, pipe lengths etc.		-	X	D13

Indicators & gap analysis of implementation process		**MD**	**TD**	**ID**
Indicators that are calculated annually in order to characterize the progress of the implementation process of the CONCERTO project	Target that was planned to be implemented in year n	X	X	E1
	Fraction of the target that was implemented in year n	X	X	E2
Thematic descriptions related to the gap between target and implemented fraction	Barriers in case of underachievement of target	-	-	E3
	Measures taken in order to deal with the barriers	-	-	E4
	Lessons learnt from barriers and measures taken in order to deal with them	-	-	E5
	Link to related documents of CONCERTO projects	-	-	E6
	Link to thematic contact person of CONCERTO projects	-	-	E7

1.11 References

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1.12 Possible improvements

- Adaptation of variables to international literature
- Improvement of number of jobs created methodology (investments * factor)
- Improvement of chapter for weather correction
- Adding equivalent energy price and CO_2 payback period to indicators
- Adding references to project status sheets

1.13 List of figures

1.14 List of tables

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