Climate and cultural based design and market valuable technology solutions for Plus Energy Buildings

Tool for economical assessment of life cycle cost in PEBs

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1 Introduction

An important question concerning PEB is how to design these buildings from an economic point of view. PEBs require higher investment costs than standard nZEB buildings due to the integration of energy generation technologies. A crucial question is to what extent these extra-costs amortise over the entire life cycle of the building compared to 2020 nZEBs. In the frame of Cultural-E, additionally to the economic aspects, the external costs are also considered in the Life Cycle Cost (LCC) evaluation in order to obtain an overall picture. In addition, embodied carbon and primary energy demand are taken into account. This makes it possible to quantify the costs of CO_2 emission savings and primary energy savings over the entire life cycle by comparing the variants.

2 Scope and use in the Cultural-E project

In this task an excel-based tool is developed to assess life cycle economic impact taking into account direct costs as well as indirect costs and it allows to evaluate finance/funding schemes in the time horizon of 30 years. One challenge on the Cultural-E project is to show solution sets that make the extra costs for PEB compared to nZEB repayable within 8 years. The current nZEB standard is therefore the reference case and the tool is designed to compare up to 5 variants. This allows 4 solution sets to be compared with each other and with the reference nZEB. The tool is used to evaluate the LCC of the solution sets in WP4 and in WP6 for the LCC evaluation of the Demo cases (T6.3).

Considered direct costs are:

- investment costs
- maintenance costs
- costs related to energy consumption
- revenues from renewable energy production

Indirect costs are difficult to capture and represent a separate field of research. A common method for assessing the costs caused by global warming is the pricing of CO_2 emissions. This concept is implemented in the tool, distinguishing between embodied carbon and CO_2 emissions from energy consumption.

Indirect costs caused by co-impacts are difficult to define and are the subject of a separate work package. Nevertheless, we have implemented two methods to consider indirect costs. It should be noted that both positive and negative impacts are considered through co-impacts.

Besides the cost, the tool allows to investigate directly the effect of grants and subsidies.

During the development process of the tool, results from other H2020 projects were built upon. A first version of the tool was distributed to the advisors of the demo cases to get their feedback for further development.

The tool was developed by Dr. Boris Mahler, Dr. Hermann Leis at SIZ-energieplus and can be obtained from Steinbeis-Innovationszentrum energieplus, email: hermann.leis@siz-egs.de

3 Methodology

A data collection template for the evaluation of life-cycle costs has been developed for the LCC tool. The template was developed on the basis of results from the CRAVEzero project and extended to include the requirements of the Cultural-E project. Its structure is according to the approach provided by two main sources:

1. The Standard ISO 15686-5 (Buildings and constructed assets - Service life planning - Part 5: Life-cycle costing)

2. The European Code of Measurement, elaborated by the European Committee of the Construction Economists (CEEC, n.d.).

The first reference provides the main principles and features of an LCC calculation, while the second one describes an EU-harmonised structure for the breakdown of the building elements, services, and processes, in order to enable a comprehensive evaluation of the building life costs.

At this stage, the end-of-life cost is included in the tool as a functionality but not included in the evaluation since, like for the most of new and existing buildings, there is no availability of structured and relevant data.

According to the standard, all revenues are part of the total lifetime costs (WLC), but not part of the LCC. One aim of the Cultural-E project is to assess the LCC of PEBs and compare them with those of a building built in accordance with the nZEB standard. In addition, it is of interest whether and in what period of time the additional investments of a PEB will amortize. It is therefore crucial to take into account revenues generated from the sale of the energy produced. In other words, these revenues come from negative energy consumption, which is expressed analogously in negative energy costs.

A second target in the Cultural-E project is a valorization of co-impacts effect. So far, these effects are mainly due to the building characteristics and less to the operation of a building. According to the standard ISO 15686-5, such effects are not part of an LCC unless they represent direct costs, such as a CO2 levy. In order to be able to take them into account, the co-impact costs are here included in the tool similarly to a CO2 levy. In the analysis of the LCC, a distinction is made between LCC with and LCC without co-impact effects. The scheme of the standard ISO 15686-5 is extended by the external costs of the co-impacts as shown in Figure 1. It should be noted here that the co-impact costs can be both positive and negative.

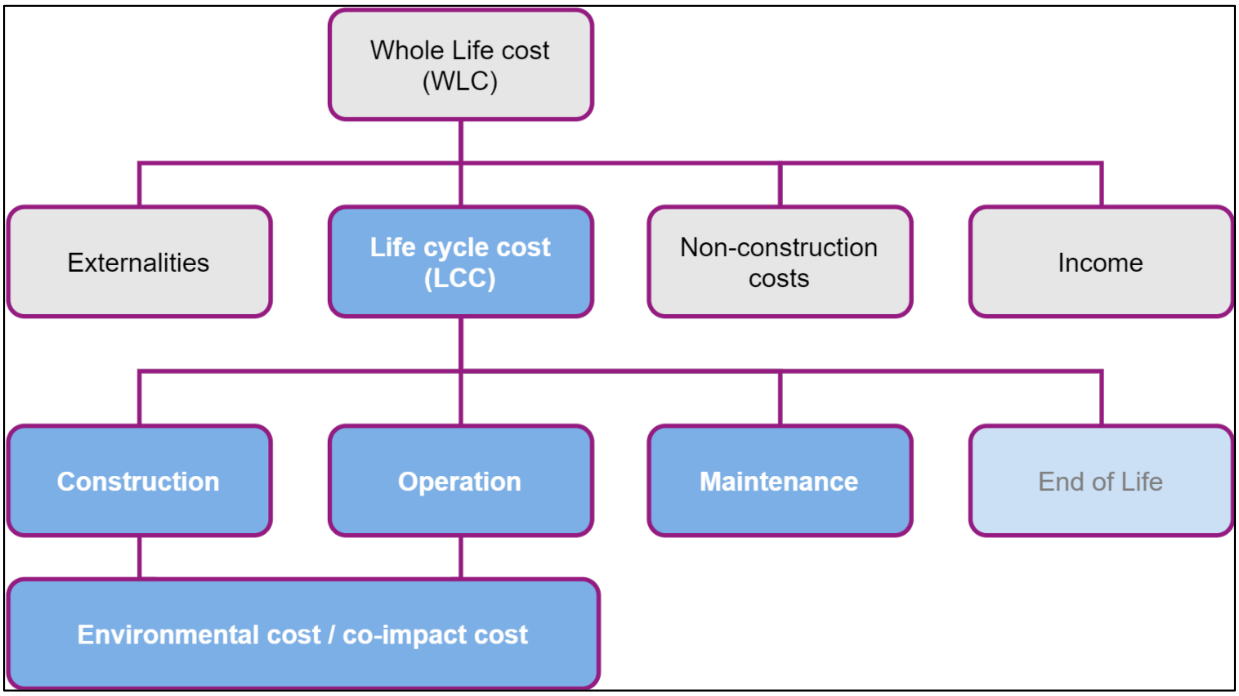


Figure 1: Scheme for Life Cycle Cost (LCC in blue) following ISO 15686-5 with the extension for assessing co-impact cost.

3.1 Life Cycle Cost calculation

According to the ISO 15686-5:2008, the LCC of a building is the Net Present Value (NPV), that is the sum of the discounted costs, revenue streams, and value during the phases of the selected period of the life cycle. Accordingly, the NPV is calculated as follows:

$$X_{NPV} = \sum (C_n * q) = \sum_{n=1}^{p} \frac{C_n}{(1+d)^n}$$

C: cost occurred in year n,
q: discount factor,
d: expected real discount rate per annum,
n: number of years between the base date and the occurrence of the cost,
p: period of analysis (30 years).

Cost elements taken into account are:

- Construction cost
- Maintenance

- Energy cost
- Revenues from energy sales
- External cost and Co-impacts
- Grants and subsidies

For each of the cost elements a price growth rate can be selected in the tool and considered in the calculation. The total annual cost is calculated according to the standard EN 15495-1(2017).

3.2 Construction cost

Initial construction cost are all costs for construction of the building that occur during or before the starting year of calculation. A replacement policy is taken into account after the expected life span of the components. For the passive building elements like walls, windows, ceilings, roofs, etc. we assume that no replacement is necessary, as the period under consideration is only 30 years. In contrast, the service life of the building services components and equipment is crucial. For this reason a separate sheet is used to calculate these costs. For the lifetime of the components, the standard values from EN 15459:2018 are used.

3.3 Maintenance

The analysis is based on standard values from EN 15459-1:2017 that provides yearly maintenance costs for each element, including operation, repair, and service, as a percentage of the initial construction cost. The standard provides a detailed breakdown of the costs for the HVAC and electrical systems. For the passive building elements like walls, windows, ceilings, roofs etc., an average yearly value of the construction cost can be adjusted for the evaluation.

3.4 Energy cost

Energy costs are calculated based on the calculation of energy demand and country-specific energy prices for each final energy source. A price increase rate can be set for each final energy source.

3.5 End of Life

The End of life costs are implemented in the tool as percentage of the initial construction cost according to EN 15459-1:2017. Within the framework of the Cultural-E project the End of life costs are not included.

3.6 Revenues from energy sales

Energy sales occur during periods where the electrical energy production, i.e. by the Photovoltaic system (PV-system), is higher than the on-site energy consumption. This amount of energy should be calculated by specific tools, i.e. a dynamic simulation based on hourly data. The revenues from energy sales are calculated from the surplus of production and the specific selling price. The result of the simulation also provides the self-consumed electricity and the amount to buy from the grid. In addition, a levy may be due i.e. in Germany for self-consumed electricity. In the tool, there is therefore a specific price for this and a corresponding price increase.

3.7 External cost and co-Impacts

External cost is defined as the cost incurred by an individual, firm or community as a result of an economic transaction which they are not directly involved in. External costs, also called ‘spillovers’ and ‘third party costs’ can arise from both production and consumption (reference: *https://www.economicsonline.co.uk)*.

Co-impacts are the added positive and negative values we obtain, in addition to the direct and measurable effects (e.g., reduced energy use, reduced CO_2 emissions), which derive from high-efficiency energy buildings.

They can be user co-impacts if they have an effect on the user's well-being and economy (e.g., comfort indoor, health improvement, lower cost of energy, higher responsible consumptions/share), or community co-impacts if they have wider economic, social and environmental effects (e.g., reduced CO_2 emissions, new business opportunities, urban heat island mitigation, reduction of water consumption and waste water production). If there is a possibility to define the co-impacts as costs, they are therefore external costs analogous to the CO_2 emission costs for climate impacts.

In the tool, external costs for CO_2-emission are separated in CO_2-cost for embodied carbon and CO_2-cost for energy consumption. This is an important distinction, as CO_2-cost for energy consumption can then be calculated considering a certain increase or decrease while the cost for embodied carbon can have a different price growth rate or can be considered as single cost during construction and replacement.

The CO_2 emissions related to energy consumption is calculated by applying specific CO_2-factors for each final energy source to the calculated energy demand.

The CO_2 emissions related to the embodied carbon of the building construction can be entered directly for each component group. The CO_2-emission related to the embodied carbon of the building services installations are calculated on the basis of the quantity of materials. In both cases, the calculation of CO_2 emissions (in CO_2 equivalents) is complex and must be carried out outside the tool as part of an LCA analysis.

At the moment, the CO_2 costs are seen as a political instrument, as there is no uniform definition of these costs to date. The tool can support the policy makers to assess the impact of accounting for CO_2 costs as a policy instrument

Furthermore, two concepts have been implemented in the calculation tool to consider the effect of co-impacts.

The first concept handles the co-impacts as demand related costs and works analogously to the approach for CO_2 costs or energy demand. The idea behind this is that a co-impact does not have a singular effect, but is continuously present and therefore potentially generates or avoids costs. In this context, a price increase rate can also take into account that the effect may decrease over time. For example, thermal comfort could be valued as a cost advantage, but this will decrease in the future as the standard level for thermal comfort generally increases over time, then the advantage decreases. In the tool, the cost of co-impacts can be positive for beneficial co-impacts or negative for adverse co-impacts.

In the second concept, a co-benefit is considered as a unique event and is therefore only valued once with costs. The year in which the valuation should take place can be selected in the tool.

3.8 Grants and subsidies

Grants and subsidies are considered one-off grants and are taken into account directly. In addition, the year in which the grants are made can be defined in the tool.

4 Structure of the tool

The EXCEL-based calculation tool is structured in 5 groups of EXCEL-sheets, while the calculation runs directly on the input data, without using macros:

- A spreadsheet for definition of the boundary conditions, which remain the same in all variants.
- A group of sheets to collect the specific data of the variants under comparison
- A group of data sheets with the compilation of the results of the variants
- A group of diagrams comparing the cost of the variants
- A group of diagrams showing and comparing the energy-demand and energy balance as well as the GWP-values and the primary energy demand.
- Spreadsheet with life span data and maintenance factors for the components according EN 15459-1 with the option to add own components data.

4.1 General boundary conditions

This sheet collects all country and case specific data as observation period, discount rate, price growth rates, energy prices, remuneration of sold energy and prices for CO_2 emission. In addition, GWP-values and primary energy factors of the energy sources can be entered in this sheet. Price growth rates are separated into capital related growth rates and those for maintenance and operation. As PV and especially power storage systems are relatively new technologies, we inserted separate inputs for the price growth rates.

General boundary conditions for the variant calculations

Boundary conditions

Year of starting observation:	2023
Observation period in years [a] (max. 50a):	30

Interest and price growth rates

General rate of price increase (yearly):	1,0%

General price growth rates	Capital-related costs	1,0%
	Maintenance&Operation costs	1,0%
PV price growth rates	Capital-related costs	-1,0%
	Maintenance&Operation costs	1,0%
Power-storage price growth rates	Capital-related costs	-3,0%
	Maintenance&Operation costs	1,0%

Energy prices and related factors

Energies purchase

Energy	purpose	price [€/MWh]	yearly price increase rate [%]	primary energy factor [-]	GWP [t CO_2eq/MWh]	relevant for CO_2-pricing?
Electricity	heating	176	2,00%	2,58	0,060	Yes
Electricity	cooling	176	2,00%	2,58	0,060	Yes
Electricity	ventilation	176	2,00%	2,58	0,060	Yes
Electricity	lighting	176	2,00%	2,58	0,060	Yes
Electricity	user	176	2,00%	2,58	0,060	Yes
Wood pellets	heating	70	0,00%	0,6	0,000	No
Natural gas	heating	86	0,02%	1	0,230	Yes

Energy generation (selling)

Name	kind and use of energy (insert above first if dropdown is empty)	price (selling into grid) [€/MWh]	yearly price increase rate for selling [%]	price for own use (e.g. tax) [€/MWh]	yearly price increase rate for own use [%]	primary energy factor for credits [-]	GWP for credits [t CO_2eq/MWh]	relevant for CO_2-pricing?
PV	Electricity	140	0,00%	0	0,00%	2,58	0,060	No
CHP	Electricity	140	0,00%	0	0,00%	2,58	0,060	No
		0	0,00%	0	0,00%	0	0,000	No

Attention: negative CO2-costs can occur if CO2-pricing for energy generation is activated

Costs for CO_2 and other costs

Energy	amount	unit	price growth rate [%]

Figure 2: Screen shot of sheet "Bound" with the general boundary conditions

4.2 Data of variants (solution sets)

For each variant three sheets contain the relevant data. In the first sheet "Info_Consum" all data summarizing the thermal envelope and floor areas as well as energy consumption and generation of the variant is collected. Additionally here is the place to fill in the subsidies, and co-impacts.

General project information / Energy consumption

V 1

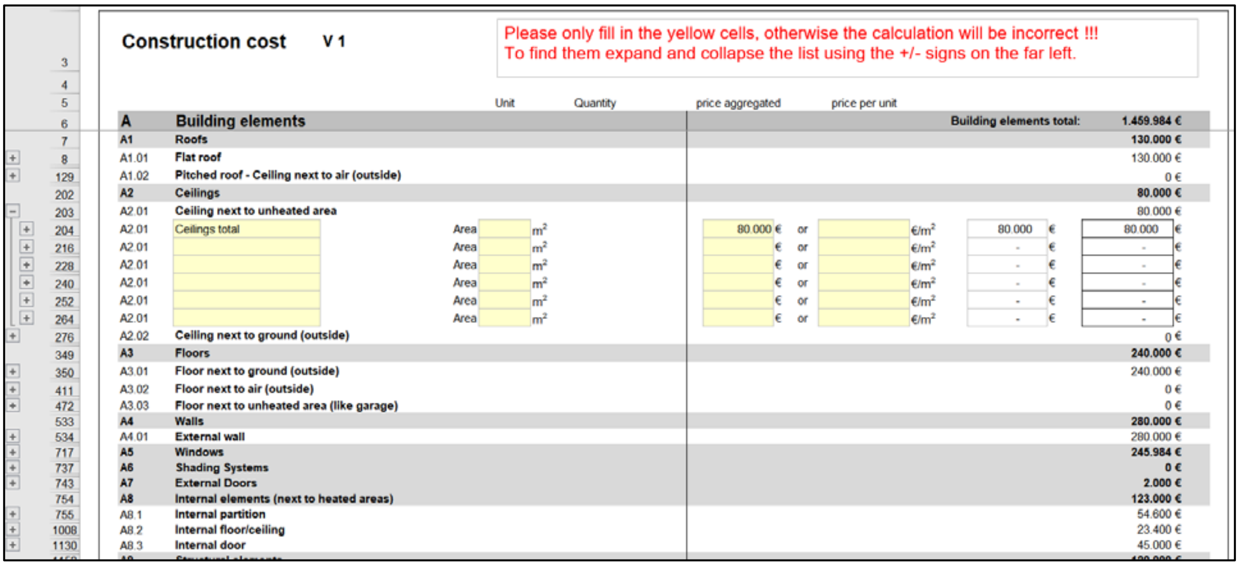
Legend

Cell to be filled-in with essential input values	Cell to be filled-in with optional input values	Automatic calculation / do not change!

General project data		
Name	Vilogia C-E demo building	
Country/Region/City	France	
Location	Leers	
Author	Hugo Viot	
Building Use/Typology	Residential	
Construction year	2023	
Building surfaces and volumes		
Gross floor area (GFA)	1.480	m^2
Net floor area (NFA)	1.110	m^2 <-- reference value for specific results
Gross volume	4.580	m^3
Net volume	3.435	m^3
Unheted areas		
Gross floor area (GFA)	120	m^2
Net floor area (NFA)	90	m^2
Gross volume	300	m^3
Net volume	225	m^3
Other areas		
Balconies, terraces, winter gardens, porches…	130	m^2
Other surfaces		m^2
Additional building data		
Treated floor area (ex: PHPP)	1.480	m^2
Window area	218	m^2
Total thermal envelope	834	m^2
Opaque surface	616	m^2
Shape factor S/V	0,18209607	-
Average U-value opaque components	0,13	$W/(m^2K)$

Figure 3:Sheet with general information and energy consumption of a variant.

The second sheet "KG_300" collects all cost data of the passive construction elements, i.e. all construction costs except those of the building services engineering and renewable energy sources. The data sheet is designed in such a flexible way that the costs can be easily added to and detailed according to the project phase. The data of components can be entered as mass or area-specific costs or, if known, also according to the layer structure.



Construction cost V 1

Please only fill in the yellow cells, otherwise the calculation will be incorrect !!!
To find them expand and collapse the list using the +/- signs on the far left.

Row	Code	Element	Unit		Quantity	price aggregated		price per unit				Total
3												
4												
5			Unit		Quantity	price aggregated		price per unit				
6	A	Building elements									Building elements total:	1.459.984 €
7	A1	Roofs										130.000 €
8	A1.01	Flat roof										130.000 €
129	A1.02	Pitched roof - Ceiling next to air (outside)										0 €
202	A2	Ceilings										80.000 €
203	A2.01	Ceiling next to unheated area										80.000 €
204	A2.01	Ceilings total	Area		m²	80.000 €	or	€/m²	80.000 €		80.000 €	
216	A2.01		Area		m²	€	or	€/m²	- €		- €	
228	A2.01		Area		m²	€	or	€/m²	- €		- €	
240	A2.01		Area		m²	€	or	€/m²	- €		- €	
252	A2.01		Area		m²	€	or	€/m²	- €		- €	
264	A2.01		Area		m²	€	or	€/m²	- €		- €	
276	A2.02	Ceiling next to ground (outside)										0 €
349	A3	Floors										240.000 €
350	A3.01	Floor next to ground (outside)										240.000 €
411	A3.02	Floor next to air (outside)										0 €
472	A3.03	Floor next to unheated area (like garage)										0 €
533	A4	Walls										280.000 €
534	A4.01	External wall										280.000 €
717	A5	Windows										245.984 €
737	A6	Shading Systems										0 €
743	A7	External Doors										2.000 €
754	A8	Internal elements (next to heated areas)										123.000 €
755	A8.1	Internal partition										54.600 €
1008	A8.2	Internal floor/ceiling										23.400 €
1130	A8.3	Internal door										45.000 €

Figure 4: Data sheet to fill in the cost of passive construction elements.

In the third sheet called “Tan_Cost” (Figure 5) building service cost and cost of renewable energy sources are filled in and calculation of LCC takes place. Here the costs from sheet “KG_300” are taken over for calculation. In this sheet, by selecting the component type, the service life and the factor for maintenance are automatically selected according to the EN 15459-1 standard. The tool opens the possibility to edit the values for life span and maintenance coming originally from the standard. This takes place in the Sheet “DIN EN 15459-1” at the end of the list (Figure 6). Additionally, the user can define his own component with dedicated life span and maintenance factor. This makes the tool flexible for new components or component groups which are not included in the standard.

In the calculation, the costs for replacement after the service life are also automatically accounted. In addition, the GWP-values in CO_2-equivalents and the primary energy demand of the embodied carbon coming from LCA analysis are to be filled here.

Investment costs, Replacements and Maintenance V 1_TanCost

Compo-nent Nr.	Component / Group	Description	Quantity	Reference pc./ m²/ m/ ...	Unit price	Cost	PE	GWP	year of investment	Typ of Component according to DIN EN 15459-1	price grow
	T_N					A_0				*add more in "DIN EN 15459-1"*	
	Building construction KG 300		-	St./ m²/ ...	€/...	€	MJ	t CO2-eq			
A1	Roofs					130.000			2023	Roofs	General pric
A2	Ceilings					80.000			2023	Internal floor/ceiling	General pric
A3	Floors					240.000			2023	Floors	General pric
A4	Walls					280.000			2023	Internal walls	General pric
A5	Windows	Add specific values in KG300-Sheet				245.984			2023	Windows	General pric
A6	Shading Systems					0			2023	Shading Systems	General pric
A7	External Doors					2.000			2023	External Doors	General pric
A8	Internal elements (next to heated areas)					123.000			2023	Internal elements (next to heated areas)	General pric
A9	Structural elements					120.000	40.000.000	650,0	2023	Structural elements	General pric
A10	Other elements					239.000			2023	Other elements	General pric
	Building services + Rewewable energy sources (RES)						**MJ per unit**	**t CO2-eq per unit**			
1	electricity installations	all	1	piece	140.000	140.000			2023	Electric wiring	General pric
2	sanitary/plumbing/heating/ventilation	all	1	piece	380.000	380.000	10.000.000	150,0	2023	Piping systems	General pric
3						0				empty	General pric
4	PV		220	piece	280	61.600			2023	PV	General pric
5	EV charger		2	piece	5.000	10.000			2023	Other	General pric
6	Battery		1	piece	55.000	55.000			2023	Battery	General pric
7	Sensors		21	piece	1.000	21.000			2023	Control system- room control	General pric
8	PHP		19	piece	7.000	133.000			2023	PHP heatpump	General pric
9						0				empty	General pric

Figure 5: Calculation sheet "TanCost" with cost of Building services and RES, Life span and maintenance factor.

Description	lifespan	factor for maintenance	disposal cost	cost category for "Cost_overview"; change categories in "TanCost_Detail"				
empty								
Battery	8	1,00%	0%	Battery	← freely editable fields			
heating systems general	20	2,00%	0%	Heating systems	← freely editable fields			
cooling systems general	20	2,00%	0%	Cooling systems	← freely editable fields			
ventilation systems general	20	2,00%	0%	Ventilation systems	← freely editable fields			
own component	5	10,00%	0%	Other building services	← freely editable fields			
PHP heatpump	12	3,00%	0%	Heating systems	← freely editable fields			
Site preparation	50	0,00%	0%	Building site	← freely editable fields			
					← freely editable fields			
					← freely editable fields			
					← freely editable fields			
					← freely editable fields			
					← freely editable fields			
					Reference values from DIN EN 15459-1			
						lifespan	**factor for maintenance**	**disposal costs**
Blower-Door-Messung	35	0,00%		Heating systems		35	0,00%	0%
Air conditioning units	15	4,00%		Ventilation systems		15	4,00%	
Air coolers	20	2,00%		Cooling systems		20	2,00%	
Air heaters, electric	20	2,00%		Heating systems		15 – 25	2,00%	
Air heaters, steam	20	2,00%		Heating systems		15 – 20	2,00%	
Air heaters, water	20	3,00%		Heating systems		15 – 20	2 – 4	
Boiler condensing	20	1,50%		Heating systems		20	1 – 2	
Burners, oil and gas	10	4,00%		Heating systems		10	4,00%	
Condensers	20	2,00%		Heating systems		20	2,00%	
Control equipment	20	4,00%		Heating systems		15 – 25	4,00%	
Control system - Central	20	4,00%		Heating systems		15 – 25	4,00%	

Figure 6: Sheet "DIN EN 15459-1" with editable life span and maintenance data.

4.3 Data summary sheets

The data summary sheet group consists of five sheets compiling cost, energy and GWP data.

4.3.1 Cost overview

The data sheet "Cost-overview" summarizes cost data of all variants in the KPIs:

- Total initial investment, Total investment per m²

- Present value of investment (including replacement and residual value)
- Present value of total cost, including and excluding co-impacts
- Total annual cost (TanCost), including and excluding co-impacts, as well as specific values per m² per month

The investment cost are subdivided in groups shown in Figure 7, while total cost are subdivided in:

- Capital cost (incl. planning & replacements)
- Maintenance costs
- Energy cost
- CO_2-costs from energies
- CO_2-costs from building (incl. replacements)
- Other costs
- Revenues
- Subsidies
- Co-Impacts

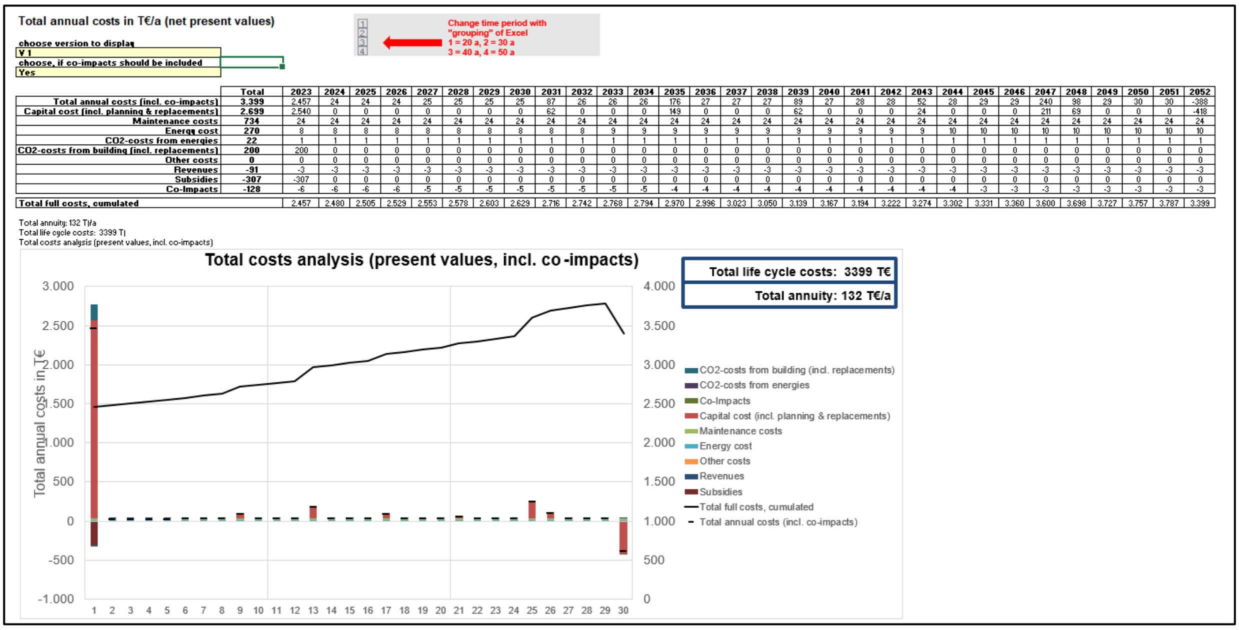
Summary of costs

Variant		V 1	V 2	V 3	V 4	V 5
Net floor area (NFA)	m²	1.110	1.110	0	0	0
Net energy balance of building	MWh/a	19	96	0	0	0
Total initial investment						
Building site	T€	0	45	0	0	0
Building	T€	1.460	1.438	0	0	0
Heating systems	T€	534	451	0	0	0
Cooling systems	T€	0	0	0	0	0
Ventilation systems	T€	0	0	0	0	0
Other building services	T€	150	140	0	0	0
PV	T€	62	0	0	0	0
Battery	T€	55	0	0	0	0
Surcharge	T€	113	104	0	0	0
Planning costs	T€	166	152	0	0	0
Total investment	**T€**	**2.540**	**2.330**	**0**	**0**	**0**
KPI of investment	T€/m² NFA	**2,3 T€/m² NFA**	**2,1 T€/m² NFA**			
Present value of the investments (including replacements, maintenance and residual values)						

Figure 7: Cost-overview sheet showing total initial investment (values are fictive).

4.3.2 Total annual Cost

The annual evolution of the present cost in the time horizon of 30 years are summarized in the sheet "TanCost-Detail", Figure 8. Here we keep the subdivision of 4.3.1. In addition, the years and amounts of replacement are clearly visible, as is the residual value. For comparison, an additional diagram showing cumulated total cost of all variants in integrated in the sheet.



	Total	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Total annual costs (incl. co-impacts)	3.399	2.457	24	24	24	25	25	25	25	87	26	26	26	176	27	27
Capital cost (incl. planning & replacements)	2.699	2.540	0	0	0	0	0	0	0	62	0	0	0	149	0	0
Maintenance costs	734	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Energy cost	270	8	8	8	8	8	8	8	8	8	8	9	9	9	9	9
CO2-costs from energies	22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CO2-costs from building (incl. replacements)	200	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenues	-91	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
Subsidies	-307	-307	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co-Impacts	-128	-6	-6	-6	-6	-5	-5	-5	-5	-5	-5	-5	-5	-4	-4	-4
Total full costs, cumulated		2.457	2.480	2.505	2.529	2.553	2.578	2.603	2.629	2.716	2.742	2.768	2.794	2.970	2.996	3.023

	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052
Total annual costs (incl. co-impacts)	27	89	27	28	28	52	28	29	29	240	98	29	30	30	-388
Capital cost (incl. planning & replacements)	0	62	0	0	0	24	0	0	0	211	69	0	0	0	-418
Maintenance costs	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Energy cost	9	9	9	9	9	9	10	10	10	10	10	10	10	10	10
CO2-costs from energies	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CO2-costs from building (incl. replacements)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Other costs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenues	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
Subsidies	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Co-Impacts	-4	-4	-4	-4	-4	-4	-4	-3	-3	-3	-3	-3	-3	-3	-3
Total full costs, cumulated	3.050	3.139	3.167	3.194	3.222	3.274	3.302	3.331	3.360	3.600	3.698	3.727	3.757	3.787	3.399

Figure 8: Cumulated cost of a chosen variant (values are fictive).

4.3.3 Energy overview

Energy demand and production, self-use of produced electricity, CO2-Emission and primary energy demand of all variants are summarized in the sheet “En_Overview”. The demand is subdivided in the categories heating, cooling, lighting, ventilation and user. We can choose absolute values, area-related values ore area related values per year for the calculation of the KPIs, see Figure 9.

Summary of energies, GWP and PE

		V 1	V 2	V 3	V 4	V 5
Net floor area (NFA)	m²	1.110	1.110	0	0	0
Net energy balance of building	MWh/a	19	96	0	0	0

Change unit: area-related/per year (absolute / aera-related / area-related/per year) — change unit of numbers and diagrams here

Overview energy - shares in energy consumption

		V 1	V 2	V 3	V 4	V 5
Shares of the systems in the heat supply						
Total heat-related energy	kWh/(m²*a)	18,4	54,1	#DIV/0!	#DIV/0!	#DIV/0!
Shares of the systems in the cooling supply						
Total cooling-related energy	kWh/(m²*a)	0,0	0,0	#DIV/0!	#DIV/0!	#DIV/0!
Shares of the systems in the user demand						
Total user-related energy	kWh/(m²*a)	12,0	12,0	#DIV/0!	#DIV/0!	#DIV/0!
Shares of the systems in the lighting demand						
Total lighting-related energy	kWh/(m²*a)	2,1	2,1	#DIV/0!	#DIV/0!	#DIV/0!
Shares of the systems in the ventialtion demand						
Total ventialation-related energy	kWh/(m²*a)	18,0	18,0	#DIV/0!	#DIV/0!	#DIV/0!

Overview energy - demand and generation

Figure 9: Energy overview sheet (values are fictive).

4.3.4 GWP and Primary Energy overview

These sheets are similar to the Total annual Cost sheet but showing the GWP and Primary energy values as cumulated values during the period of 30 years.

4.4 Results

4.4.1 Cost diagrams

For straightforward comparison of the variants, we find diagrams showing the initial investment cost (Figure 10), total annual cost and total annual cost without co-impacts.

The total annual costs are compiled in two columns for each variant, see Figure 11. The left column shows the total annual costs broken down into capital costs, energy costs, maintenance costs and CO_2 costs. The right-hand column shows the resulting total annual costs in red, after subtracting the revenues from the sale of electricity, the subsidies and the costs saved through the co-impacts. To compare the variants, therefore, this red column is of primary relevance. In case that the co-impacts do not save any costs but cause them, this amount does not appear on the right-hand side but on the left-hand side. This makes the tool flexible with regard to the evaluation of the co-impacts.

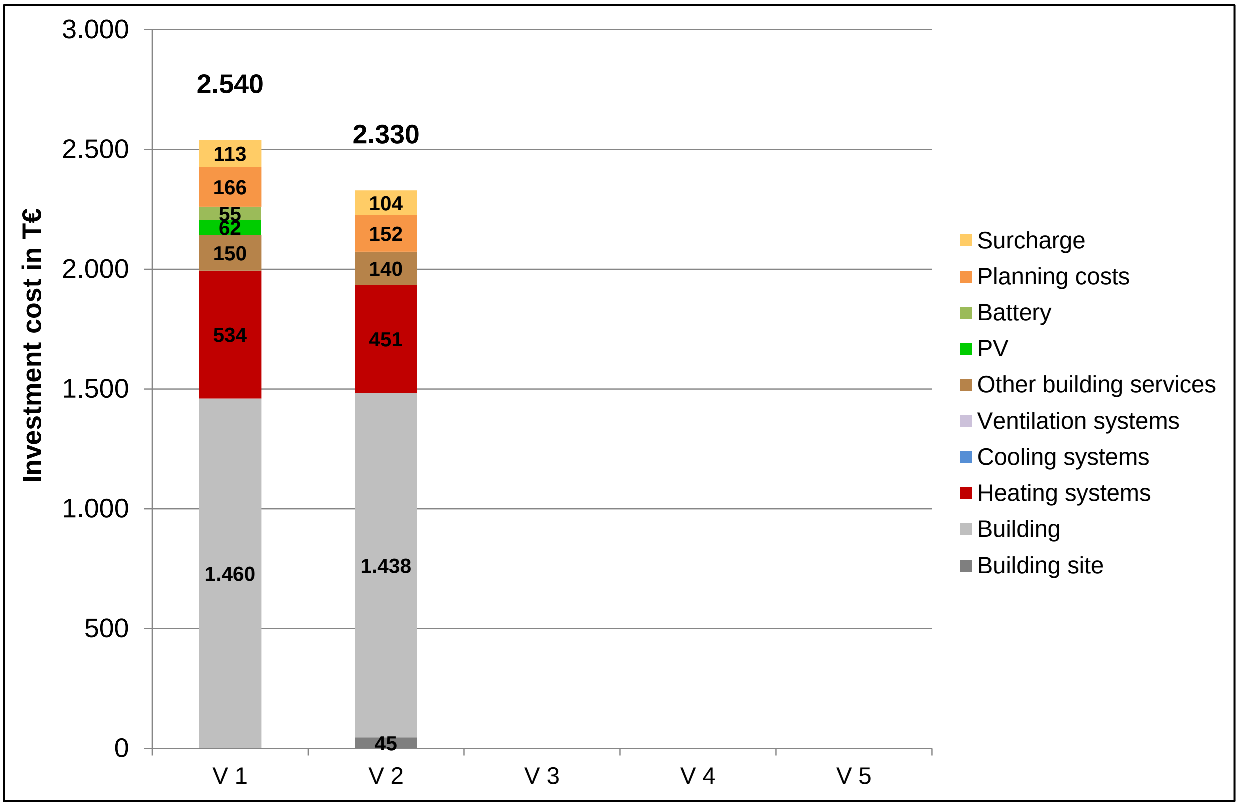


Figure 10 Diagram with initial invest cost (values are fictive)

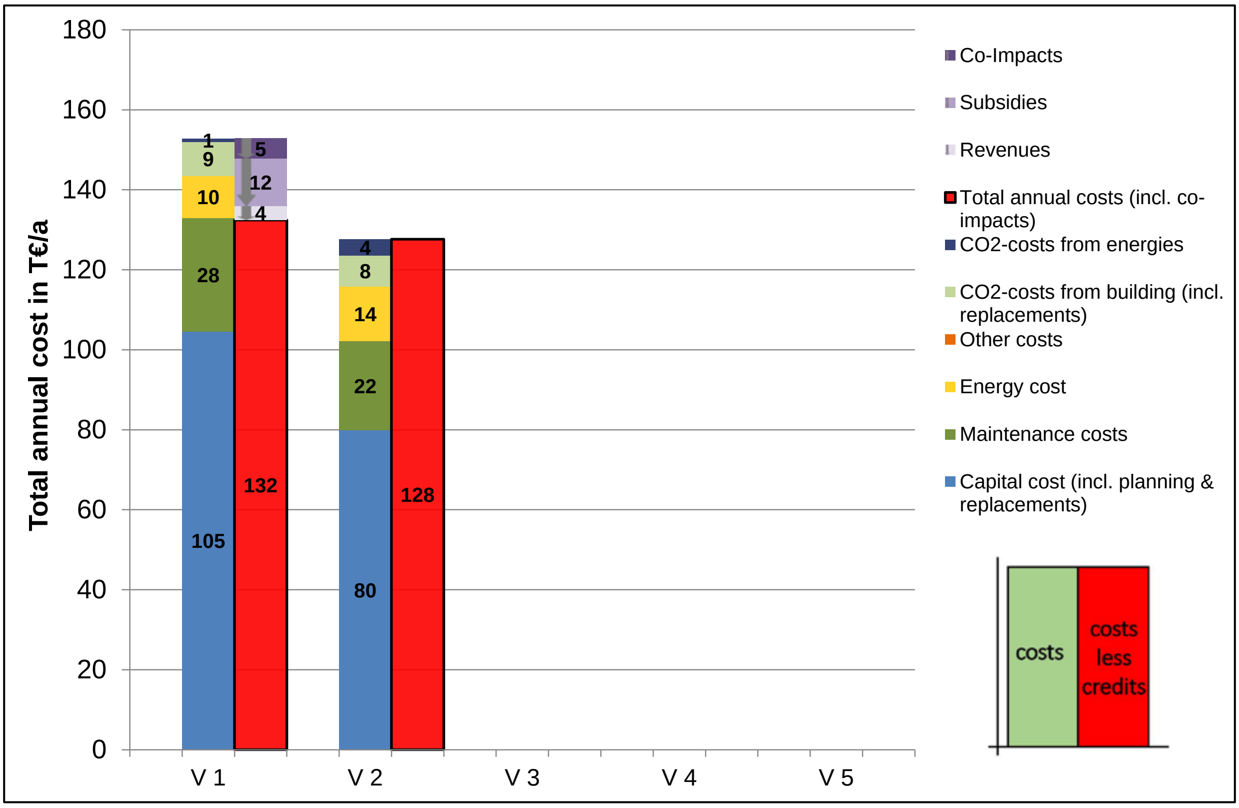


Figure 11: Diagram comparing total annual cost of variants (values are fictive).

4.4.2 Energy diagrams

The energy diagrams compare the variants in terms of energy balance, final energy demand, primary energy demand and GWP values. For direct comparison, all variants are shown in a diagram, Figure 12. All diagrams have the same structure. For GWP and primary energy, two diagrams are available, one including embodied energy and another only showing the demand for operation. The black bars indicate the KPIs, Figure 13.

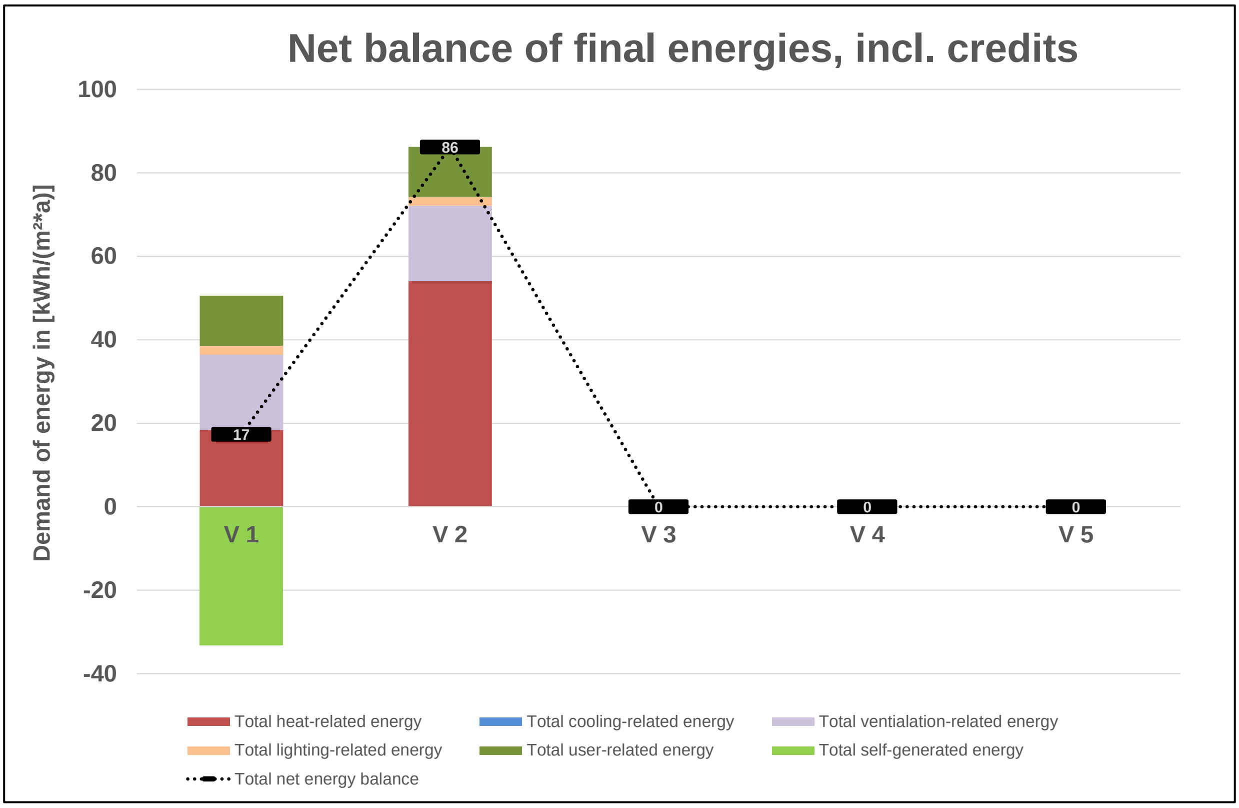


Figure 12: Diagram comparing energy demand, generation and net balance of all variants (values are fictive).

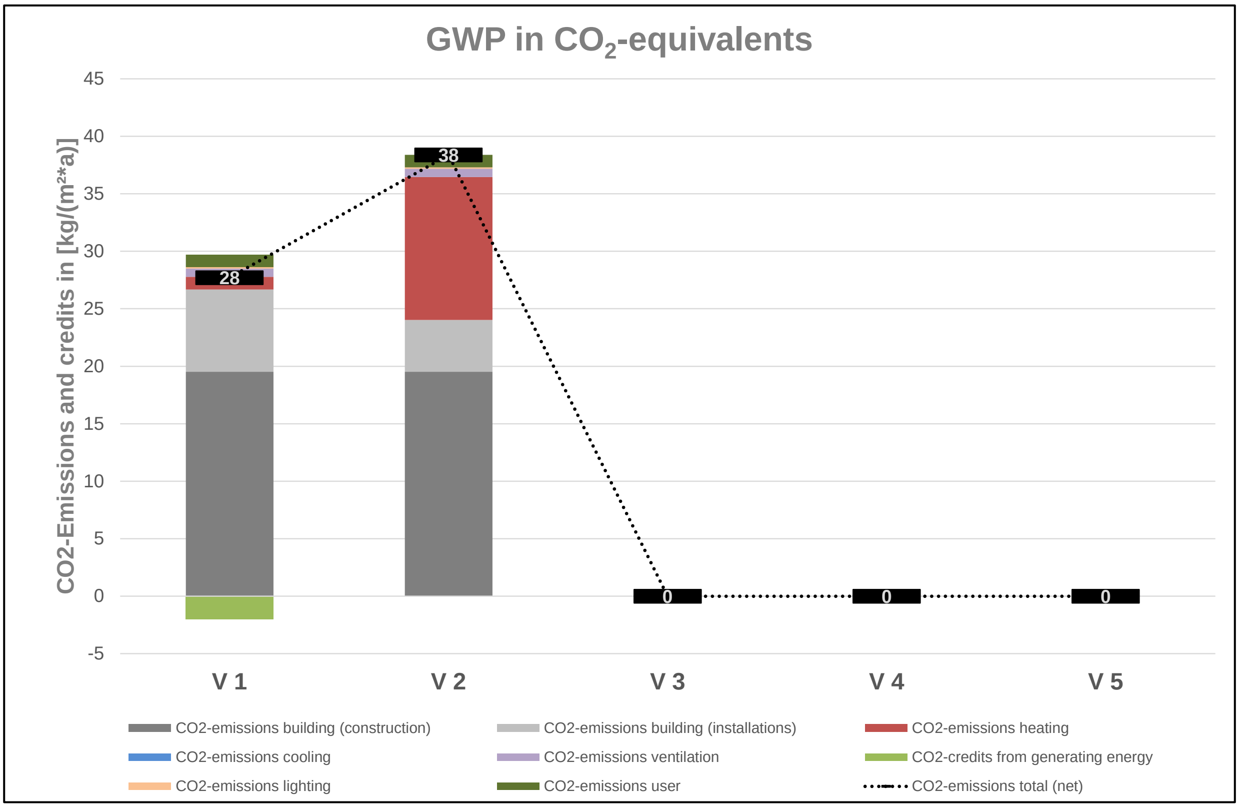


Figure 13: Diagram comparing GWP-values of all variants (values are fictive).

4.4.3 KPIs and other considerations

At the moment the following KPIs are calculated in the tool. All KPIs consider price growth rates, replacements of components, residual value and the discount rate over the calculation period (30 years):

Name of KPI	Unit 1	Unit 2
Cost KPIs		
Initial invest cost	€	€/m²
Energy costs	€/a	€/(m²*month)
Maintenance and operation cost	€/a	€/(m²*month)
Total annual cost excluding co-impacts	T€/a	€/(m²*month)
Total annual cost including co-impacts	T€/a	€/(m²*month)
Life-Cycle-Cost (LCC) excluding co-impacts	T€	-
Life-Cycle-Cost (LCC) including co-impacts	T€	-
Pay-Back-Period, compared to reference (nZEB)	y	-
Electricity generation cost by PV	€/MWh	-
Cost of saved emission of CO_2-equ. during operation	€/(tCO2-equivalent saved * y)	
Cost of saved emission of CO_2-equ. Including building constructio	€/(tCO2-equivalent saved * y)	
KPIs derived directly from input data to complete the overview of the variants		

Energy KPIs		
Energy demand values (input data)	MWh	kWh/(m²*y)
Energy generation values (from PV)	MWh	kWh/(m²*y)
Self-used rate of PV (input data)	%	-
Self-supply rate of PV (input data)	%	-
Environmental impact KPIs		
Primary energy demand values	GJ	MJ/m²
Yearly area related primary energy damand values	MJ/(m²*a)	-
CO_2-Emission equivalents (GWP)	t	kg/m²
Yearly area related CO_2-Emission equivalents (GWP)	kg/(m²*a)	-

By collecting project, cost, energy and environmental data in the tool, it is in principle possible to calculate further KPIs.

By integrating CO_2 pricing, the tool can also be used to investigate the impact of different CO_2 prices on life cycle costs. In this way, the tool is useful for policy makers working in the field of building legislation.

5 Conclusion

With the EXCEL tool, up to 5 variants can be compared in terms of life cycle costs (LCC). The results are clearly presented in the diagrams so that the variants can be compared at a glance. The structure of the cost input is so flexible that it can be updated during the planning process. In addition to the LCC KPIs, the tool also displays the energy demand KPIs.

The tool also offers the option of integrating the GWP data and the primary energy demand including embodied carbon, if the corresponding data is available. This gives the user a holistic overview of the economic and environmental impact of each variant and supports decision makers in choosing environmentally neutral solutions.

6 References

ISO 15686-5, 2017-07: Buildings and constructed assets — Service life planning — Part 5: Life-cycle costing.

EN 15459-1:2017: Energy performance of buildings – Economic evaluation procedure for energy systems in buildings – Part 1: Calculation procedures, Module M1-14.

VDI 2067, Part 1: Economic efficiency of building installations Fundamentals and economic calculation.

DIN 276:2018-12 Building costs