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DURABILITY AND/OR CHANGE?

«VADEMECUM» Master’s Thesis HS 22 Revision 06.06.2022

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HS 22

DURABILITY AND/OR CHANGE?

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«VADEMECUM»
LCA Data and Parameters

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Cover photo: ***Lower Saxony Sky*****, AK 2020**

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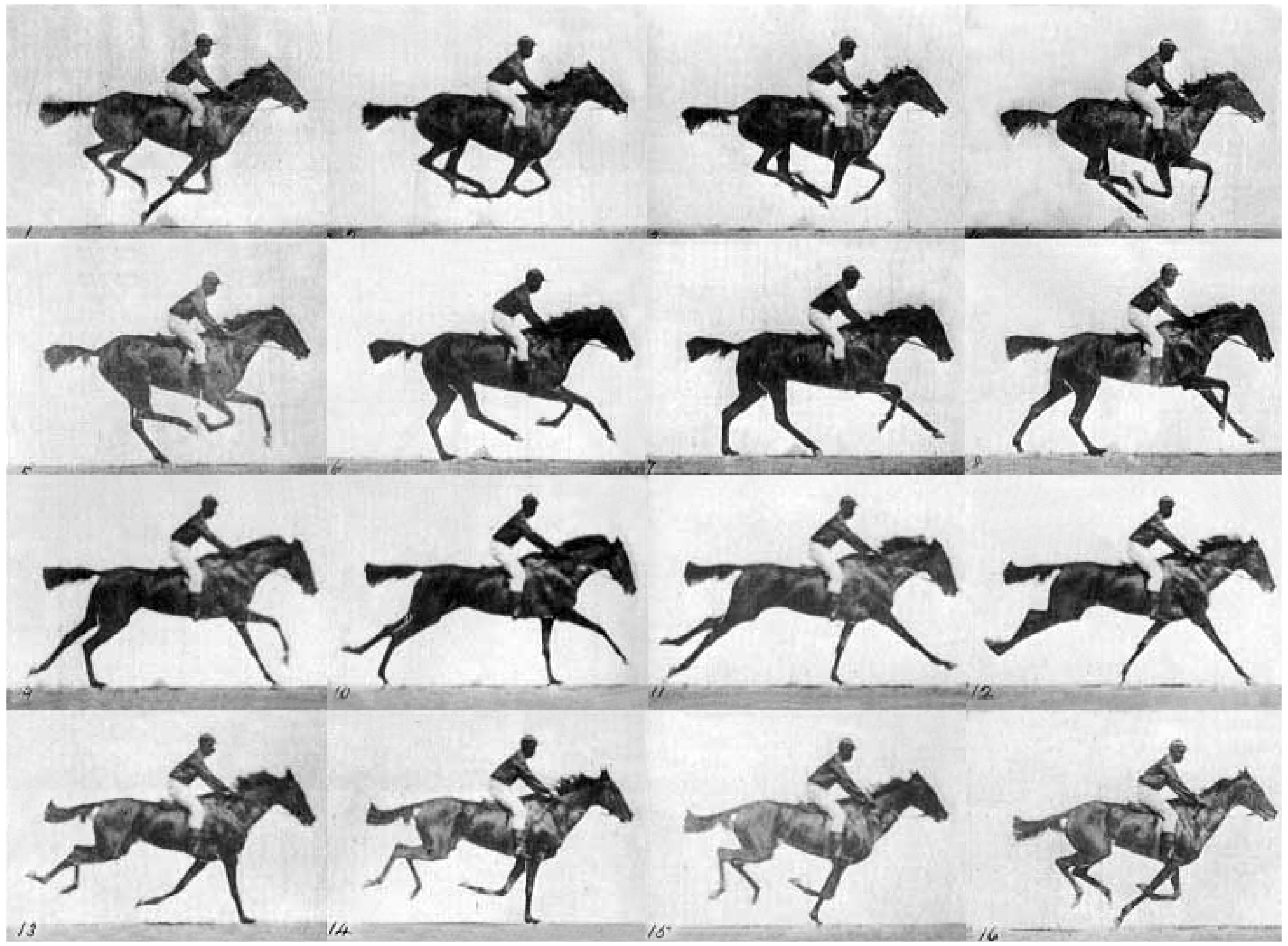
INTRODUCTION



Annie G. galloping, **photographic motion study by Eadweard Muybridge, 1878**

Preface

This "Vademecum" with data and tables serves as a supplement to the reader with background texts.

The intent is to convey a basic understanding of the physical environmental impact of construction, namely energy consumption and greenhouse gas emissions.

The "Vademecum" offers an introduction to the life cycle assessment of buildings and aims to encourage its application and broadening.

Examples of data questions

- **How do building materials differ in terms of embodied energy, embodied emissions and service life?**
- **How much energy do photovoltaic surfaces on the roof provide? How much on the facade?**
- **How can existing buildings be energetically upgraded with minimal use of resources?**
- **To what extent can building components serve as carbon storage?**

Energy

- **In the context of sustainable construction, the unit of measure for energy is most commonly kilowatt hour (kWh) = 3,6 Megajoule (MJ)**
- **Not to be confused with power: watt (W), kilowatt (kW) = 1000 W**

10 kWh of energy is released when burning approx. 1 m^3 of natural gas / 1 l of oil / 2 kg of wood.
The human body converts around 2 kWh of energy per day.
1 m^2 photovoltaic with good alignment and good efficiency supplies approx. 200 kWh per year.

Primary energy

- **Primary energy means the energy that is available with the naturally occurring forms of energy or energy carriers.**
- **The non-renewable portion of primary energy is ecologically significant.**
- **Unit of measure: kilowatt hour of oil equivalent (kWh oil-eq)**

Renewable primary energy comes from solar radiation (photovoltaic and solar thermal), hydroelectric power, wind power, biomass and geothermal energy.
Fossil fuels (hard coal, lignite, oil, natural gas) and nuclear fuels are non-renewable.

Greenhouse gas emissions

- **Greenhouse gas emissions include all climate-impacting gases in relation to the effect of carbon dioxide.**
- **Unit of measure: kilogram of CO_2 equivalent ($kg\ CO_2$-eq)**

The Swiss per capita emissions (incl. imports) is approx. 14 tons per year.
14 t of CO_2 corresponds to a volume of approx. 8,000 m³ (cube 20 × 20 × 20 m).
The global average per capita emissions are 4.8 t.
(Data of 2019. Source: www.globalcarbonatlas.org, accessed 10.03.2022)

Example: Energy carriers (siehe S. 26)

Environmental Parameters	Primary energy non-renewable	Greenhouse gas emissions
	kWh Öl-eq	$kg\ CO_2$-eq
Energy carriers (final energy)		
1 kWh natural gas ≙ approx. 0,1 m³	1.05	0.230
1 kWh oil ≙ approx. 0,1 liter	1.25	0.324
1 kWh electricity, CH consumer mix	2.08	0.125
1 kWh electricity, photovoltaics *	0.14	0.038

In words:
The combustion of 0.1 m³ of natural gas generates 1 kWh of final energy in the heating system. Together with upstream processes, transport, etc., the consumption of non-renewable primary energy adds up to 1.05 kWh oil eq., and a total of 230 g of greenhouse gases are emitted.
With Swiss grid power, transport and conversion losses lead to a primary energy consumption that is about twice as high per kWh of final energy at the wall socket (2.08 kWh oil-eq), but thanks to the comparatively low fossil share in electricity production, only 125 g CO_2-eq are incurred.
The environmental parameters of PV electricity are determined by the embodied energy and embodied emissions of the PV system; they are significantly lower than grid electricity.

Operational energy / emissions

Consumption of non-renewable primary energy or greenhouse gas emissions for the operation of a building: space heating/cooling, hot water, ventilation, electricity consumption for systems and devices (including building use)

Embodied energy / emissions

Consumption of non-renewable primary energy or greenhouse gas emissions for the construction and disposal of a building or components

Reference values for comparisons

- **Total/absolute**
  kWh Öl-eq — $kg\ CO_2$-eq
- **per area**
  kWh Öl-eq/m² — $kg\ CO_2$-eq/m²
- **per year**
  kWh Öl-eq/a — $kg\ CO_2$-eq/a
- **per area and year**
  kWh Öl-eq/(m²×a) — $kg\ CO_2$-eq/(m²×a)
- **per person, per housing unit, …**

Further definitions of terms

- «Vademecum» from p. 83
- Reader from p. 316

Why life cycle assessment?

- The efforts of “sustainable building” initially focused on reducing energy consumption in operation.
- The lower the operational energy consumption, the more embodied energy and embodied emissions come into focus.
  It turns out that in contemporary buildings they exceed those from operation.
- Life cycle assessment attempts a synopsis.

Definition

“Life Cycle Assessment (LCA) is a method for estimating the environmental impact of a product [or service]. It is based on an approach that takes into account the whole life cycle. This records and assesses the environmental impact of a product from the extraction of raw materials, the manufacture, and the use up to the disposal of the product, i.e. from the cradle to the grave.”

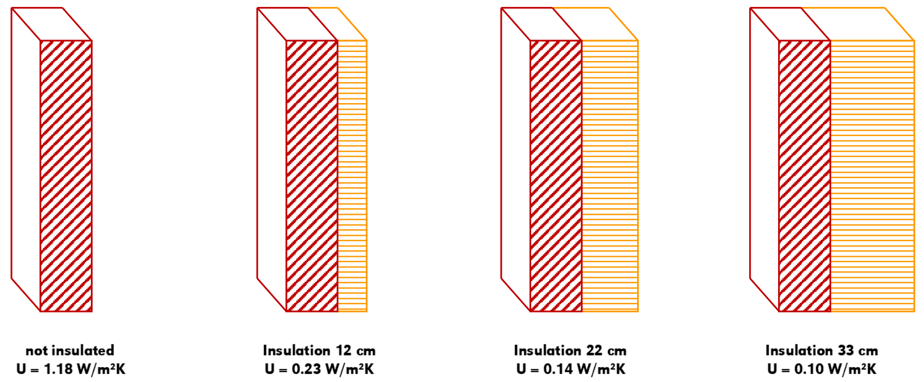
Rolf Frischknecht, Lehrbuch der Ökobilanzierung, Berlin 2020, p. 11 (trad. AK)

Example, life cycle assessment: 1 m² exterior wall in construction variants

Objective: assessment of environmental impacts

- depending on the insulation thickness (here: without / 12 cm / 22 cm / 33 cm)
- depending on the insulation material (here: exterior wall insulation with EPS or rock wool)
- depending on the heating energy source (here: natural gas or electricity for heat pump)

Brick 20 cm – 1 000 kg/m³, λ-value 0.30 W/(m×K)
Thermal insulation – 30 kg/m³ (EPS) or 93 kg/m³ (rock wool), λ-value 0.035 W/(m×K)

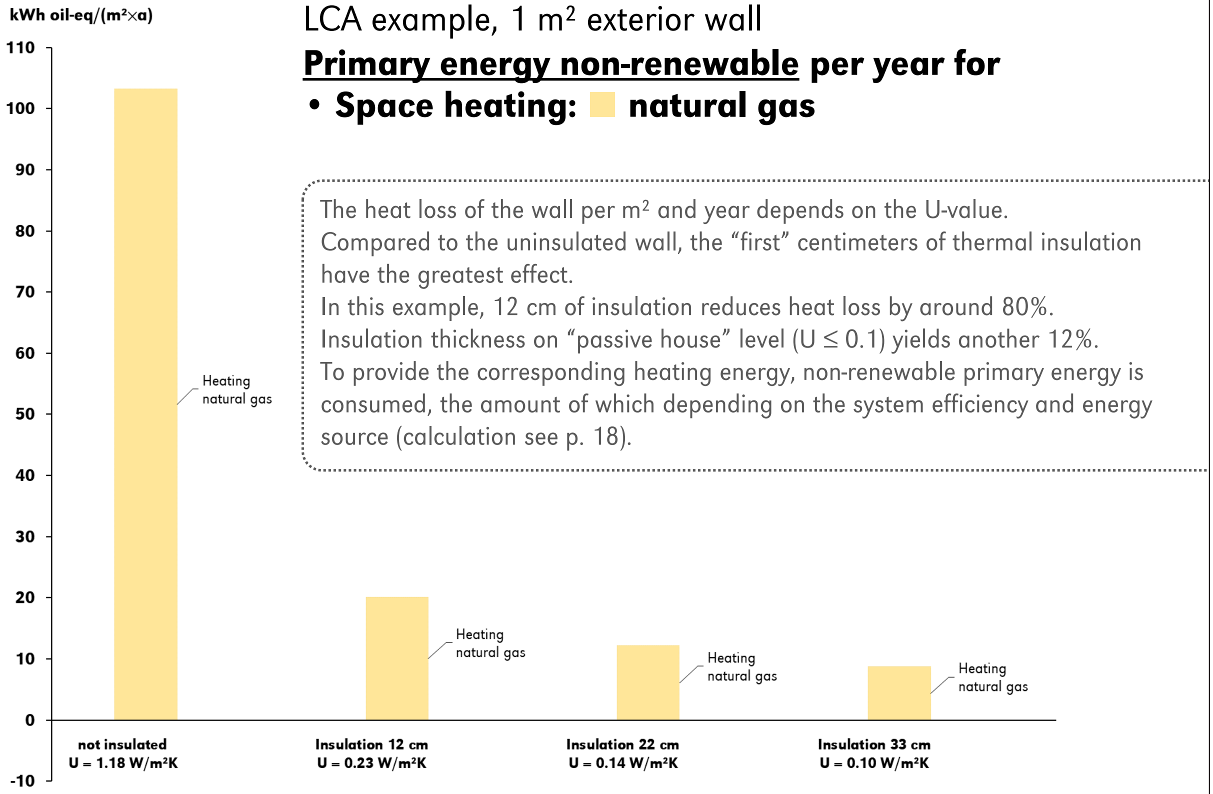


Context | Units and terminology | **Life cycle assessment** | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

LCA example, 1 m² exterior wall

Primary energy non-renewable per year for
- **Space heating: natural gas**

The heat loss of the wall per m² and year depends on the U-value.
Compared to the uninsulated wall, the “first” centimeters of thermal insulation have the greatest effect.
In this example, 12 cm of insulation reduces heat loss by around 80%.
Insulation thickness on “passive house” level (U ≤ 0.1) yields another 12%.
To provide the corresponding heating energy, non-renewable primary energy is consumed, the amount of which depending on the system efficiency and energy source (calculation see p. 18).

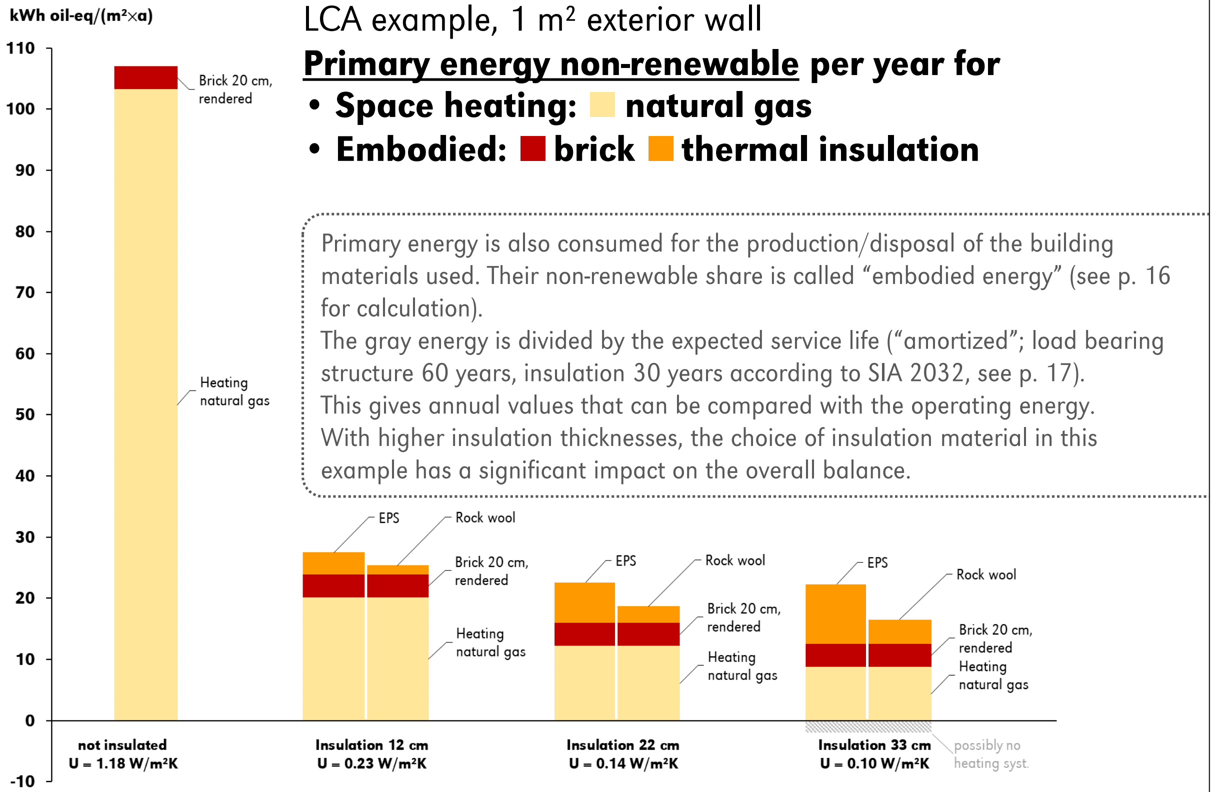


Context | Units and terminology | **Life cycle assessment** | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

LCA example, 1 m² exterior wall

Primary energy non-renewable per year for
- **Space heating: natural gas**
- **Embodied: brick thermal insulation**

Primary energy is also consumed for the production/disposal of the building materials used. Their non-renewable share is called “embodied energy” (see p. 16 for calculation).
The gray energy is divided by the expected service life (“amortized”; load bearing structure 60 years, insulation 30 years according to SIA 2032, see p. 17).
This gives annual values that can be compared with the operating energy.
With higher insulation thicknesses, the choice of insulation material in this example has a significant impact on the overall balance.

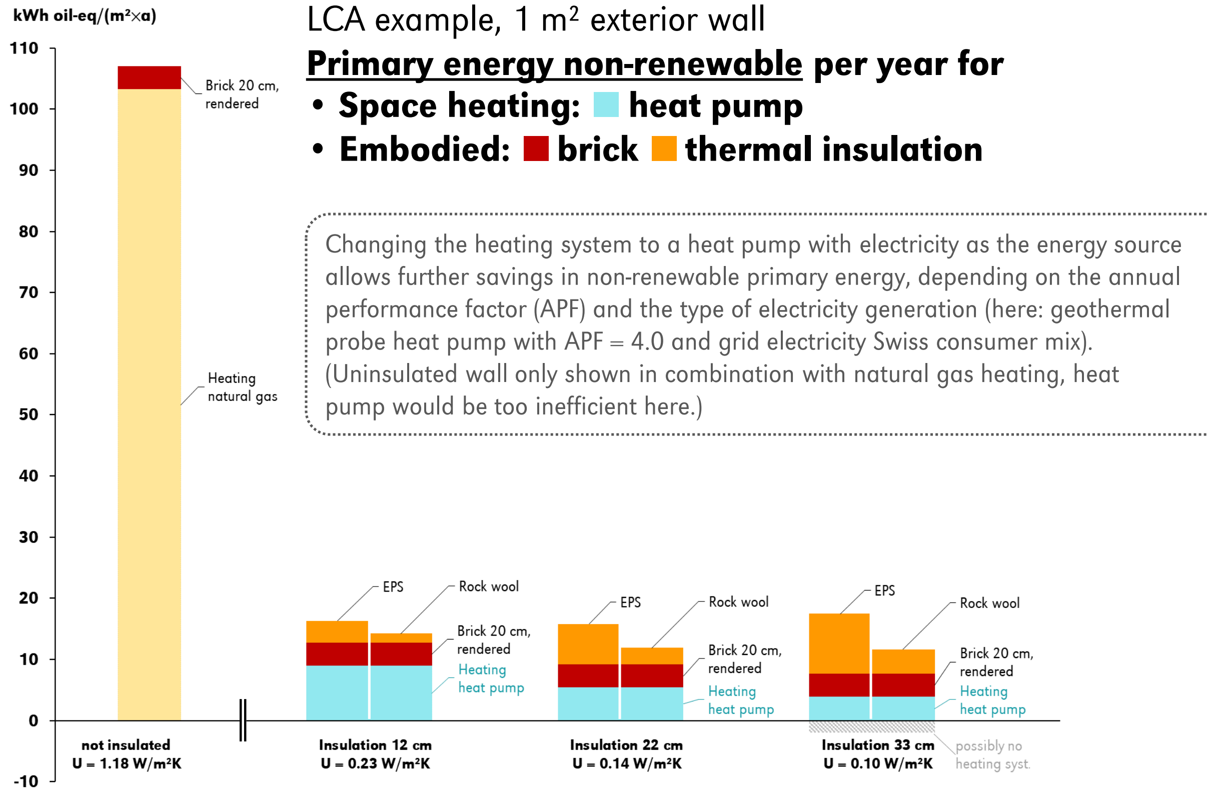


Context | Units and terminology | **Life cycle assessment** | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

LCA example, 1 m² exterior wall

Primary energy non-renewable per year for
- **Space heating: heat pump**
- **Embodied: brick thermal insulation**

Changing the heating system to a heat pump with electricity as the energy source allows further savings in non-renewable primary energy, depending on the annual performance factor (APF) and the type of electricity generation (here: geothermal probe heat pump with APF = 4.0 and grid electricity Swiss consumer mix).
(Uninsulated wall only shown in combination with natural gas heating, heat pump would be too inefficient here.)

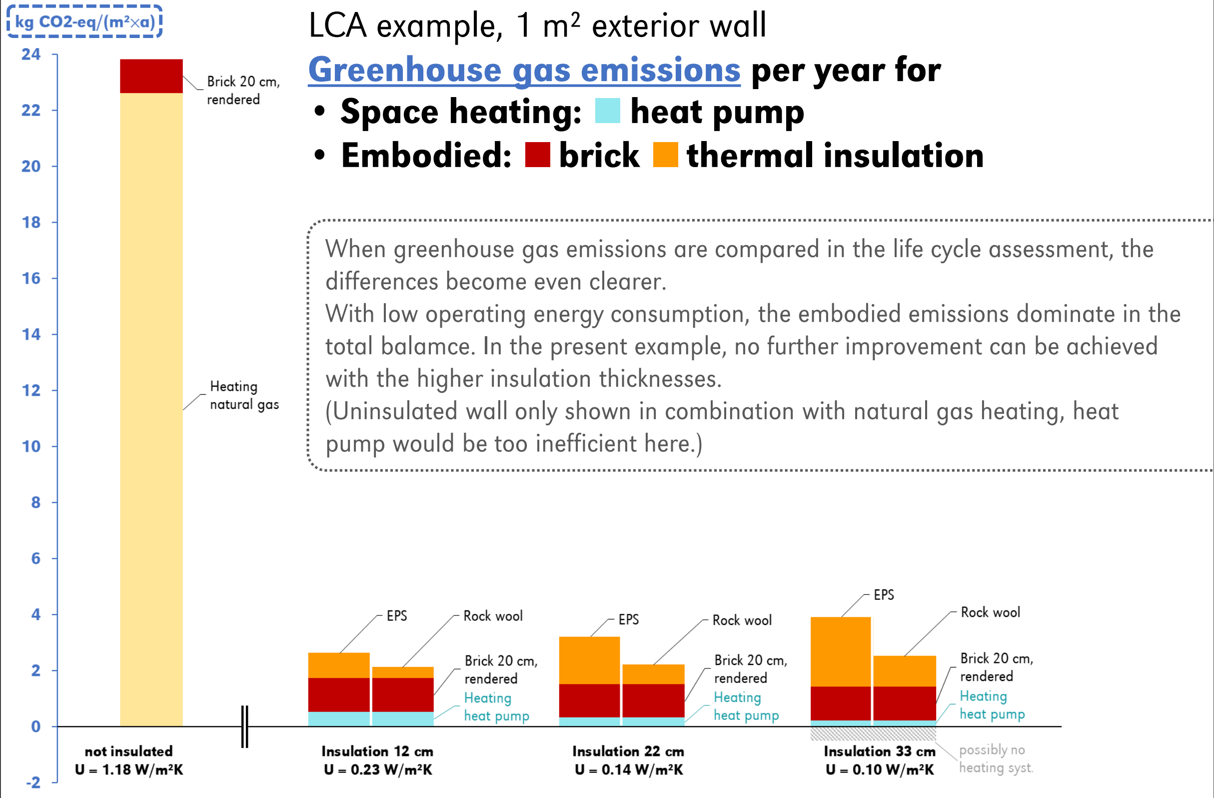


Context | Units and terminology | **Life cycle assessment** | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

LCA example, 1 m² exterior wall

Greenhouse gas emissions per year for
- **Space heating: heat pump**
- **Embodied: brick thermal insulation**

When greenhouse gas emissions are compared in the life cycle assessment, the differences become even clearer.
With low operating energy consumption, the embodied emissions dominate in the total balamce. In the present example, no further improvement can be achieved with the higher insulation thicknesses.
(Uninsulated wall only shown in combination with natural gas heating, heat pump would be too inefficient here.)



Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

LCA in the context of architecture/design

Life cycle considerations, even in the rough manner shown here, enable users to specify sustainable building concepts, by means of

- **data-based estimates,**
- **development and evaluation of variants,**
- **questioning of prejudices.**

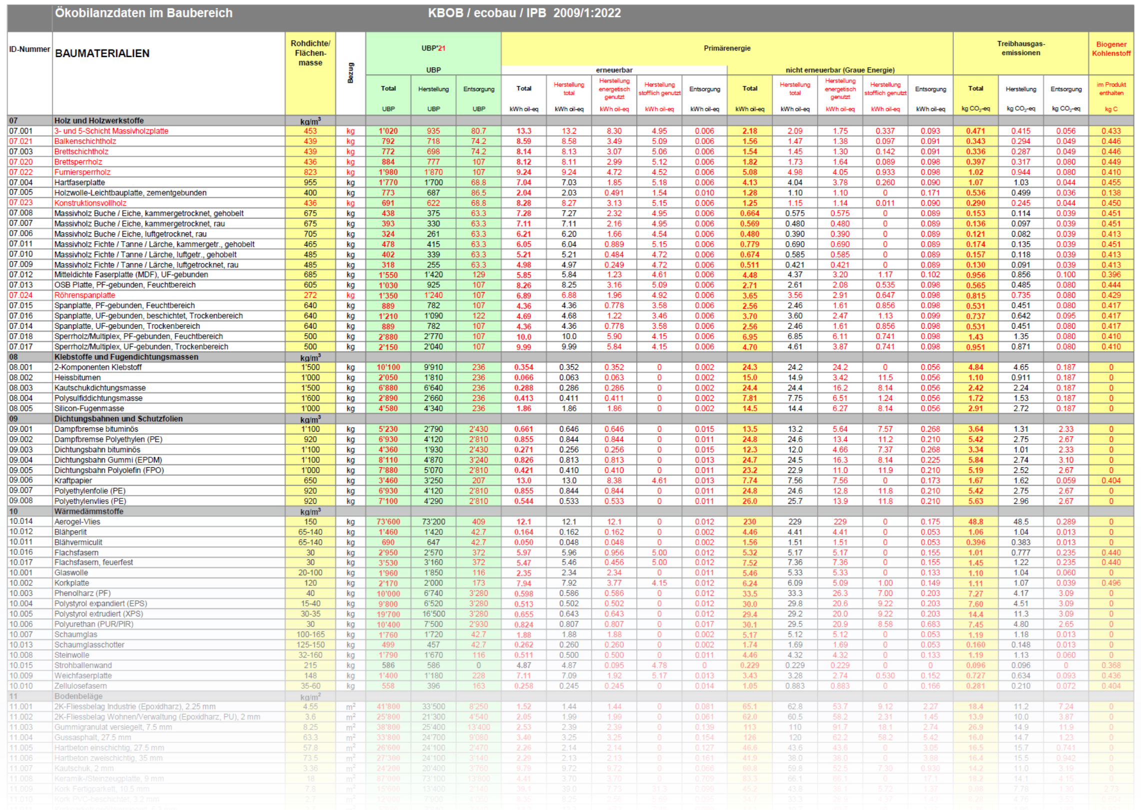
Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

Sources of LCA data

- **Research**
- **Manufacturer information**
  (Environmental Product Declaration, EPD)
- **Databases**
- **Switzerland: KBOB** (Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren)
  Tables "Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022"

An excerpt is included in this "Vademecum" p. 66–75
(Yellow highlighting by chair of Annette Gigon / Mike Guyer)

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.



Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

Comparisons …

LCA data in the KBOB tables are mostly based on the unit kilogram.

Editor's note: "Significant comparisons are only possible on the basis of the quantities of material required for a specific, equivalent use case. Comparisons based on 1 kg of different materials are misleading!"

LCA data of selected building materials, application-oriented (p. 28–31, excerpt)

Load-bearing construction, 1 m²						
Building material / part	**λ value**	**Density**	**Typical thickness**	**Weight**	**Primary energy non-renewable**	**Greenhouse gas emissions**
	W/(m×K)	**kg/m³**	**cm**	**kg/m²**	**kWh oil-eq**	**kg CO_2-eq**
Reinforced concrete wall	2.20	2 360	20	473	169	73
*Structural concrete (without reinforcement) **		*2 300*		*455*	*80*	*46*
Reinforcing steel, 90 kg per m³ (approx. 1 % Vol.)		*7 850*		*18*	*90*	*27*
Brick (Swissmodul)	0.30	1 000	20	200	158	53
Insulation brick (Porotherm T7)	0.07	575	49	282	258	80
Sand-lime brick	0.70	1 400	20	280	109	45
Aerated concrete block (Ytong ThermStrong)	0.10	500	20	100	86	43
Aerated concrete block (Ytong ThermUltra)	0.07	300	48	144	124	61
Natural limestone	1.40	2 500	20	500	170	37
Solid timber wall (glue laminated timber GLT)	0.13	439	20	88	135	30
Solid timber wall, spruce (unglued)	0.13	465	20	93	72	16

For a better understanding, common building materials were selected for the "Vademecum", and their environmental parameters were given for 1 m² component area with typical material thickness. In this way, approximate comparisons between materials are possible.

Calculation example:
from kg to m² component area (per rule of three)

Load-bearing construction, 1 m²						
Building material / part	**λ value**	**Density**	**Typical thickness**	**Weight**	**Primary energy non-renewable**	**Greenhouse gas emissions**
	W/(m×K)	**kg/m³**	**cm**	**kg/m²**	**kWh oil-eq**	**kg CO_2-eq**
Brick (Swissmodul)	0.30	1 000	20	200	158	53

Value from product data sheet (Swissmodul). 1 000 kg/m³

Choose based on requirement/availability. Here: 20 cm

Density times typical thickness (in meters). 1 000 kg/m³ × 0.20 m = 200 kg/m²

Per-kg-value from KBOB table times weight. 0.788 kWh oil-eq/kg × 200 kg = 158 kWh oil-eq

Per-kg-value from KBOB table times weight. 0.267 kg CO_2-eq/kg × 200 kg = 53 kg CO_2-eq

Ökobilanzdaten im Baubereich		KBOB / ecobau / IPB 2009/1													
ID-Nummer	BAUMATERIALIEN	Rohdichte/ Flächen-masse	Bezug	UBP'21			Primärenergie						Treibhausgas-emissionen		
				UBP			erneuerbar			nicht erneuerbar (Graue Energie)					
				Total	Herstellung	Entsorgung	Total	Herstellung	Entsorgung	Total	Herstellung	Entsorgung	Total	Herstellung	Entsorgung
				UBP	UBP	UBP	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq
02	Mauersteine	kg/m³													
02.001	Backstein	900	kg	372	329	42.7	0.080	0.078	0.002	0.788	0.735	0.053	0.267	0.254	0.013
02.002	Kalksandstein	1'400	kg	259	216	42.7	0.039	0.037	0.002	0.390	0.337	0.053	0.162	0.149	0.013
02.003	Leichtlehmstein	700	kg	354	311	42.7	0.793	0.790	0.002	0.764	0.712	0.053	0.180	0.167	0.013
02.004	Leichtzementstein, Blähton	1'200	kg	610	568	42.7	0.055	0.053	0.002	1.43	1.37	0.053	0.429	0.416	0.013

Exterior building components, approximate LCAs (p. 33–37, excerpt)

Exterior wall, insulated, 1 m²									
Construction	**Layers / energy**	**Service life**	**Useful energy**	**Primary energy non-renewable**			**Greenhouse gas emissions**		
			kWh	**kWh oil-eq**			**kg CO_2-eq**		
		years	**per year**	**total**	**per year**		**total**	**per year**	
Reinforced concrete wall with EPS insulation (U = 0,10 W/m²K)	Reinforced concrete 20 cm	60		169		2.8	73		1.2
	EPS 35 cm	30		315		10.5	80		2.7
	Exterior rendering	30		34		1.1	9		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**23.2**	**18.4**		**6.1**	**4.4**
Brick wall with rock wool insulation (U = 0,10 W/m²K)	Brick Swissmodul 20 cm	60		158		2.6	53		0.9
	Rock wool 35 cm	30		121		4.0	33		1.1
	Exterior rendering	30		34		1.1	9		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**16.6**	**11.7**		**4.2**	**2.5**

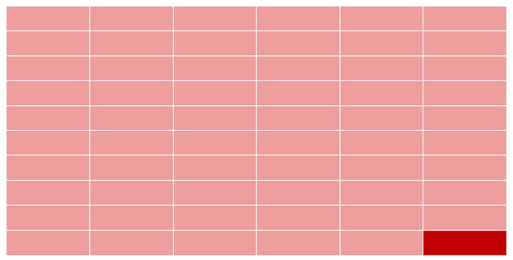
As in the example shown before, the environmental impacts for the production/disposal of the component and for the heating operation (in the variants natural gas and heat pump variants) are added together. The embodied energy/emissions are amortized over the service life.

Calculation example:
From total values to per-year values

Converting embodied energy or embodied emissions into per-year values:

Amortization, i.e. total value divided by assumed service life according to SIA 2032.

Example: 1 m² brick, 20 cm, primary energy non-renewable



Embodied energy total: 158 kWh oil-eq

divided by 60 years (a)

gives 2.6 kWh oil-eq/a

Note: The gradual amortization is fictitious; in truth, the environmental impact of construction occurs in the first year (manufacture) or last year (disposal) of its lifespan. In addition, it is assumed that the component is not destroyed before the end of its service life.

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

Calculation example: Environmental impacts of heating operation

Heating system, calculation parameters

Type	Reference / Final energy carrier	Efficiency	Primary energy non-renewable	Greenhouse gas emissions
Natural gas heating (condensing boiler)	1 kWh natural gas (HHV) ≙ ca. 0,1 m³	Boiler efficiency 0.9	1.05 kWh oil-eq	0.230 kg CO2-eq
Brine/water heat pump with borehole heat exchanger(s)	1 kWh electricity CH consumer mix	Annual perf. factor 4.0	2.08 kWh oil-eq	0.125 kg CO2-eq

Heating degree days, Zurich Fluntern average 2011–2020: 3 125 (K×d)/a

1. Estimate (rough) of annual useful energy required for heating :
useful energy ≈ heat losses per heating period: heating degree days × U-value × 24 h/d ÷ 1000

Example: component with U-value 0.10, location Zurich Fluntern
3 125 (K×d)/a × 0.10 W/(m²×K) × 24 h/d ÷ 1000 = 7.5 kWh/(m²×a)

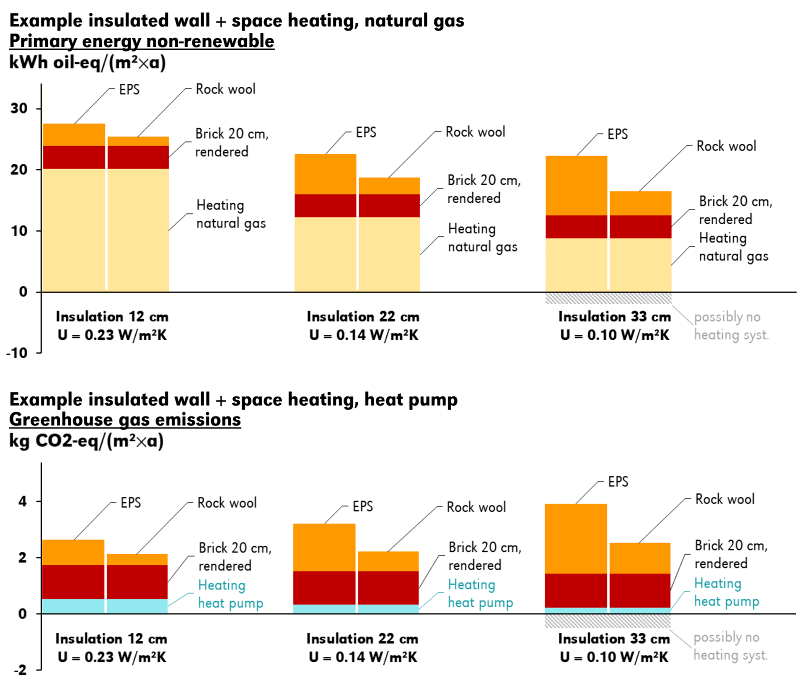
2. Calculation of final energy consumption:
useful energy ÷ efficiency of the heating system = final energy

3. Calculation of the environmental impacts
final energy × env. parameters of the energy carrier = env. impacts of heating operation

Example with heat pump:
7.5 kWh/(m²×a) ÷ 4.0 × 2.08 kWh oil-eq/kWh = 3.9 kWh oil-eq/(m²×a)
7.5 kWh/(m²×a) ÷ 4.0 × 0.125 kg CO_2-eq/kWh = 0.23 kg CO_2-eq/(m²×a)

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.

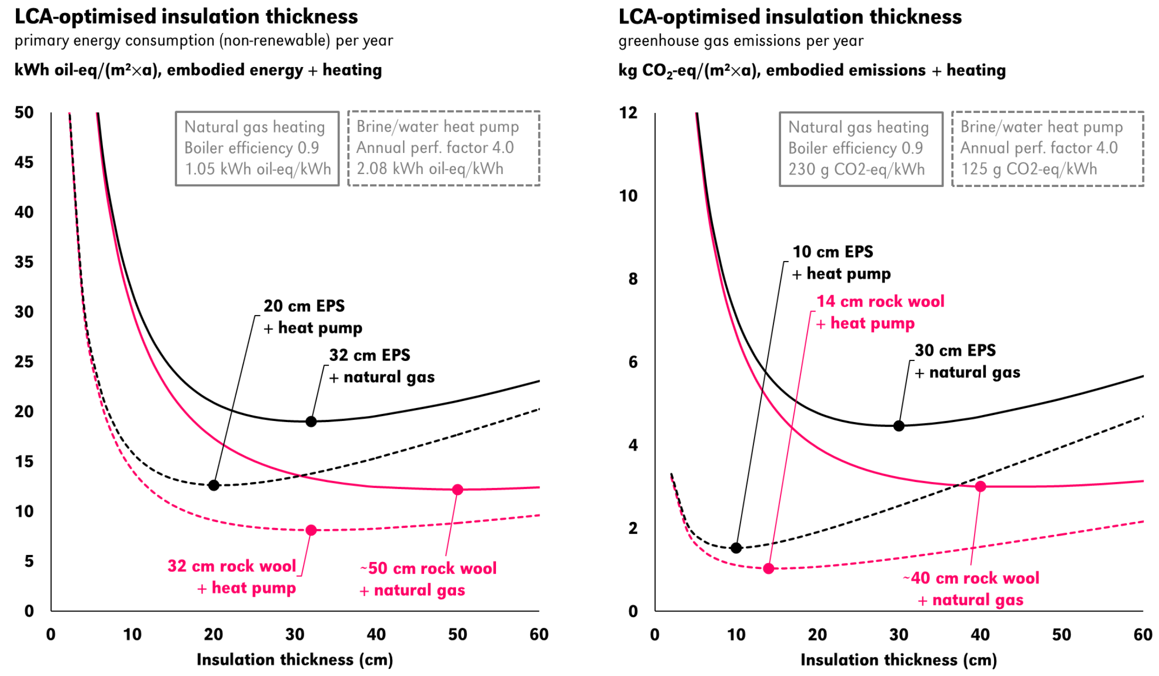
Insulation thickness: Where is the “sweet spot”?



The example of the life cycle analysis shows: for every insulating material there is a point after which the additional material expenses outweigh the extra savings in heating operation – depending on the energy source.

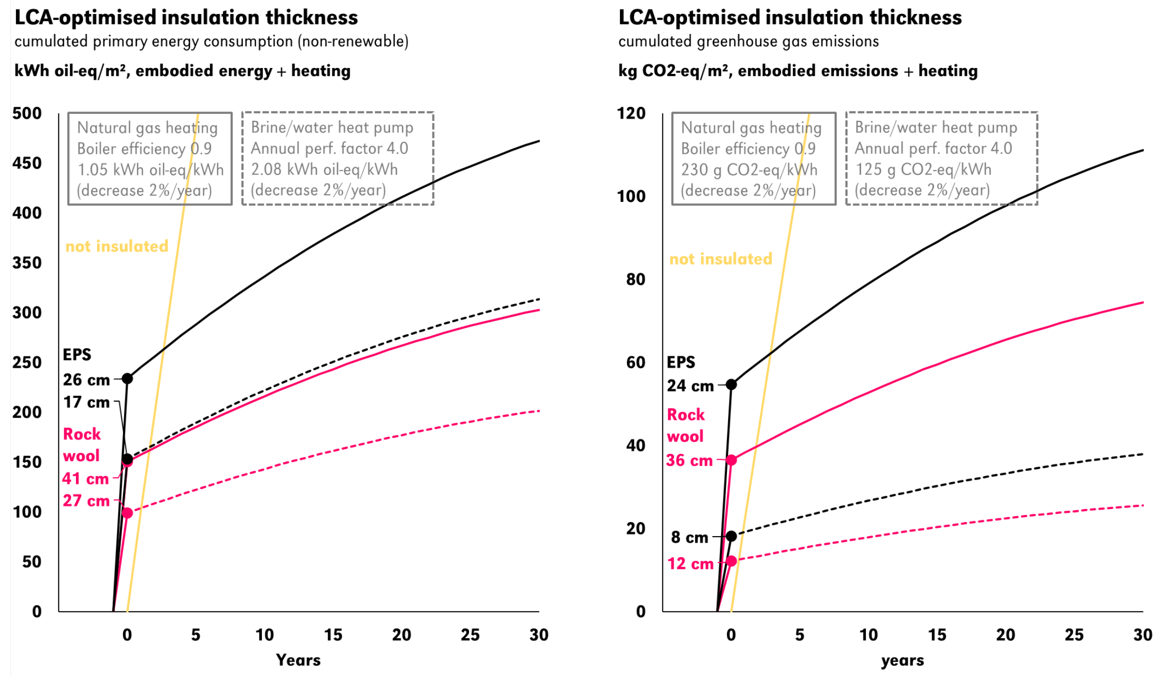
Optimization towards the lowest primary energy consumption or greenhouse gas emissions is possible, see also the following graphs and p. 38-41.

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.



Such an isolated, component-focused consideration is useful for estimates, but should be placed in the context of further optimization approaches: sufficiency, mobility, compactness, orientation, window area, etc. may influence the ecological footprint more than the choice of material!

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | Tools, links, etc.



Here is another, dynamic way of looking at it: cumulative environmental impacts over 30 years. Obviously, the initial “spike” of embodied energy or embodied emissions dominates the balance if the operational energy consumption is reduced and increasingly covered by renewable sources.

Load bearing components, approximate LCAs
(p. 44–47, excerpt)

Pillar/support/post h = 3 m, version 1, per unit

Type / dimensions	Components / material	Weight	Service life	Primary energy non-renewable (kWh oil-eq)		Greenhouse gas emissions (kg CO_2-eq)	
		kg	years	total	per year	total	per year
Concrete 20 x 20 cm	Concrete C30/37	276.0	60	48	0.8	28	0.5
	Reinforcement B500B 4 x ⌀ 20	41.5	60	207	3.5	63	1.1
	Stirrups B500B	6.0	60	30	0.5	9	0.2
	total	**323.5**	–	**285**	**4.8**	**100**	**1.7**
Timber round ⌀ 32 cm	Timber C24 (unglued)	**112.2**	60	**87**	**1.5**	**20**	**0.3**
Timber rectangular 20 x 36 cm	Glue laminated timber GL24h	**94.8**	60	**146**	**2.4**	**32**	**0.5**

If the material and dimensions of a component are known, the environmental parameters can be determined from the life cycle assessment data and compared in variants. In the “Vademecum” this is exemplified by means of columns and ceilings in common types of construction.
The examples show that a closer look is worthwhile:
Wood generally performs better than reinforced concrete in the LCA, especially unglued wood. However, wood cannot replace reinforced concrete everywhere.

Carbon storage in building materials
(S. 48–49, excerpt)

Biogenic building materials, temporary storage, 1 m²

Building material	Density	Carbon content	Typical thickness	Weight	Embodied emissions	Carbon content	≙ Carbon-dioxide
	kg/m³	kg C/kg	cm	kg	kg CO_2-eq	kg C	kg CO_2
Solid timber beech / oak, kiln-dried	675	0.451	20	135	21	61	**223**
Solid timber spruce / fir / larch, kiln-dried	465	0.451	20	93	16	42	**154**
Cellulose (loose-fill)	50	0.404	20	10	3	4	**15**
Wood-fibre insulation board (behind cladding / in cavity)	115	0.436	20	23	17	10	**37**
Hemp-lime brick (Schönthaler)	300	0.150	20	60	22	9	**33**
Straw (BauStroh)	115	0.368	35	40	4	15	**54**

Biogenic building materials (wood, straw, etc.) bind considerable amounts of carbon during plant growth (included in the KBOB LCA data since March 2022). Depending on the material, the corresponding amount of CO_2 that is removed from the atmosphere can significantly exceed the embodied emissions. But: At the end of a component’s service life, the stored carbon is released again when the material rots or is burned.
When carbon (C) combines with oxygen (O) to form CO_2, the weight multiplies by a factor of 3.67.
Example: 40 kg of straw consists of 37% carbon, i.e. 15 kg of C. Converted into carbon dioxide, this corresponds to 54 kg of CO_2.

Biogenic building materials, CO_2 sink effect within a time frame <100 years, 1 m²

Building material	Density	Carbon content	Typical thickness	Weight	Embodied emissions	CO2 sink effect	Net result
	kg/m³	kg C/kg	cm	kg	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq
Solid timber (hardwood), supporting structure	640	0.491	20	128	10	-28	**-18**
Bamboo (Glue Laminated Bamboo GLB)	636	0.518	20	127	98	-117	**-19**
Straw insulation	95	0.409	35	33	5	-24	**-19**

In the Swiss practice of life cycle assessment, biogenic carbon is usually treated as a “transit item”, i.e. there are no credits for carbon storage, nor are the emissions from disposal (e.g. combustion in a biomass power plant) accounted for. However, a quantification of the delayed climate impact is currently being discussed: Within a limited time frame (<100 years) and with a sufficiently long storage period (here ~60 years), a reduction in the CO_2 footprint can be calculated – a useful time gain on the path to climate neutrality. The effect is particularly pronounced in the case of fast-growing plant building materials. (If they are used for thermal insulation, they also have the additional benefit of lower operational emissions. So the following applies to biogenic insulation materials: the thicker, the better!)

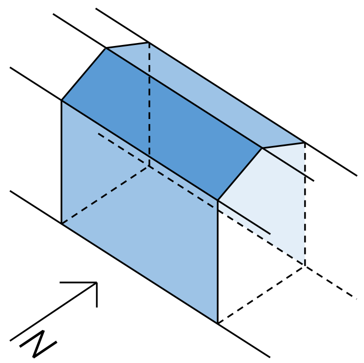
Example 33 kg straw insulation: The sum of embodied emissions (5 kg CO_2-eq) plus CO_2 sink effect (-24 kg CO_2-eq) results in net negative emissions of -19 kg CO_2-eq.
(Note: The data are from the study "Material Diets for Climate-Neutral Construction" by Olga Beatrice Carcassi, Guillaume Habert et al. (2022). They are not readily compatible with the KBOB/SIA data.)

Example, life cycle assessment: Photovoltaics and solar thermal energy on a building

Given: an apartment building, heated with a geothermal heat pump.
Electricity requirement for space heating, hot water and residential use 24 000 kWh/year.
Available for a possible use of solar energy:
100 m² on each roof surface, inclined 37° south / north
50 m² on each facade surface south / north

Assessment:

- Possible yields of electricity from photovoltaics
- Solar coverage of the electricity demand
- Environmental impact of PV electricity vs. grid electricity
  … *“does a PV system make sense here?”*
- Environmental impact of solar thermal energy vs. heat pump operated with PV electricity
  … *“does a solar thermal system make sense here?”*



Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | **Photovoltaic, solar thermal** | Tools, links, etc.

LCA example, PV and solar thermal energy
Photovoltaics, energy yields (p. 54–55, excerpt)

Absolute yields in kWh/(m²×a)										
Cell type	**Placement**	**kWh/(m²×a), for different orientations** (degradation included)								
		hori-zontal	**0° south**	**45°**	**90° west**	**135°**	**180° north**	**-135°**	**-90° east**	**-45°**
Silicon, monocrystalline	Roof, horizontal	186	–	–	–	–	–	–	–	–
	Roof, inclined	–	219	208	175	133	113	131	171	204
	Facade	–	154	145	109	63	39	62	105	140

Yield of roof inclined south: 100 m² × 219 kWh/(m²×a) = 21 900 kWh/a
Yield of roof inclined north: 100 m² × 113 kWh/(m²×a) = 11 300 kWh/a
Yield of south facade: 50 m² × 154 kWh/(m²×a) = 7 700 kWh/a
Yield of north facade: 50 m² × 39 kWh/(m²×a) = 1 950 kWh/a
Yield total: 42 850 kWh/a
Solar coverage: yield 42 850 kWh/a ÷ requirement 24 000 kWh/a = 179 %

If all available surfaces are used in the example, the photovoltaic system produces significantly more energy than the building consumes in a year (shading is not taken into account).
However, the majority of the electricity is generated in the summer, so that electricity from the grid is also needed in the winter months.

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | **Photovoltaic, solar thermal** | Tools, links, etc.

LCA example, PV and solar thermal energy
Comparison: PV vs. Swiss grid electricity (p. 56, excerpt)

Environmental parameters for self-produced PV electricity (worse than / equal to / better than benchmark)																			
Cell type	**Placement**	**Primary energy non-renewable** kWh oil-eq/kWh, for different orientations									**Greehouse gas emissions** g CO_2-eq/kWh, for different orientations								
		hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°	hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Silicon, monocrystalline	Roof, horizontal	0.18	–	–	–	–	–	–	–	–	51	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.14	0.15	0.17	0.23	0.27	0.23	0.18	0.15	–	38	40	48	63	75	64	49	41
	Facade	–	0.24	0.26	0.34	0.59	0.97	0.60	0.35	0.27	–	66	70	94	162	265	166	97	73
Benchmark 1 kWh final energy, grid electricity from Swiss consumer mix		2.08									125								

The environmental parameters of the PV electricity result from the embodied energy and embodied emissions of the system (p. 53) allocated to the kWh produced.

Only on the north facade, the PV electricity in the example has poorer values than Swiss grid electricity. If this part of the system is left out, the degree of coverage is still 170%.

Note: The high proportion of hydroelectric and nuclear power in Swiss electricity production results in low emissions of greenhouse gases by international standards. Since it makes sense to first replace fossil-based (imported) electricity with PV electricity, PV surfaces with a less favorable (north) orientation are also justifiable.

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | **Photovoltaic, solar thermal** | Tools, links, etc.

LCA example, PV and solar thermal energy
Comparison: Solar thermal vs. heat pump + PV (p. 63, excerpt)

Environmental parameters for useful heat from solar thermal energy (worse than / equal to / better than benchmark)																			
Collector type and application	**Placement**	**Primary energy non-renewable** kWh oil-eq/kWh, for different orientations									**Greehouse gas emissions** g CO2-eq/kWh, for different orientations								
		hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°	hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Flat-plate collector for hot water, MFH	Roof, horizontal	0.07	–	–	–	–	–	–	–	–	17	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.04	0.05	0.06	0.10	0.13	0.10	0.07	0.05	–	11	11	16	25	33	26	17	12
	Facade	–	0.07	0.07	0.10	0.15	0.20	0.16	0.12	0.08	–	17	18	26	37	50	41	29	20
Benchmark hot water / space heating and hot water heat pump with PV electricity		variable									variable								

Similarly, the environmental parameters of solar thermal energy are determined by allocating the embodied energy and emissions of the system (p. 59) to the kWh produced.

These can be compared with the parameters of a system which combines photovoltaics and heat pump. In the example, all of the examined surfaces would be suitable for the production of hot water from solar thermal energy, the south-facing roof being the best.

For hot water, the heat pump operates with an annual performance factor (APF) of approx. 2.0.
Calculation example roof inclined south, useful energy for hot water (approx.):
Greenhouse gas emissions of PV electricity 38 g CO_2-eq/kWh ÷ APF 2.0 = 19 g CO_2-eq/kWh.
So the value of the solar thermal system, 11 g CO_2-eq/kWh, is better in comparison.

Context | Units and terminology | Life cycle assessment | LCA data | Building materials and components | Photovoltaic, solar thermal | **Tools, links, etc.**

Tools, Links, etc.

At the end of the booklet there are links to other planning tools that can be used depending on the project requirements (p. 77-81).

Neither the list of tools nor the data tables in the “Vademecum” are conclusive. They are intended to form a basis for further learning about the topic of life cycle assessment and including it in the planning process from the start.

DATA COMPILATION
BUILDING PARTS
BUILDING ELEMENTS

Charles-Édouard Jeanneret on the Acropolis, near a collapsed column at the Parthenon, September 1911
Photo: August Klipstein ©FLC/ADAGP

Comparison Values / "Yardsticks"

The dimensions of energy and gases are literally hard to grasp. The following collection is intended to give an idea of the relevant orders of magnitude. (Without any claim to completeness, but with the suggestion to add your own comparison values to the list!)

Yearly greenhouse gas emissions, total

Frame of reference	CO_2-eq/a
worldwide (2018)	48. 9 bil. t
worldwide, per capita (2018, population 7.59 bil.)	6.4 t
Switzerland, domestic (2018)	46. 4 mil. t
Switzerland, domestic, per capita (2018, population 8.48 mil.)	5.5 t
Switzerland, per capita, including GHG emissions abroad	11.5–14 t
Switzerland, building sector (2018, 24%)	11.1 mil. t

Data: https://www.climatewatchdata.org/ (acc. 03-2022), https://www.bafu.admin.ch/ (acc. 04-2021)

Energy consumption in buildings, Switzerland (2.3 mil.*)

Usage	Final energy	Share
	bil. kWh/a	%
Space heating	62.0	30.1
Hot water	12.7	6.1
Ventilation, air conditioning, building services	5.8	2.8
Lighting	5.2	2.5
Buildings, total	85.6	41.6
Switzerland, domestic, total consumption	206.0	100.0

* 1.8 mil. buildings with residential use
Data: as of 2019, Bundesamt für Energie BFE / Prognos TEP 2020 / Bundesamt für Statistik BFE 2020

Electricity consumption of households, Switzerland (3.7 mil.)

Average consumption (inkl. "outliers")	approx. 5'000 kWh/a
Typical consumption, 2-person household MFH	2'190 kWh/a (± 1 person: 460 kWh)
Typical consumption, 4-person household SFH	4'050 kWh/a (± 1 person: 590 kWh)

Ohne Wärmepumpen, E-Autos. Data: https://pubdb.bfe.admin.ch/de/publication/download/10559

Environmental Parameters

	Primary energy non-renewable	Greenhouse gas emissions
	kWh Öl-eq	kg CO_2-eq
Energy carriers (final energy)		
1 kWh natural gas ≙ approx. 0,1 m³	1.05	0.230
1 kWh oil ≙ approx. 0,1 liter	1.25	0.324
1 kWh electricity, CH consumer mix	2.08	0.125
1 kWh electricity, photovoltaics *	0.14	0.038
Mobility (pkm = passenger kilometers)		
10.000 pkm air travel **	5 330	2 830
10.000 pkm in car, petrol	8 700	2 120
10.000 pkm in car, electricity, CH-Mix	6 400	928
10.000 pkm in car, electricity, renewables	3 850	791
10.000 pkm in coach/bus	2 500	612
10.000 pkm in tram	3 950	432
10.000 pkm in local train	598	91
10.000 pkm in long-distance train	441	74
Transports (tkm = ton kilometers)		
100 tkm freight transport by sea-going vessel	2.9	0.74
100 tkm freight transport by train	5.4	1.23
100 tkm freight transport by lorry, average	60.4	14.4

Note: The high proportion of hydroelectric and nuclear power in Swiss electricity production leads to comparatively low emissions of greenhouse gases; E.g. Germany approx. 0.4 kg CO_2-eq per kWh electricity.
* Silicon monocrystalline, efficiency 20%, optimal orientation towards the sun (own calculation)
** incl. climate effects from contrails, ozone formation
*** CH consumer mix
Data: KBOB Ökobilanzdaten 2009/1:2022

Requirements according to SIA 2040:2017 Effizienzpfad Energie (extracts)

Based on the objectives of the "2000-Watt Society", the document SIA 2040 defines guideline and target values for various types of new and renovated buildings.
Buildings that comply with the target values and the additional requirements are considered compatible with the SIA Effizienzpfad; it is possible to deviate from the individual guideline values. The values are defined in relation to the energy reference area (EBF). Note: SIA 2040 is currently being revised and will probably be reissued with stricter target values.

Requirements: values per m² EBF, per year

	Primary energy non-renewable	Greenhouse gas emissions
	kWh Öl-eq new / renovat.	kg CO_2-eq new / renovat.
Residential (60 m² EBF / person)		
Guiding values, embodied	*30 / 20*	*9 / 5*
Guiding values, operational	*60 / 70*	*3 / 5*
Guiding values, mobility	*30 / 30*	*4 / 4*
Target values (= embod. + operat. + mob.)	120 / 120	16 / 14
Additional requirements (= embod. + operat.)	90 / 90	12 / 10
Residential, regulated occupancy (45 m² EBF / person)		
Guiding values, embodied	*30 / 20*	*9 / 5*
Guiding values, operational	*90 / 100*	*6 / 8*
Guiding values, mobility	*40 / 40*	*6 / 6*
Target values (= embod. + operat. + mob.)	160 / 160	21 / 19
Additional requirements (= embod. + operat.)	120 / 120	15 / 13
Administration, office		
Guiding values, embodied	*40 / 20*	*9 / 6*
Guiding values, operational	*80 / 100*	*4 / 6*
Guiding values, mobility	*40 / 40*	*7 / 7*
Target values (= embod. + operat. + mob.)	160 / 160	20 / 19
Additional requirements (= embod. + operat.)	120 / 120	13 / 12

Requirements: values per m² EBF, per year

	Primary energy non-renewable	Greenhouse gas emissions
	kWh Öl-eq new / renovat.	kg CO_2-eq new / renovat.
School		
Guiding values, embodied	*30 / 20*	*9 / 6*
Guiding values, operational	*50 / 60*	*2 / 4*
Guiding values, mobility	*20 / 20*	*3 / 3*
Target values (= embod. + operat. + mob.)	100 / 100	14 / 13
Additional requirements (= embod. + operat.)	80 / 80	11 / 10
Specialised store		
Guiding values, embodied	*40 / 20*	*9 / 6*
Guiding values, operational	*130 / 150*	*6 / 7*
Guiding values, mobility	*30 / 30*	*6 / 6*
Target values (= embod. + operat. + mob.)	200 / 200	21 / 19
Additional requirements (= embod. + operat.)	170 / 170	15 / 13
Restaurant		
Guiding values, embodied	*40 / 20*	*9 / 5*
Guiding values, operational	*200 / 220*	*10 / 12*
Guiding values, mobility	*140 / 140*	*24 / 24*
Target values (= embod. + operat. + mob.)	380 / 380	43 / 41
Additional requirements (= embod. + operat.)	240 / 240	19 / 17

EBF = Energy reference area (Energiebezugsfläche), i.e. heated and/or cooled gross floor area within the thermal building envelope.
Determination of energy and emissions parameters: embodied SIA 2032, operational SIA 380 (etc.), mobiliy SIA 2039.
For the preliminary studies / project phases, a calculation aid SIA 2040 (Excel tool) can be obtained from the SIA at www.energytools.ch.

LCA data of selected building materials, application-oriented

Embodied energy, i.e. non-renewable primary energy, and embodied greenhouse gas emissions for production and disposal of various materials can be found in the KBOB tables "Ökobilanzdaten im Baubereich". These also form the basis for most of the data listed below.
However, the KBOB data is not immediately applicable in planning and design because it is usually given per kg.
A conversion into 1 m² component area is given below for a selection of common building materials, based on a typical layer thickness.
Some materials not included in the KBOB list have been supplemented using environmental product declarations (EPDs).

Load-bearing construction, 1 m²

Building material / part	λ value	Density	Typical thickness	Weight	Primary energy non-renewable	Greenhouse gas emissions
	W/(m×K)	kg/m³	cm	kg/m²	kWh oil-eq	kg CO_2-eq
Reinforced concrete wall	2.20	2 360	20	473	169	73
*Structural concrete (without reinforcement) **		*2 300*		*455*	*80*	*46*
Reinforcing steel, 90 kg per m³ (approx. 1 % Vol.)		*7 850*		*18*	*90*	*27*
Brick (Swissmodul)	0.30	1 000	20	200	158	53
Insulation brick (Porotherm T7)	0.07	575	49	282	258	80
Sand-lime brick	0.70	1 400	20	280	109	45
Aerated concrete block (Ytong ThermStrong)	0.10	500	20	100	86	43
Aerated concrete block (Ytong ThermUltra)	0.07	300	48	144	124	61
Natural limestone	1.40	2 500	20	500	170	37
Solid timber wall (glue laminated timber GLT)	0.13	439	20	88	135	30
Solid timber wall, spruce (unglued)	0.13	465	20	93	72	16

* Average values for concrete from Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022. Specific values can be determined with the concrete type calculator: https://treeze.ch/fileadmin/user_upload/calculators/Betonsortenrechner_Planer_DE/Betonsortenrechner_Planer.htm
Example 1 m² reinforced concrete wall with portland cement (CEM I): 77 kg CO_2-eq (incl. reinforcing steel)
Example 1 m² reinforced concrete wall with blast furnace slag cement (CEM III/B): 52 kg CO_2-eq (incl. reinforcing steel)
Assumption for masonry walls: flat blocks, mortar is neglected in calculations.

Insulation, 1 m²

Building material / part	λ value	Density	Typical thickness	Weight	Primary energy non-renewable	Greenhouse gas emissions
	W/(m×K)	kg/m³	cm	kg/m²	kWh oil-eq	kg CO_2-eq
Rock wool (Flumroc, external wall insulation)	0.035	93	20	18.6	73	20
Glass wool (Isover, behind cladding / in cavity)	0.035	30	20	6.0	31	6
Foam glass	0.040	115	20	23.0	119	27
Mineral insulation board (Multipor)	0.045	115	20	23.0	71	21
Mineral insulation board (calcium silicate)	0.060	185	8	14.8	375	117
EPS expanded polystyrol	0.035	30	20	6.0	180	46
XPS extruded polystyrol	0.035	35	20	7.0	206	101
PUR/PIR polyurethane	0.026	30	20	6.0	181	45
VIP vacuum insulation panels (ZZ Vacucomp/Vacuspeed)	0.007	175	4	7.0	338	67
Cellulose (loose-fill)	0.040	50	20	10.0	11	3
Wood-fibre insulation board (behind cladding / in cavity)	0.040	115	20	23.0	79	17
Hemp-lime brick (Schönthaler)	0.070	300	20	60.0	115	22
Straw (BauStroh)	0.049	115	35	40.3	9	4

The λ (lambda) value [W/(m×K)] describes the thermal conductivity of a substance. The lower the value, the lower the thermal conductivity.
The thermal insulance R is determined from the λ value and the material thickness d: $R = d/\lambda$ [(m²×K)/W].
Example 20 cm insulation: R = 0.2 / 0.035 = 5.71 (m²×K)/W.
From the thermal insulance of each material layer and the thermal transfer resistance R_{si}, R_{se} at the inner and outer surfaces one can calculate the U-value of a construction, the thermal transmittance: $U = 1 / (R_{si} + R_1 + R_2 + ... + R_{se})$ [W/(m²×K)].
The lower the U-value, the lower the heat losses.
Example exterior wall 20 cm brick and insulation (simplified without rendering): U = 1 / (0.13 + 0.57 + 5.71 + 0.04) = 0.16 W/(m²×K)

Exterior finish or cladding, 1 m²

Building material / part	λ value	Density	Typical thickness	Weight	Primary energy non-renewable	Greenhouse gas emissions
	W/(m×K)	kg/m³	cm	kg/m²	kWh oil-eq	kg CO_2-eq
Clinker brick shell			11.5	221.7	259	89
Clinker bricks (80 %)	*1.0*	*2 000*		*184.0*	*206*	*71*
Mortar (20 %)	*1.0*	*1 550*		*35.7*	*23*	*9*
Wall ties, stainless steel		*7 900*		*2.0*	*29*	*8*
Ceramic tiles			1.5	31.8	100	22
Ceramic/stoneware tile	*1.2*	*2 600*	*0.9*	*23.4*	*87*	*19*
mineral adhesive/mortar	*1.0*	*1 400*	*0.6*	*8.4*	*13*	*3*
Exterior rendering			1.2	17.6	34	9
Paint				*0.3*	*4*	*1*
Final rendering (lime-cement)	*1.0*	*1 550*	*0.2*	*3.1*	*2*	*1*
Reinforcement fabric				*0.2*	*6*	*2*
Mineral base coat	*1.0*	*1 400*	*1.0*	*14.0*	*21*	*6*
Ventilated timber cladding				14.4	34	8
Stain/coating				*0.3*	*4*	*1*
Wood (boards, planks)		*465*	*2.8*	*13.0*	*10*	*2*
Galvanised steel profiles				*0.6*	*9*	*3*
Stainless steel (Rogger anchors, 3.5 pcs./m²)				*0.4*	*6*	*2*
Polyamide, glass fibre reinforced (Rogger anchors)				*0.1*	*4*	*1*
Steel sheet, bare	50	7 850	0.1	7.9	61	22
Steel sheet, galvanised	50	7 850	0.1	7.9	122	35
Steel sheet, stainless	15	7 900	0.1	7.9	115	33
Aluminium sheet, bare	160	2 690	0.1	2.7	67	15
Aluminium sheet, powder-coated	160	2 690	0.1	2.7	83	19
Bronze/brass sheet	65	8 300	0.1	9.1	101	25

Glass / Windows, 1 m²

Building material / part	λ value	Density	Typical thickness	Weight	Primary energy non-renewable	Greenhouse gas emissions
	W/(m×K)	kg/m³	cm	kg/m²	kWh oil-eq	kg CO_2-eq
Flat glass, uncoated	0.760	2 500	0.8	20.0	82	23
Flat glass, coated	0.760	2 500	0.8	20.0	93	24
Insulating double glazing , U_g-value 1.1			2.4		167	44
Insulating triple glazing, U_g-value 0.5			3.6		320	78
Window: frame, glazing, sun protection					753	180
Frame wood-metal			*8.2*		*300*	*66*
Insulating triple glazing, U_g-value 0.6 (glass area = 0.8 m²)			*4.0*		*204*	*54*
Horizontal slat blinds, motorised					*249*	*60*

Photovoltaics and solar thermal panels

Data on photovoltaics and solar thermal are given separate tables.
Depending on the design, PV modules or solar thermal collectors can fulfill the function of cladding.

Calculation / instructions for expanding the table
Columns density [kg/m³] und λ value [thermal conductivity; W/(m×K)]: values from data sources.
Column typical thickness [cm]: Select according to project requirement. Observe the domensions available in practice.
Column weight [kg/m²]: Density × thickness (in metres).
Column primary energy non-renewable [kWh oil-eq]: Per-kg-value from data source × weight.
Column greenhouse gas emissions [kg CO_2-eq]: Per-kg-value from data source × weight.

Data sources
Material parameters: Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022.
Multi-layered constructions based on SIA Merkblatt 2032 Anhang D. λ values: ubakus.de.
Values for Multipor according to manufacturer's EPD, plus disposal «Dämmstoff mineralisch» from KBOB Ökobilanzdaten.
Values for Calcium silicate board according to manufacturer's EPD (Calsitherm, accessed 05.05.2022)
Values for VIP: https://www.ecobau.ch/index.cfm?Nav=27&ID=8091 (accessed 28.10.2021)
Valies for Straw insulation (density, thermal conductivity): https://baustroh.de/extra/wissenswertes.html (accessed 18.06.2021)

Exhibition «Embodied Energy and Embodied Emissions – per m² of Material»
ETH Material Hub, Architecture and Civil Engineering Library, Chair Annette Gigon / Mike Guyer HS 21

Exterior building components, approximate LCAs

The table provides a rough combined assessment of embodied and operational energy and emissions, using examples of various external components, based on 1 year of service life and 1 m² component area. Such an approach allows comparisons of component variants without having to model a building completely. The parameters for the heating system (useful energy ≈ heat losses per heating period) and the totals are shown in two variants: natural gas heating (orange) or brine/water heat pump (cyan).

Note: This is not a comprehensive life cycle analysis! Location, building shape, ventilation, solar and internal heat gains and energy losses within the heating system are not taken into account, nor is the wall covering on the inside.

Exterior wall, not insulated, 1 m² (just for comparison; no efficient heating with high energy losses!)

Construction	Layers / energy	Service life	Useful energy	Primary energy non-renewable		Greenhouse gas emissions	
			kWh	kWh oil-eq		kg CO_2-eq	
		years	per year	total	per year	total	per year
Concrete wall not insulated (U = 3.89 W/m²K)	Reinforced concrete 20 cm	60		169	2.8	73	1.2
	Space heating		292		340.4		74.6
	total				**343.2**		**75.8**
Brick wall not insulated (U = 1.18 W/m²K)	Brick Swissmodul 20 cm	60		158	2.6	53	0.9
	Exterior rendering	30		34	1.1	9	0.3
	Space heating		89		103.3		22.6
	total				**107.0**		**23.8**
Aerated concrete wall, not insulated (U = 0.46 W/m²K)	Aerated concrete 20 cm	60		86	1.4	43	0.7
	Exterior rendering	30		34	1.1	9	0.3
	Space heating		35		40.3		8.8
	total				**42.8**		**9.8**
Solid timber wall, not insulated (U = 0.59 W/m²K)	Solid timber 20 cm (unglued)	60		72	1.2	16	0.3
	Space heating		44		51.6		11.3
	total				**52.8**		**11.6**

Exterior wall, insulated, 1 m²

Construction	Layers / energy	Service life	Useful energy	Primary energy non-renewable			Greenhouse gas emissions		
			kWh	kWh oil-eq			kg CO_2-eq		
		years	per year	total	per year		total	per year	
Reinforced concrete wall with EPS insulation (U = 0,10 W/m²K)	Reinforced concrete 20 cm	60		169		2.8	73		1.2
	EPS 35 cm	30		315		10.5	80		2.7
	Exterior rendering	30		34		1.1	9		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**23.2**	**18.4**		**6.1**	**4.4**
Reinforced concrete wall with rock wool insulation (U = 0,10 W/m²K)	Reinforced concrete 20 cm	60		169		2.8	73		1.2
	Rock wool 35 cm	30		129		4.3	35		1.2
	Exterior rendering	30		34		1.1	9		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**17.0**	**12.2**		**4.6**	**2.9**
Brick wall with rock wool insulation (U = 0,10 W/m²K)	Brick Swissmodul 20 cm	60		158		2.6	53		0.9
	Rock wool 35 cm	30		121		4.0	33		1.1
	Exterior rendering	30		34		1.1	9		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**16.6**	**11.7**		**4.2**	**2.5**

Exterior wall, insulated, 1 m² *continued*

Construction	Layers / energy	Service life	Useful energy	Primary energy non-renewable			Greenhouse gas emissions		
			kWh	kWh oil-eq			kg CO_2-eq		
		years	per year	total	per year		total	per year	
Aerated concrete wall, Multipor exterior insulation (U = 0,10 W/m²K)	Aerated concrete 36.5 cm	60		157		2.6	78		1.3
	Multipor 28 cm	30		100		3.3	29		1.0
	Exterior rendering	30		34		1.1	9		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**15.8**	**11.0**		**4.5**	**2.8**
Wood stud wall with cellulose insulation (U = 0,10 W/m²K)	Wood panelling 2.5 cm	60		17		0.3	4		0.1
	Timber (GLT) 40 cm × 8%	60		11		0.2	2		0.0
	Cellulose 40 cm × 92%	30		19		0.6	5		0.2
	Wood fibre insulation 4 cm	30		16		0.5	3		0.1
	Timber cladding	30		34		1.1	8		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**11.5**	**6.6**		**2.6**	**0.9**
Solid timber wall with wood fibre insulation (U = 0,10 W/m²K)	Timber (GLT) 20 cm	60		135		2.3	30		0.5
	Wood fibre insulation 2 × 16 cm	30		126		4.2	27		0.9
	Timber cladding	30		34		1.1	8		0.3
	Space heating		7.5		8.8	3.9		1.9	0.2
	total				**16.3**	**11.5**		**3.6**	**1.9**

Exterior wall with PV facade, 1 m²

Construction	Layers / energy	Service life	Useful energy	Primary energy non-renewable		Greenhouse gas emissions	
			kWh	kWh oil-eq		kg CO_2-eq	
		years	per year	total	per year	total	per year
Solid timber wall with glass wool insulation and PV facade	Timber (GLT) 20 cm	30		135	4.5	30	1.0
oriented south,	Glass wool 18 cm	30		28	0.9	6	0.2
silicon polycrystalline	Photovoltaic modules, facade	30		1 020	34.0	275	9.2
(U = 0,15 W/m²K)	Space heating		11		13.1 5.9		2.9 0.4
	total				**52.6 45.3**		**13.2 10.7**
	PV electricity yield		**-139**				
Sand-lime brick wall with rock wool insulation and PV facade	Sand-lime brick 20 cm	60		109	1.8	45	0.8
oriented west, CdTe	Rock wool 22 cm	30		81	2.7	22	0.7
(U = 0,15 W/m²K)	Photovoltaic modules, facade	25		643	25.7	155	6.2
	Space heating		11		13.1 5.9		2.9 0.4
	total				**43.4 36.1**		**10.6 8.1**
	PV electricity yield		**-84**				

PV electricity for self-consumption can potentially replace an energy source with poorer environmental characteristics. However, the associated savings in terms of primary energy consumption and emissions are only of limited significance at the component level and are not listed here.

Other exterior building components, 1 m²

Construction	Layers / energy	Service life	Useful energy	Primary energy non-renewable		Greenhouse gas emissions	
			kWh	kWh oil-eq		kg CO_2-eq	
		years	per year	total	per year	total	per year
Window incl. frame and sun protection	Window	40		753	18.8	180	4.5
(U_w = 0,95)	Space heating		71		83.1 37.1		18.2 2.2
	total				**102.0 55.9**		**22.7 6.7**
Natural limestone wall, Multipor internal insulation	Limestone, 20 cm	60		170	2.8	37	0.6
(U = 0,27 W/m²K)	Multipor 14 cm	40		50	1.2	15	0.4
	Space heating		20		23.6 10.5		5.2 0.6
	total				**27.7 14.6**		**6.2 1.6**

Calculation / instructions for expanding the table
Column service life: Plausible assumption. See also component tables for SIA 2032 Appendix D, column "Amortisation"
Column useful energy:
a) Space heating: Heating degree days (see below) × U-value × 24 h/d ÷ 1000
b) PV electricity yield: Annual yield from chapter "Data collection: photovoltaics and solar thermal energy"
Columns primary energy / greenhouse gas emissions total: see tables "LCA data of selected building materials, application-oriented".
Columns primary energy / greenhouse gas emissions per year:
a) Component layers: Total values ÷ service life
b) Space heating: Useful energy ÷ efficiency of the heating system × environmental parameters of the energy carriers.

Heating system, calculation parameters

Type	*Reference / Final energy carrier*	*Efficiency*	*Primary energy non-renewable*	*Greenhouse gas emissions*
Natural gas heating (condensing boiler)	1 kWh natural gas (HHV) ≙ ca. 0,1 m³	Boiler efficiency 0.9	1.05 kWh oil-eq	0.230 kg CO2-eq
Brine/water heat pump with borehole heat exchanger(s)	1 kWh electricity CH consumer mix	Annual perf. factor 4.0	2.08 kWh oil-eq	0.125 kg CO2-eq

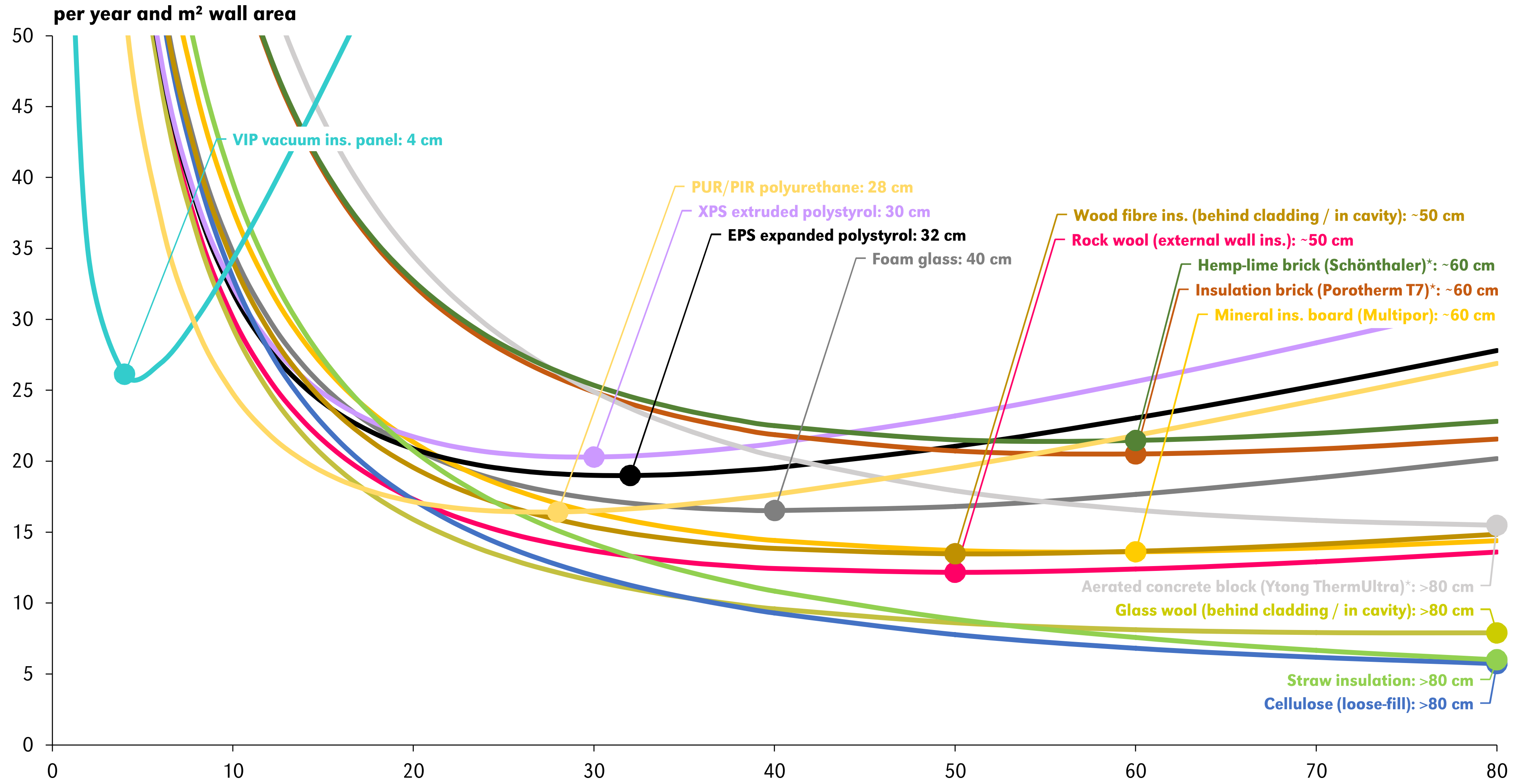
Heating degree days, Zurich Fluntern average 2011–2020: 3 125 (K×d)/a
(https://www.stadt-zuerich.ch/gud/de/index/umwelt_energie/energie-in-zahlen/heizgradtage.html; accessed 2021-12-23)

LCA-optimised insulation thickness in terms of primary energy consumption (non-renewable)

Natural gas heating

Boiler efficiency 0.9
1.05 kWh oil-eq/kWh

PENRT (kWh oil-eq)
embodied energy + heating
per year and m² wall area



Insulation thickness (cm) **

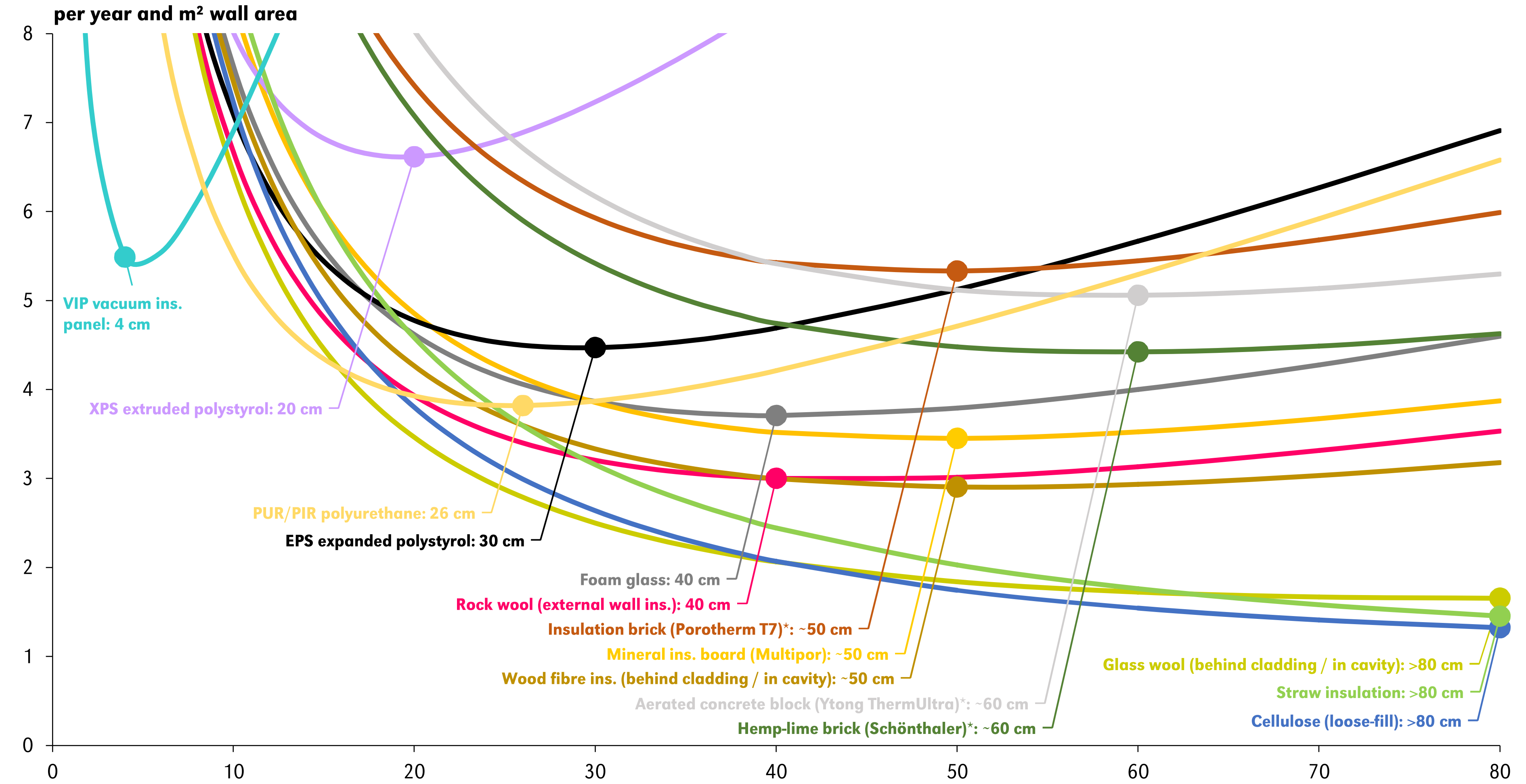
Annual values "embodied" = environmental parameter of material × weight ÷ service life (30 years).
Annual values "heating" = energy loss per heating period (location: Zurich Fluntern) ÷ efficiency of heating system × environmental parameter of energy carrier.
Environmental parameters of building materials and energy carriers according to KBOB Ökobilanzdaten 2009/1:2022 or manufacturer EPD.
* Building material also serves as wall solid, therefore not comparable with pure insulating materials.
** Not all combinations of insulating material and thickness are available or constructively/economically realizable.

LCA-optimised insulation thickness in terms of greenhouse gas emissions

Natural gas heating

Boiler efficiency 0.9
230 g CO2-eq/kWh

GHG (kg CO2-eq)
embodied emissions + heating
per year and m² wall area



Insulation thickness (cm) **

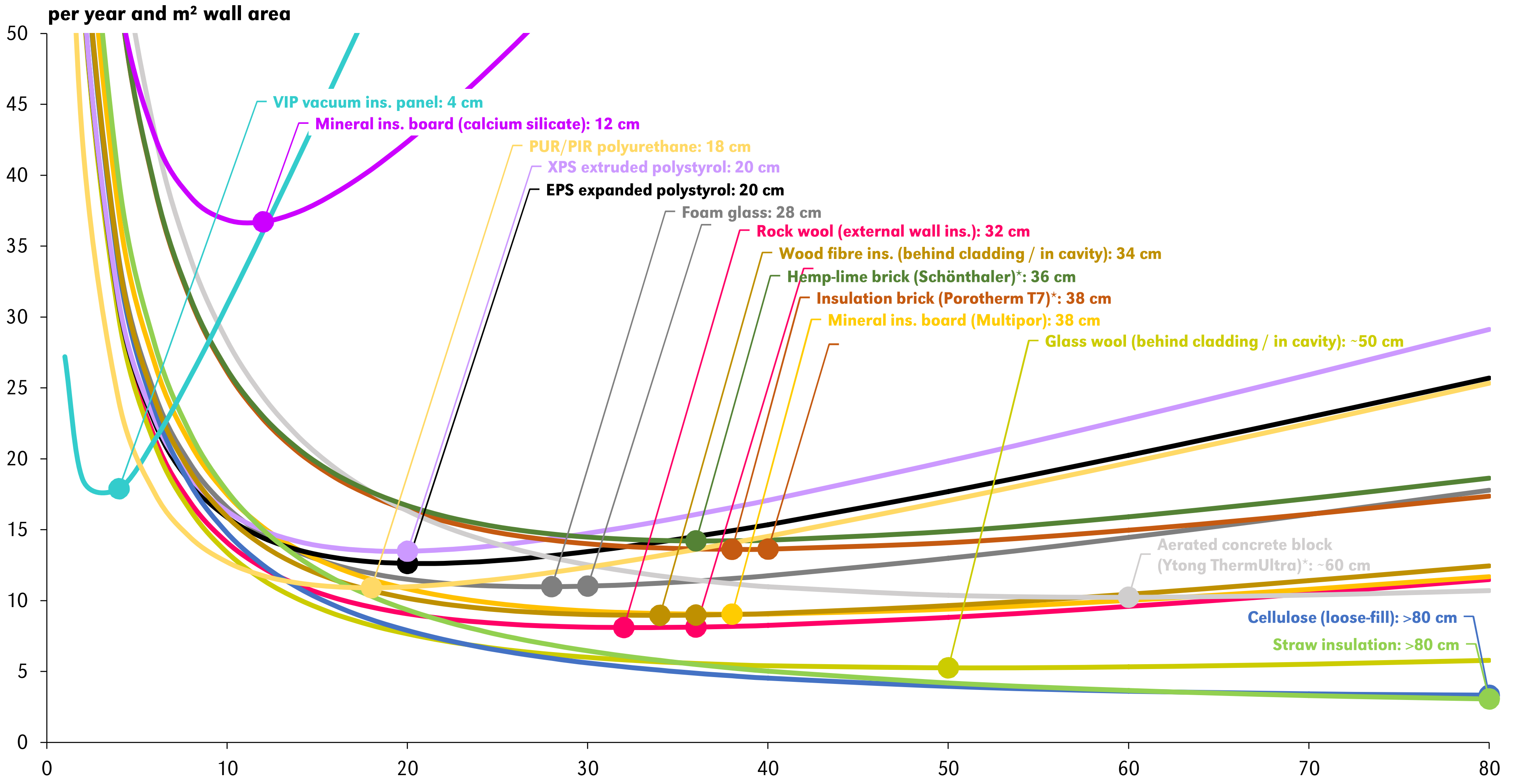
Annual values "embodied" = environmental parameter of material × weight ÷ service life (30 years).
Annual values "heating" = energy loss per heating period (location: Zurich Fluntern) ÷ efficiency of heating system × environmental parameter of energy carrier.
Environmental parameters of building materials and energy carriers according to KBOB Ökobilanzdaten 2009/1:2022 or manufacturer EPD.
* Building material also serves as wall solid, therefore not comparable with pure insulating materials.
** Not all combinations of insulating material and thickness are available or constructively/economically realizable.

LCA-optimised insulation thickness in terms of primary energy consumption (non-renewable)

Brine/water heat pump

PENRT (kWh oil-eq)
embodied energy + heating
per year and m² wall area

Annual perf. factor 4
2.08 kWh oil-eq/kWh



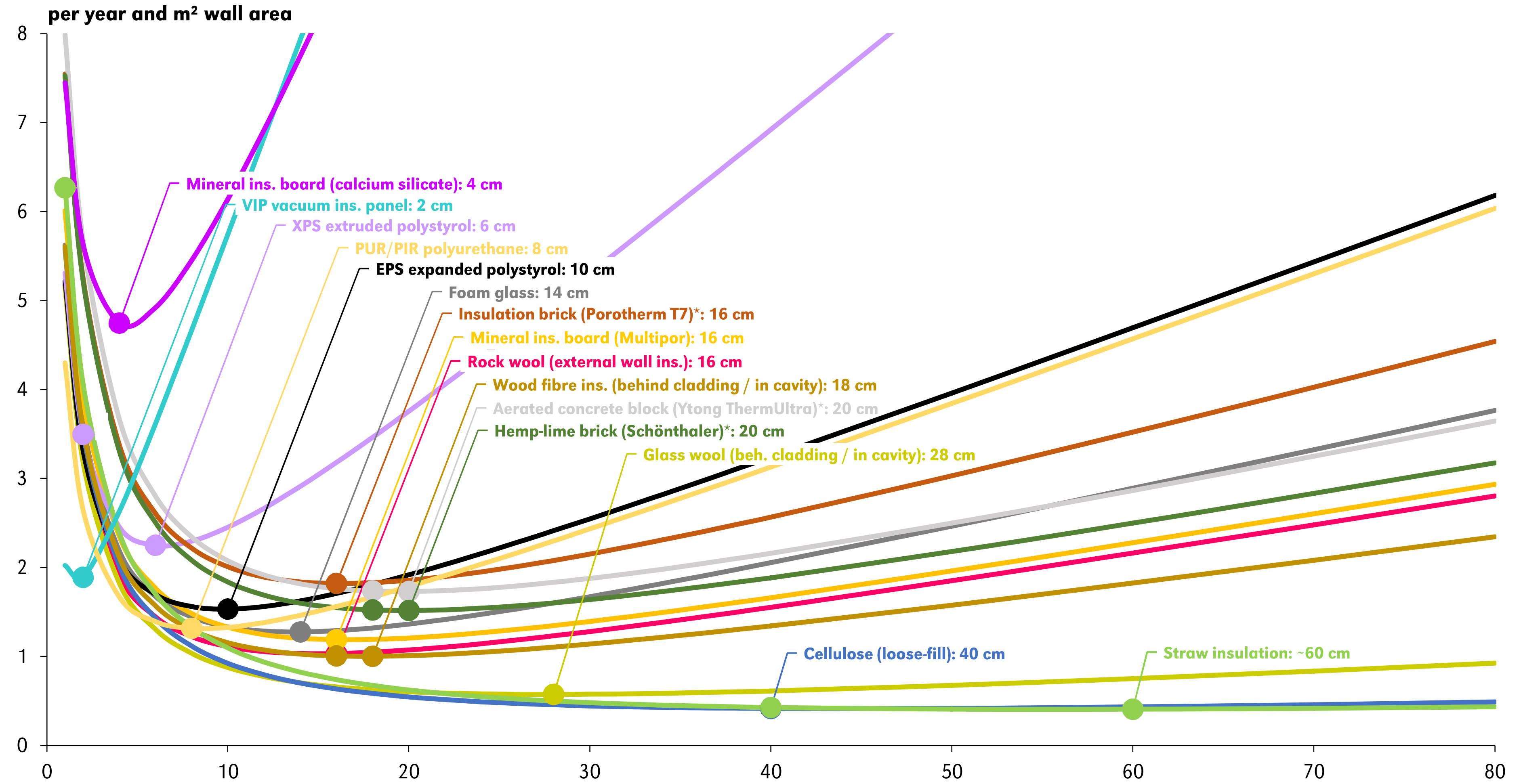
Annual values "embodied" = environmental parameter of material × weight ÷ service life (30 years).
Annual values "heating" = energy loss per heating period (location: Zurich Fluntern) ÷ efficiency of heating system × environmental parameter of energy carrier.
Environmental parameters of building materials and energy carriers according to KBOB Ökobilanzdaten 2009/1:2022 or manufacturer EPD.
* Building material also serves as wall solid, therefore not comparable with pure insulating materials.
** Not all combinations of insulating material and thickness are available or constructively/economically realizable.

LCA-optimised insulation thickness in terms of greenhouse gas emissions

Brine/water heat pump

GHG (kg CO2-eq)
embodied emissions + heating
per year and m² wall area

Annual perf. factor 4
125 g CO2-eq/kWh



Annual values "embodied" = environmental parameter of material × weight ÷ service life (30 years).
Annual values "heating" = energy loss per heating period (location: Zurich Fluntern) ÷ efficiency of heating system × environmental parameter of energy carrier.
Environmental parameters of building materials and energy carriers according to KBOB Ökobilanzdaten 2009/1:2022 or manufacturer EPD.
* Building material also serves as wall solid, therefore not comparable with pure insulating materials.
** Not all combinations of insulating material and thickness are available or constructively/economically realizable.

Overview of thermal insulation standards

The minimum insulation standard for new buildings and conversions are the limits according to SIA 380/1 (corresponds to the Minergie standard or MuKEn 2014).
Improved standards are 70% of the limit values (corresponds to Minergie-P) or the target value according to SIA 380/1 ("passive house").
The values for individual components are listed below. (Lower insulation thicknesses can be determined specifically when modelling the complete building.)
Notes: The insulation layers listed as examples are approximate values; other component layers and thermal bridges (anchors, battens, etc.) are not taken into account.
Internal insulation of external walls is not possible with all insulating materials, as is insulation of components in contact with the ground.
Some insulating materials are only available in certain thicknesses.

Limit values U_{li} according to SIA 380/1 – corresponds to the Minergie standard

Building components	Towards outdoor climate or less than 2 m underground		Towards unheated rooms or more than 2 m underground		Material examples
	W/(m²·K)	Insulation layer	W/(m²·K)	Insulation layer	
Opaque, new (roof, ceiling, wall, floor)	**0.17**	04 cm with λ = 0.007 15 cm with λ = 0.025 20 cm with λ = 0.035 23 cm with λ = 0.040 26 cm with λ = 0.045 29 cm with λ = 0.050 40 cm with λ = 0.070	**0.25**	03 cm with λ = 0.007 10 cm with λ = 0.025 14 cm with λ = 0.035 16 cm with λ = 0.040 18 cm with λ = 0.045 20 cm with λ = 0.050 27 cm with λ = 0.070	VIP vacuum insulation panels PUR/PIR Mineral wool, EPS, XPS, ... Foam glass, cellulose, wood fibre, ... Multipor, ... Straw, cork, ... Insul. brick, aerated concrete, ...
Opaque, renovation (roof, ceiling, wall, floor)	**0.25**	03 cm with λ = 0.007 10 cm with λ = 0.025 14 cm with λ = 0.035 16 cm with λ = 0.040 18 cm with λ = 0.045 20 cm with λ = 0.050 27 cm with λ = 0.070	**0.28**	2.5 cm with λ = 0.007 09 cm with λ = 0.025 12 cm with λ = 0.035 14 cm with λ = 0.040 16 cm with λ = 0.045 18 cm with λ = 0.050 24 cm with λ = 0.070	VIP vacuum insulation panels PUR/PIR Mineral wool, EPS, XPS, ... Foam glass, cellulose, wood fibre, ... Multipor, ... Straw, cork, ... Insul. brick, aerated concrete, ...
Windows	**1.0**		**1.3**		Triple insulation glazing
Doors	**1.2**		**1.5**		
Doors for vehicle access	**1.7**		**2.0**		
Blind casing	**0.50**		**0.50**		

70 % U_{li} (new) / 90 % U_{li} (renovation) – corresponds to Minergie-P standard

Building components	Towards outdoor climate or less than 2 m underground		Towards unheated rooms or more than 2 m underground		Material examples
	W/(m²·K)	Insulation layer	W/(m²·K)	Insulation layer	
Opaque, new (roof, ceiling, wall, floor)	**0.12**	06 cm with λ = 0.007 20 cm with λ = 0.025 28 cm with λ = 0.035 32 cm with λ = 0.040 36 cm with λ = 0.045 40 cm with λ = 0.050 57 cm with λ = 0.070	**0.17**	04 cm with λ = 0.007 15 cm with λ = 0.025 20 cm with λ = 0.035 23 cm with λ = 0.040 26 cm with λ = 0.045 29 cm with λ = 0.050 40 cm with λ = 0.070	VIP vacuum insulation panels PUR/PIR Mineral wool, EPS, XPS, ... Foam glass, cellulose, wood fibre, ... Multipor, ... Straw, cork, ... Insul. brick, aerated concrete, ...
Opaque, renovation (roof, ceiling, wall, floor)	**0.15**	4.5 cm with λ = 0.007 16 cm with λ = 0.025 23 cm with λ = 0.035 26 cm with λ = 0.040 30 cm with λ = 0.045 33 cm with λ = 0.050 46 cm with λ = 0.070	**0.22**	03 cm with λ = 0.007 11 cm with λ = 0.025 15 cm with λ = 0.035 18 cm with λ = 0.040 20 cm with λ = 0.045 22 cm with λ = 0.050 31 cm with λ = 0.070	VIP vacuum insulation panels PUR/PIR Mineral wool, EPS, XPS, ... Foam glass, cellulose, wood fibre, ... Multipor, ... Straw, cork, ... Insul. brick, aerated concrete, ...
Windows	**0.70** (new) / **0.90** (renovation)		**0.90** (new) / **1.2** (renovation)		Triple insulation glazing
Doors	**0.80** (new) / **1.1** (renovation)		**1.0** (new) / **0.90** (renovation)		
Doors for vehicle access	**1.2** (new) / **1.5** (renovation)		**1.4** (new) / **1.8** (renovation)		
Blind casing	**0.35** (new) / **0.45** (renovation)		**0.35** (new) / **0.45** (renovation)		

Target values U_{ta} according to SIA 380/1 – analogous to "passive house"

Building components	W/(m²·K)	Insulation layer	Material examples
Opaque (roof, ceiling, wall, floor)	**0.10**	07 cm with λ = 0.007 25 cm with λ = 0.025 35 cm with λ = 0.035 40 cm with λ = 0.040 45 cm with λ = 0.045 50 cm with λ = 0.050 70 cm with λ = 0.070	VIP vacuum insulation panels PUR/PIR Mineral wool, EPS, XPS, ... Foam glass, cellulose, wood fibre, ... Multipor, ... Straw, cork, ... Insul. brick, aerated concrete, ...
Windows and doors	**0.80**		Triple insulation glazing

Pillars/supports/posts, approximate LCAs

The tables show examples of approximate life cycle assessments of structural supports in common dimensions.
The construction types summarized under version 1 and version 2 each have the same static properties (cold-state design).
To simplify things, the same environmental parameters were used for all types of profile steel. Montage and cladding/coating are not included.

Pillar/support/post h = 3 m, version 1, per unit

Type / dimensions	Components / material	Weight	Service life	Primary energy non-renewable (kWh oil-eq)		Greenhouse gas emissions (kg CO_2-eq)	
		kg	years	total	per year	total	per year
Concrete 20 x 20 cm	Concrete C30/37	276.0	60	48	0.8	28	0.5
	Reinforcement B500B 4 x ⌀ 20	41.5	60	207	3.5	63	1.1
	Stirrups B500B	6.0	60	30	0.5	9	0.2
	total	**323.5**	–	**285**	**4.8**	**100**	**1.7**
Steel H-profile HEA 200	Steel S235	129	60	436	7.3	95	1.6
	Top/base plate 15 mm	14.7	60	50	0.8	11	0.2
	total	**143.7**	–	**486**	**8.1**	**106**	**1.8**
Steel H-profile HEA 180	Steel S235	109.2	60	369	6.2	81	1.3
	Top/base plate 15 mm	12.5	60	42	0.7	9	0.2
	total	**121.7**	–	**411**	**6.9**	**90**	**1.5**
Steel rectangular profile RRW 120 x 120 x 8	Steel S235	82.8	60	280	4.7	61	1.0
	Top/base plate 15 mm	9.4	60	32	0.5	7	0.1
	total	**92.2**	–	**312**	**5.2**	**68**	**1.1**
Timber round ⌀ 32 cm	Timber C24 (unglued)	**112.2**	60	**87**	**1.5**	**20**	**0.3**
Timber rectangular 20 x 36 cm	Glue laminated timber GL24h	**94.8**	60	**146**	**2.4**	**32**	**0.5**

Pillar/support/post h = 3 m, version 2, per unit

Type / dimensions	Components / material	Weight	Service life	Primary energy non-renewable (kWh oil-eq)		Greenhouse gas emissions (kg CO_2-eq)	
		kg	years	total	per year	total	per year
Concrete 20 x 20 cm	Concrete C30/37	276.0	60	48	0.8	28	0.5
	Reinforcment B500B 4 x ⌀ 16	25.3	60	126	2.1	38	0.6
	Stirrups B500B	6.0	60	30	0.5	9	0.2
	total	**307.3**	–	**204**	**3.4**	**75**	**1.3**
Steel H-profile HEA 180	Steel S235	109.2	60	369	6.2	81	1.3
	Top/base plate 12 mm	10.0	60	34	0.6	7	0.1
	total	**119.2**	–	**403**	**6.7**	**88**	**1.5**
Steel H-profile HEA 160	Steel S235	93.6	60	316	5.3	69	1.2
	Top/base plate 12 mm	8.3	60	28	0.5	6	0.1
	total	**101.9**	–	**344**	**5.7**	**75**	**1.3**
Steel rectangular profile RRW 120 x 120 x 6,3	Steel S235	66.6	60	225	3.8	49	0.8
	Top/base plate 12 mm	7.5	60	25	0.4	6	0.1
	total	**74.1**	–	**251**	**4.2**	**55**	**0.9**
Timber round ⌀ 30 cm	Timber C24 (unglued)	**98.6**	60	**77**	**1.3**	**17**	**0.3**
Timber rectangular 24 x 30 cm	Timber C24 (unglued)	**100.4**	60	**78**	**1.3**	**17**	**0.3**
Timber rectangular 16 x 44 cm	Glue laminated timber GL24h	**92.7**	60	**143**	**2.4**	**31**	**0.5**

Calculation / instructions for expanding the table
Column weight [kg]: Component volume × density from data source
Column service life [years]: Plausible assumption. See also component tables for SIA 2032 Appendix D, column "Amortisation"
Columns primary energy / greenhouse gas emissions total: Per-kg-value from data source × weight
Columns primary energy / greenhouse gas emissions per year: Total values ÷ service life

Data sources
Dimensions and components of structural supports provided by C. Aerni, Aerni + Aerni Ingenieure AG, Zurich (June 2021)
Material parameters: Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022

Floors/ceilings, approximate LCAs

The tables show examples of approximate life cycle assessments of various common ceiling constructions based on the same requirements.
The cladding/coating of the underside is not included.

Floor/ceiling on structural grid 5 × 5 m, per m²

Type / dimensions	Components / material	Weight	Service life	Primary energy non-renewable		Greenhouse gas emissions	
				kWh oil-eq		kg CO_2-eq	
		kg	years	total	per year	total	per year
Reinforced concrete slab portland cement (CEM I) two-way slab	22 cm concrete C30/37, CEM I	474.4	60	108	1.8	58	1.0
	rebar approx. 120 kg per m³	26.4	60	132	2.2	40	0.7
	4 cm sound insulation rock wool	3.6	60	16	0.3	4	0.1
	8 cm cement screed	148.0	60	34	0.6	18	0.3
	1.5 cm parquet flooring	7.9	30	40	1.3	8	0.3
	total (height 35.5 cm)	**660.3**	–	**330**	**6.2**	**128**	**2.3**
Reinforced concrete slab blast furnace cement (CEM III/B) two-way slab	22 cm concrete C30/37, CEM III/B	474.4	60	102	1.7	29	0.5
	rebar approx. 120 kg per m³	26.4	60	132	2.2	40	0.7
	4 cm sound insulation rock wool	3.6	60	16	0.3	4	0.1
	8 cm cement screed	148.0	60	34	0.6	18	0.3
	1.5 cm parquet flooring	7.9	30	40	1.3	8	0.3
	total (height 35.5 cm)	**660.3**	–	**325**	**6.1**	**100**	**1.8**
Glue laminated timber floor one-way slab, incl. bearers	Share of bearer 64×24 cm GLT	14.4	60	22	0.4	5	0.1
	20 cm GLT GL24	86.0	60	132	2.2	29	0.5
	8 cm levelling fill	160.0	60	14	0.2	3	0.0
	4 cm sound insulation rock wool	3.6	60	16	0.3	4	0.1
	8 cm cement screed	148.0	60	34	0.6	18	0.3
	1.5 cm parquet flooring	7.9	30	40	1.3	8	0.3
	total (height 41.5 cm)	**419.9**	–	**259**	**5.0**	**67**	**1.2**

Floor/ceiling on structural grid 5 × 5 m, per m² *continued*

Type / dimensions	Components / material	Weight	Service life	Primary energy non-renewable		Greenhouse gas emissions	
				kWh oil-eq		kg CO_2-eq	
		kg	years	total	per year	total	per year
Timber-concrete composite slab (CEM I) one-way slab, incl. bearers	Share of bearer 96×24 cm GLT	21.6	60	33	0.6	7	0.1
	14 cm timber C24 (unglued)	60.8	60	47	0.8	11	0.2
	12 cm concrete C30/37, CEM I	259.6	60	59	1.0	32	0.5
	rebar approx. 100 kg per m³	11.6	60	58	1.0	18	0.3
	4 cm sound insulation rock wool	3.6	60	16	0.3	4	0.1
	8 cm cement screed	148.0	60	34	0.6	18	0.3
	1.5 cm parquet flooring	7.9	30	40	1.3	8	0.3
	total (height 39.5 cm)	**513.1**	–	**288**	**5.5**	**97**	**1.8**
Timber-concrete composite slab (CEM III/B) one-way slab, incl. bearers	Share of bearer 96×24 cm GLT	21.6	60	33	0.6	7	0.1
	14 cm timber C24 (unglued)	60.8	60	47	0.8	11	0.2
	12 cm concrete C30/37, CEM III/B	259.6	60	56	0.9	16	0.3
	rebar approx. 100 kg per m³	11.6	60	58	1.0	18	0.3
	4 cm sound insulation rock wool	3.6	60	16	0.3	4	0.1
	8 cm cement screed	148.0	60	34	0.6	18	0.3
	1.5 cm parquet flooring	7.9	30	40	1.3	8	0.3
	total (height 39.5 cm)	**513.1**	–	**285**	**5.4**	**82**	**1.5**

Calculation / instructions for expanding the table
Column weight [kg]: Component volume × density from data source
Column service life [years]: Plausible assumption. See also component tables for SIA 2032 Appendix D, column "Amortisation"
Columns primary energy / greenhouse gas emissions total: Per-kg-value from data source × weight
Columns primary energy / greenhouse gas emissions per year: Total values ÷ service life

Data sources
Floor/ceiling constructions provided by G. Meleshko, WaltGalmarini AG, Zürich (März 2022)
Material parameters: Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022 and
https://treeze.ch/fileadmin/user_upload/calculators/Betonsortenrechner_Planer_DE/Betonsortenrechner_Planer.htm (retr. 25.03.2022 AK)

Carbon storage in building materials

Building materials can be viewed as carbon stores. In the case of biogenic building materials such as wood, straw, etc., the growth of plants binds CO_2 from the atmosphere. If the component is incinerated or rots at the end of its service life, the CO_2 is released again – the greenhouse balance is therefore evened out in the long term. But if the assessment period is limited to 100 years, a biogenic building material serves as a (temporary!) carbon sink if it is stored in the built environment for longer than half of its rotation period, i.e. the time for regrowth (rule of thumb). Consequently, the effect is particularly pronounced in the case of fast-growing plant building materials (straw, hemp, reed, bamboo).

Biogenic building materials, temporary storage, 1 m²

Building material	Density	Carbon content	Typical thickness	Weight	Embodied emissions	Carbon content	≙ Carbon-dioxide
	kg/m³	kg C/kg	cm	kg	kg CO_2-eq	kg C	kg CO_2
Hemp concrete	600	0.065	20	120	39	8	**29**
Solid timber beech / oak, kiln-dried	675	0.451	20	135	21	61	**223**
Solid timber spruce / fir / larch, kiln-dried	465	0.451	20	93	16	42	**154**
Glue laminated timber	439	0.446	20	88	30	39	**144**
Mineral bonded wood wool board	400	0.138	2.5	10	5	1	**5**
Particle board, PF-bonded, humidity-resistant	640	0.417	2.5	16	8	7	**24**
OSB board, PF-bonded, humidity-resistant	605	0.444	2.5	15	9	7	**25**
Cellulose (loose-fill)	50	0.404	20	10	3	4	**15**
Wood-fibre insulation board (behind cladding / in cavity)	115	0.436	20	23	17	10	**37**
Cork insulating panel	120	0.496	20	24	27	12	**44**
Flax fibre insulation, fire-resistant	30	0.440	20	6	9	3	**10**
Hemp-lime brick (Schönthaler)	300	0.150	20	60	22	9	**33**
Straw (BauStroh)	115	0.368	35	40	4	15	**54**

About 50% of the dry weight of biogenic building materials consists of carbon. When carbon (C) combines with oxygen (O) to form CO_2, the weight multiplies by a factor of 3.67. Example: 22 kg of wood consists of 45% carbon, i.e. 10 kg of C. Converted into carbon dioxide, this corresponds to 36.7 kg of CO_2.
Material parameters: Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022.

Carbon dioxide can also react with concrete (carbonatation) and is permanently bound in the mineral matrix. New methods are trying to accelerate this process by bringing recycled concrete granules into contact with concentrated CO2. This improves the CO_2 balance of the concrete produced in this way, however the amount of carbon dioxide stored per m³ is currently still well below the embodied greenhouse gas emissions.

Concrete, permanent storage, 1 m²

Concrete type (excl. reinforcement)	Density	Storage capacity	Typical thickness	Weight	Embodied emissions	Carbon content	≙ Carbon-dioxide
	kg/m³	kg CO_2/m³	cm	kg	kg CO_2-eq	kg C	kg CO_2
Concrete CEM I, recycled aggregates, carbonated	2 190	10	20	438	49	0.5	**2**
Concrete CEM III/B, recycled aggregates, carbonated	2 190	10	20	438	25	0.5	**2**

Company information on the CO_2 storage capacity of the technology (10 kg per m³):
https://de.neustark.com/produce, https://zirkulit.ch/co2-speicherung/co2-speichertechnologie (accessed 26.03.2022 AK)
Concrete type calculator: https://treeze.ch/fileadmin/user_upload/calculators/Betonsortenrechner_Planer_DE/Betonsortenrechner_Planer.htm

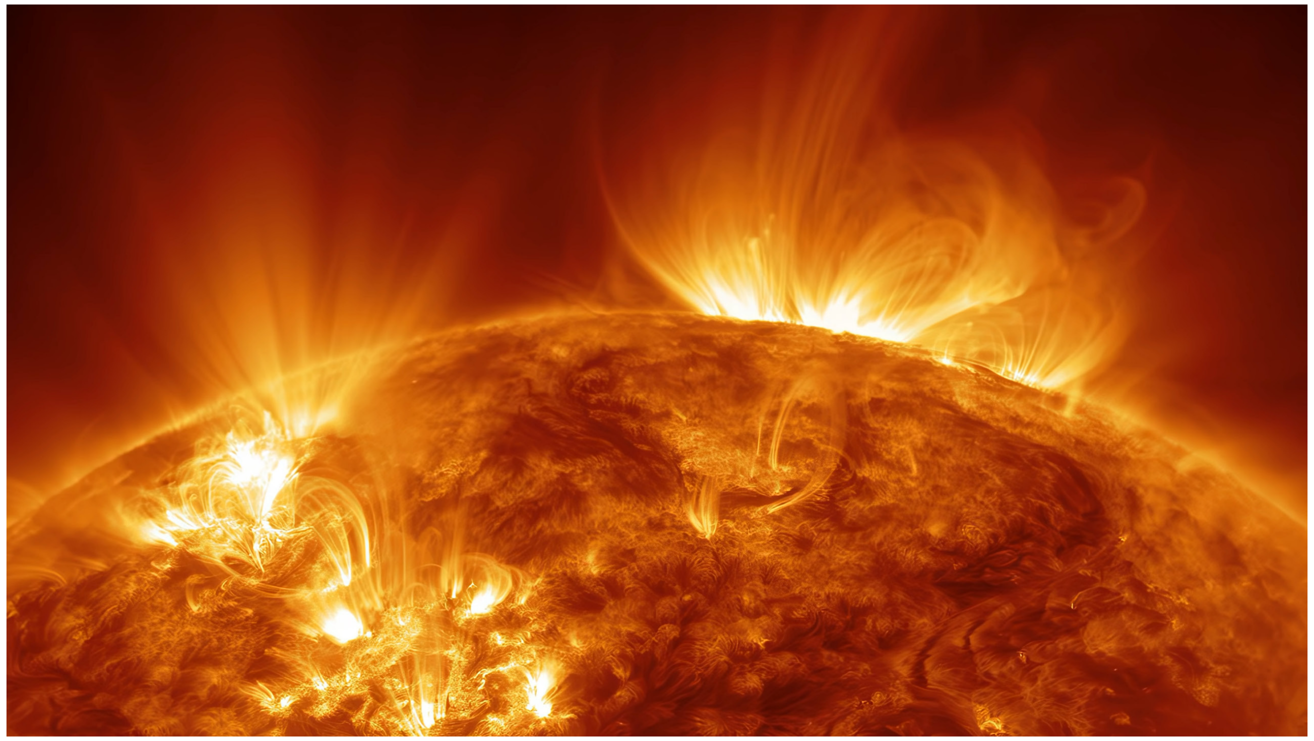
When assessed dynamically within a time frame of <100 years and taking into account the global carbon cycle, the biogenic carbon storage in components can be quantified as a CO_2 sink. This approach is currently the subject of professional debate; as an example, here is a selection of biogenic building materials from the study "Material Diets for Climate-Neutral Construction" by Olga Beatrice Carcassi, Guillaume Habert et al. (2022). The storage period is assumed at 60 years.

Biogenic building materials, CO_2 sink effect within a time frame <100 years, 1 m²

Building material	Density	Carbon content	Typical thickness	Weight	Embodied emissions	CO2 sink effect	Net result
	kg/m³	kg C/kg	cm	kg	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq
Solid timber (hardwood), supporting structure	640	0.491	20	128	10	-28	**-18**
Bamboo (Glue Laminated Bamboo GLB)	636	0.518	20	127	98	-117	**-19**
Bamboo (Cross Laminated Bamboo CLB)	636	0.518	20	127	98	-118	**-20**
Hemp fibre insulation	85	0.300	35	30	3	-16	**-13**
Reed mat insulation	180	0.464	35	63	24	-54	**-29**
Straw insulation	95	0.409	35	33	5	-24	**-19**

Source: https://pubs.acs.org/doi/abs/10.1021/acs.est.1c05895; accessed 07.05.2022. Typical thickness assumed by chair Gigon/Guyer.
Note: The data is not readily compatible with the «static» life cycle assessment according to KBOB/SIA.

DATA COMPILATION PHOTOVOLTAICS SOLAR THERMAL ENERGY



Surface of the Sun, Wavelength 171 Ångström. NASA Solar Dynamics Observatory 2014

Photovoltaics, basic parameters

Properties and environmental parameters (embodied energy, embodied emissions)

Cell type	Typical efficiency		Area required	Service life	Placement	Primary energy non-renewable		Greenhouse gas emissions	
						kWh oil-eq/m²		kg CO_2-eq/m²	
	%	kW_P/m^2	m^2/kW_P	years		total	per year	total	per year
Silicon, monocrystalline	20.0	0.20	5.00	30	Roof, horizontal	1 030	34.3	287	9.6
					Roof, inclined	910	30.3	252	8.4
					Facade	1 120	37.3	307	10.2
Silicon, multicrystalline	18.0	0.18	5.56	30	Roof, horizontal	930	31.0	257	8.6
					Roof, inclined	820	27.3	225	7.5
					Facade	1 020	34.0	275	9.2
Thin-film CdTe	16.0	0.16	6.25	25	Roof, horizontal	590	23.6	145	5.8
					Roof, inclined	520	20.8	127	5.1
					Facade	643	25.7	155	6.2
Thin-film CIS	15.0	0.15	6.67	25	Roof, horizontal	784	31.4	185	7.4
					Roof, inclined	692	27.7	162	6.5
					Facade	856	34.2	198	7.9

Module efficiency: Electricity generation of the PV module in relation to solar irradiation (under standard conditions).
Example efficiency 18 %: With solar irradiation 1 kW/m², the module delivers a peak power output of 0.18 kW_P/m^2 (kW_P = kilowatt peak, nominal power).
The reciprocal corresponds to the area requirement: 1 ÷ 0.18 = 5.56 m^2/kW_P.
The service life of modules with silicon cells is assumed to be 30 years and 25 years for thin-film modules.
Environmental parameters: Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022.Partly interpolated (flat roof, facade) and converted to m² module area.
Example silicon polycrystalline, flat roof: greenhouse gas emissions 1 425 kg CO_2-eq/kW_P × module efficiency 0.18 kW_P/m^2 = 257 kg CO_2-eq/m².
Amortized as per-year values by service life: 257 kg CO_2-eq/m² ÷ 30 years = 8.6 kg CO_2-eq/(m²×a).

Photovoltaics, energy yields

The annual yield, i.e. the amount of energy produced by a PV system in one year, depends on the geographic location, inclination and orientation.
(The amount of shade and any surface treatment also play an important role; this is not taken into account here.)

Relative yields in %

Cell type	Placement	%, for different orientations								
		hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Silicon, monocrystalline Silicon, multicrystalline	Roof, horizontal	85	–	–	–	–	–	–	–	–
	Roof, inclined	–	100	95	80	60	51	60	78	93
	Facade	–	70	66	50	29	18	28	48	64
Thin-film CdTe	Roof, horizontal	84	–	–	–	–	–	–	–	–
	Roof, inclined	–	100	95	79	58	48	57	77	93
	Facade	–	68	65	48	26	14	25	45	62
Thin-film CIS	Roof, horizontal	85	–	–	–	–	–	–	–	–
	Roof, inclined	–	100	95	80	61	51	60	78	93
	Facade	–	70	66	50	29	18	29	48	64

The table shows the yields of differently oriented PV systems relative to the best possible alignment to the sun (south, 37° inclined).
Data source: PVGIS (Photovoltaic Geographical Information System), EU Science Hub. https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP, accessed 2022-04-08. Location Zurich, ETH Hönggerberg, roof inclination 37°, system loss 10%, no shade.
Note: According to PVGIS, the optimal orientation is south +3° to the west, not taken into account here.

Absolute yields in kWh/(m²×a)

Cell type	Placement	kWh/(m²×a), for different orientations (degradation included)								
		hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Silicon, monocrystalline	Roof, horizontal	186	–	–	–	–	–	–	–	–
	Roof, inclined	–	219	208	175	133	113	131	171	204
	Facade	–	154	145	109	63	39	62	105	140
Silicon, multicrystalline	Roof, horizontal	168	–	–	–	–	–	–	–	–
	Roof, inclined	–	197	187	157	119	101	118	154	184
	Facade	–	139	131	98	57	35	56	95	126
Thin-film CdTe	Roof, horizontal	149	–	–	–	–	–	–	–	–
	Roof, inclined	–	177	168	139	103	86	102	136	165
	Facade	–	121	114	84	46	25	44	81	109
Thin-film CIS	Roof, horizontal	137	–	–	–	–	–	–	–	–
	Roof, inclined	–	161	153	129	98	83	97	126	150
	Facade	–	113	107	81	47	29	46	78	103

Here, the yields that can be achieved according to the data source (PVGIS) per cell type and orientation are converted (via area requirement and degradation) to the annual average yields that can actually be expected per m² of module area.
Example Si. multi. flat roof: Achievable yield 976 kWh/(kW_P×a) ÷ area requirement 5.56 m²/kW_P × degradation 95.5 % = yield 168 kWh/(m²×a).
Degradation: Reduction in efficiency over the service life (simplified: linear decrease)
Example: Annual reduction 0.3 %/a × service life 30 a = 9.0 % total reduction. Corresponds to an average annual yield of 95.5%.

Comparison: Photovoltaic vs. Swiss grid electricity

Dividing the embodied energy and emissions by the PV yields gives the environmental parameters of the self-produced solar power, which can be compared with electricity from the grid. If the parameters for solar are lower, the ecological impact of the building can be improved by the PV system, assuming the yield is used to cover the building's own energy needs.

Environmental parameters for self-produced PV electricity (worse than / equal to / better than benchmark)

Cell type	Placement	Primary energy non-renewable kWh oil-eq/kWh, for different orientations									Greehouse gas emissions g CO_2-eq/kWh, for different orientations								
		horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°	horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Silicon, monocrystalline	Roof, horizontal	0.18	–	–	–	–	–	–	–	–	51	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.14	0.15	0.17	0.23	0.27	0.23	0.18	0.15	–	38	40	48	63	75	64	49	41
	Facade	–	0.24	0.26	0.34	0.59	0.97	0.60	0.35	0.27	–	66	70	94	162	265	166	97	73
Silicon, multicrystalline	Roof, horizontal	0.18	–	–	–	–	–	–	–	–	51	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.14	0.15	0.17	0.23	0.27	0.23	0.18	0.15	–	38	40	48	63	74	63	49	41
	Facade	–	0.24	0.26	0.35	0.60	0.98	0.61	0.36	0.27	–	66	70	93	161	264	165	97	73
Thin-film CdTe	Roof, horizontal	0.16	–	–	–	–	–	–	–	–	39	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.12	0.12	0.15	0.20	0.24	0.20	0.15	0.13	–	29	30	36	49	59	50	37	31
	Facade	–	0.21	0.22	0.30	0.56	1.04	0.59	0.32	0.24	–	51	54	74	136	251	141	77	57
Thin-film CIS	Roof, horizontal	0.23	–	–	–	–	–	–	–	–	54	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.17	0.18	0.22	0.28	0.34	0.29	0.22	0.18	–	40	42	50	66	79	67	52	43
	Facade	–	0.30	0.32	0.42	0.72	1.17	0.74	0.44	0.33	–	70	74	98	168	271	172	102	77
Benchmark 1 kWh final energy, grid electricity from Swiss consumer mix		2.08									125								

Example Si. multi. flat roof: Primary energy non-renewable 31.0 kWh oil-eq/(m²×a) ÷ yield 168 kWh/(m²×a) = 0.18 kWh oil-eq/kWh.
This corresponds to 9% of the benchmark (2.08 kWh oil-eq/kWh).
Note: The high proportion of hydroelectric and nuclear power in Swiss electricity production results in low greenhouse gas emissions by international standards.
Since it makes sense to first replace fossil-based (imported) electricity with PV electricity, PV areas with a less favorable (north) orientation are also justifiable.

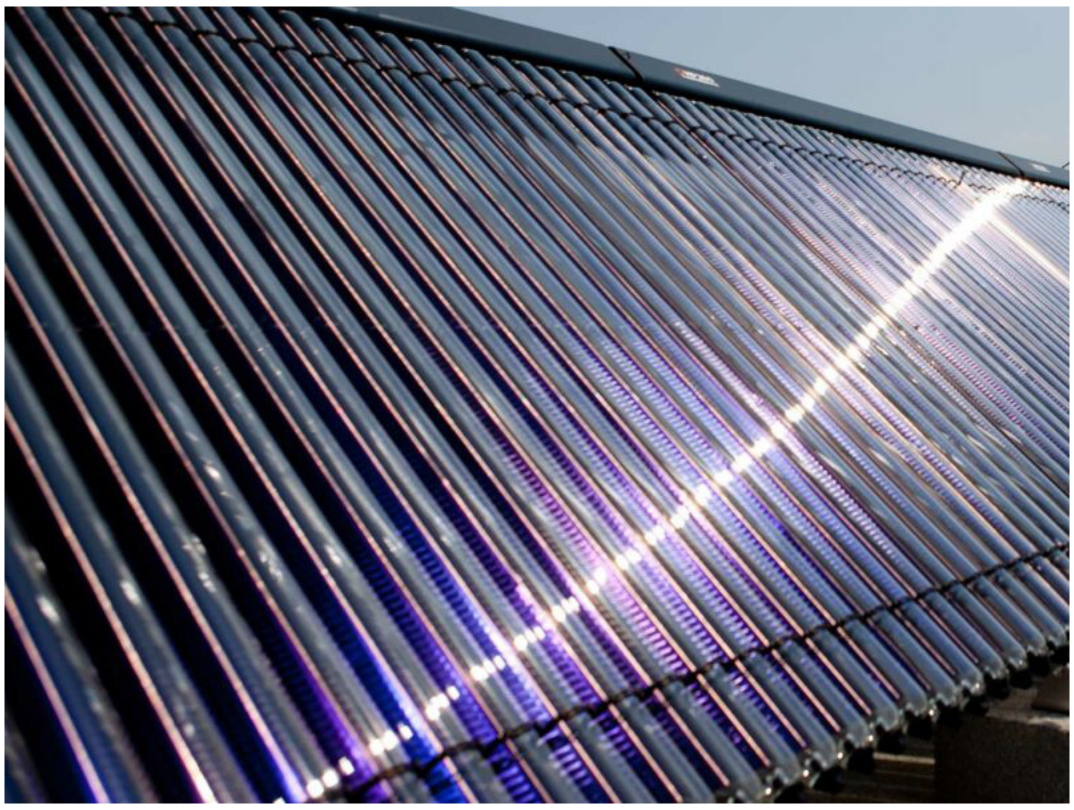
Comparison: Photovoltaic vs. Swiss grid electricity, shown as payback time

To determine the amortization period of a PV system (payback time), its embodied energy and emissions are divided by the environmental parameters of the grid electricity saved annually. If the payback time is shorter than the service life of the system, it has a positive ecological balance overall (– the economics would have to be considered separately).

Payback time of the photovoltaic system (worse than / equal to / better than benchmark)

Cell type	Placement	Primary energy non-renewable years, for different orientations									Greehouse gas emissions years, for different orientations								
		horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°	horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Silicon, monocrystalline	Roof, horizontal	2.7	–	–	–	–	–	–	–	–	12.3	–	–	–	–	–	–	–	–
	Roof, inclined	–	2.0	2.1	2.5	3.3	3.9	3.3	2.6	2.1	–	9.2	9.7	11.5	15.2	17.9	15.3	11.8	9.9
	Facade	–	3.5	3.7	4.9	8.5	14.0	8.7	5.1	3.8	–	15.9	16.9	22.5	38.8	63.7	39.8	23.3	17.5
Silicon, multicrystalline	Roof, horizontal	2.7	–	–	–	–	–	–	–	–	12.2	–	–	–	–	–	–	–	–
	Roof, inclined	–	2.0	2.1	2.5	3.3	3.9	3.3	2.6	2.1	–	9.1	9.6	11.4	15.1	17.8	15.2	11.7	9.8
	Facade	–	3.5	3.7	5.0	8.6	14.1	8.8	5.2	3.9	–	15.8	16.8	22.4	38.6	63.4	39.6	23.2	17.4
Thin-film CdTe	Roof, horizontal	1.9	–	–	–	–	–	–	–	–	7.8	–	–	–	–	–	–	–	–
	Roof, inclined	–	1.4	1.5	1.8	2.4	2.9	2.5	1.8	1.5	–	5.7	6.1	7.3	9.9	11.9	10.0	7.5	6.2
	Facade	–	2.6	2.7	3.7	6.8	12.5	7.0	3.8	2.8	–	10.2	10.8	14.7	27.2	50.2	28.2	15.4	11.3
Thin-film CIS	Roof, horizontal	2.8	–	–	–	–	–	–	–	–	10.8	–	–	–	–	–	–	–	–
	Roof, inclined	–	2.1	2.2	2.6	3.4	4.0	3.4	2.6	2.2	–	8.0	8.5	10.1	13.3	15.7	13.4	10.3	8.6
	Facade	–	3.7	3.9	5.1	8.7	14.1	9.0	5.3	4.0	–	14.1	14.8	19.6	33.5	54.1	34.5	20.4	15.4
Benchmark 1 kWh final energy, grid electricity from Swiss consumer mix		30 / 25									30 / 25								

Example Si. multi. flat roof: Embodied primary energy non-renewable 930 kWh oil-eq/m² ÷ (annual yield PV 168 kWh/(m²×a) × primary energy non-renewable Swiss grid electricity 2.08 kWh oil-eq/kWh) = payback time 2.7 years, i.e. shorter than the service life of the system (30 years)
Example Si. multi. north facade: Embodied greenhouse gas emissions 275 kg CO_2-eq/m² ÷ (annual yield PV 34.7 kWh/(m²×a) × greenhouse gas emissions Swiss grid electricity 0.125 kg CO_2-eq/kWh) = payback time 63.4 years, i.e. longer than the service life of the system (30 years)



Solar thermal energy, basic parameters

Properties and environmental parameters (embodied energy, embodied emissions)

Collector type and application	Area required: m² for 1 000 kWh usable final energy per year			Service life	Primary energy non-renewable (kWh oil-eq/m²)		Greenhouse gas emissions (kg CO_2-eq/m²)	
	inclined roof, south	flat roof or inclined east/west, facade south	facade east/west	years	total	per year	total	per year
Flat-plate collector for hot water multi-family house	approx. 1.9	approx. 2.9	approx. 4.9	30	668	22.3	169	5.6
Flat-plate collector for hot water single-family house	approx. 2.2	approx. 3.2	approx. 5.2	30	1 070	35.7	290	9.7
Flat-plate collector for space heating and hot water, SFH	approx. 3.0	approx. 4.9	approx. 8.6	30	784	26.1	204	6.8
Tube collector for space heating and hot water, SFH	approx. 2.5	approx. 4.0	approx. 6.7	30	886	29.5	231	7.7

The usable final energy of a solar thermal system depends, among other things, on the application: hot water is needed all year round, space heating only during the heating period, when the sun supplies less energy.
Thus, systems that are also to be used for space heating require more area.
The service life of solar collectors is assumed to be 30 years (see SIA 2032 Appendix C).
Environmental parameters according to Ökobilanzdaten im Baubereich KBOB / ecobau / IPB 2009/1:2022. Amortized as per-year values by service life.
Example flat-plate collector for hot water, multi-family house: greenhouse gas emissions 169 kg CO_2-eq/m² ÷ 30 years = 5.6 kg CO_2-eq/(m²×a).

Rules of thumb: solar coverage, heat requirement (space heating + hot water), collector area, storage tank size

For 50 % solar coverage: Per 4 000 kWh of total annual heat demand, 1 000 l storage volume and 7 m² collector area are required.
For 70 % solar coverage: Per 4 000 kWh of total annual heat demand, 2 000 l storage volume and 13 m² collector area are required.
For 80 % solar coverage: Per 4 000 kWh of total annual heat demand, 4 000 l storage volume and 17 m² collector area are required.
For 100 % solar coverage: Per 4 000 kWh of total annual heat demand, 10 000 l storage volume and 28 m² collector area are required.

Roof with a 30° inclination (or 30° mounted on a flat roof) and ±30° south deviation. Collector yield Zurich city.
Other combinations of storage tank size and collector area are possible. Information supplied by Jenni Energietechnik AG, 19.11.2021 (without guarantee)

Solar thermal energy yields

The annual yield, i.e. the amount of energy produced by a solar thermal system in one year, depends on the geographic location, inclination and orientation. (The shading and any surface treatment also play a role; this is not taken into account here.)

Relative yields in %

Collector type and application	Placement	%, for different orientations								
		hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Flat-plate collector for hot water, MFH	Roof, horizontal	63	–	–	–	–	–	–	–	–
	Roof, inclined	–	**100**	92	67	41	32	40	63	88
	Facade	–	61	58	41	28	21	25	36	53
Flat-plate collector for hot water, SFH	Roof, horizontal	70	–	–	–	–	–	–	–	–
	Roof, inclined	–	**100**	95	71	45	35	43	67	92
	Facade	–	64	64	45	24	17	22	39	58
Flat-plate collector for hot water and space heating, SFH	Roof, horizontal	59	–	–	–	–	–	–	–	–
	Roof, inclined	–	**100**	88	62	35	25	34	58	83
	Facade	–	62	57	38	18	12	16	31	51
Tube collector for hot water and space heating, SFH	Roof, horizontal	60	–	–	–	–	–	–	–	–
	Roof, inclined	–	**100**	88	63	38	29	36	59	83
	Facade	–	66	59	40	21	16	20	35	54

The table shows the yields of differently oriented systems relative to the best possible orientation to the sun (south, sloping roof).
Data source: Energieschweiz Solarrechner (Tachion), see table "Absolute yields" below.

Absolute yields in kWh/(m²×a)

Collector type and application	Placement	annual usable final energy kWh/(m²×a), for different orientations								
		hori-zontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Flat-plate collector for hot water, MFH	Roof, horizontal	340	–	–	–	–	–	–	–	–
	Roof, inclined	–	537	492	360	221	173	214	340	474
	Facade	–	326	311	220	153	113	137	192	284
Flat-plate collector for hot water, SFH	Roof, horizontal	323	–	–	–	–	–	–	–	–
	Roof, inclined	–	463	441	331	207	162	199	312	425
	Facade	–	298	298	207	112	77	102	179	269
Flat-plate collector for hot water and space heating, SFH	Roof, horizontal	200	–	–	–	–	–	–	–	–
	Roof, inclined	–	338	297	209	118	85	114	195	282
	Facade	–	209	193	127	60	42	54	106	172
Tube collector for hot water and space heating, SFH	Roof, horizontal	240	–	–	–	–	–	–	–	–
	Roof, inclined	–	400	353	254	150	116	146	236	334
	Facade	–	266	235	160	84	66	80	139	214

Data source: Energieschweiz Solarrechner (Tachion), https://www.energieschweiz.ch/tools/solarrechner/, accessed 2022-03-18.
Location 8049 Zürich, roof inclination 37°.
SFH = single-familiy house MINERGIE, 200 m² living space, 5 people. MFH = multi-family house, 20 people (assumptions by chair Gigon/Guyer)
Collector type "Standardkollektor", automatic dimensioning of the system size by the calculator.
The system includes a storage tank of approx. 100 l/m² collector area (not included in environmental parameters).
The yields were determined from the difference between the calculation results with and without a solar system (electric heating).

Comparison: Solar thermal system vs. heat pump with Swiss grid electricity

Dividing the embodied energy and emissions by the energy yield gives the environmental parameters of the self-produced heat from solar thermal energy, which can be compared with other systems. Instead of a solar thermal system, the heating can also be provided with a heat pump. The electrical energy from the power grid is "multiplied" by the heat pump (e.g. annual performance factor 3.0: one kWh of electricity becomes three kWh of heat). The comparison provides a rough guide as to whether solar thermal energy is more environmentally friendly on a specific roof/facade surface than the combination of heat pump + grid electricity. More precise calculations are required in individual cases. *[Comparison with gas heating not shown; solar thermal is definitely better here!]*

Environmental parameters for useful heat from solar thermal energy (worse than / equal to / better than benchmark)

Collector type and application	Placement	Primary energy non-renewable: kWh oil-eq/kWh, for different orientations									Greehouse gas emissions: g CO2-eq/kWh, for different orientations								
		horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°	horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Flat-plate collector for hot water, MFH	Roof, horizontal	0.07	–	–	–	–	–	–	–	–	17	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.04	0.05	0.06	0.10	0.13	0.10	0.07	0.05	–	11	11	16	25	33	26	17	12
	Facade	–	0.07	0.07	0.10	0.15	0.20	0.16	0.12	0.08	–	17	18	26	37	50	41	29	20
Flat-plate collector for hot water, SFH	Roof, horizontal	0.11	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.08	0.08	0.11	0.17	0.22	0.18	0.11	0.08	–	21	22	29	47	60	49	31	23
	Facade	–	0.12	0.12	0.17	0.32	0.46	0.35	0.20	0.13	–	32	32	47	86	125	94	54	36
Flat-plate collector for hot water and space heating, SFH	Roof, horizontal	0.13	–	–	–	–	–	–	–	–	34	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.08	0.09	0.12	0.22	0.31	0.23	0.13	0.09	–	20	23	32	57	80	60	35	24
	Facade	–	0.13	0.14	0.21	0.44	0.62	0.49	0.25	0.15	–	33	35	53	114	161	127	64	39
Tube collector for hot water and space heating, SFH	Roof, horizontal	0.12	–	–	–	–	–	–	–	–	32	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.07	0.08	0.12	0.20	0.26	0.20	0.12	0.09	–	19	22	30	51	67	53	33	23
	Facade	–	0.11	0.13	0.19	0.35	0.45	0.37	0.21	0.14	–	29	33	48	92	117	96	55	36
Benchmark hot water / space heating and hot water heat pump with grid electricity		1.04 / 0.69									63 / 42								

Calculation of benchmarks for useful heat, generated with a heat pump on grid electricity: environmental parameters for electricity ÷ annual performance factor of the heat pump (APF)
Env. parameters of 1 kWh Swiss grid electricity (consumer mix): Primary energy non-renewable 2.08 kWh oil-eq Greenhouse gas emissions 125 g CO2-eq
APF hot water: 2.0 (because of the high temperatures required for hot water)
APF space heating and hot water: 3.0 (mean value from APF 2.0 for hot water and APF 4.0 for space heating)

Example flat-plate collector for hot water, MFH, flat roof: Primary energy non-renewable 22.3 kWh oil-eq/(m²×a) ÷ yield 340 kWh/(m²×a) = 0.07 kWh oil-eq/kWh useful heat.
This is better than the benchmark (primary energy non-renewable 2.08 kWh oil-eq/kWh grid electricity ÷ APF heat pump 2.0 = 1.04 kWh oil-eq/kWh useful heat).
Storage and distribution are not taken into account here (embodied energy and emissions, and efficiency losses), as are the embodied energy and emissions of the heat pump.

Comparison: Solar thermal system vs. heat pump with PV electricity

Dividing the embodied energy and emissions by the energy yield gives the environmental parameters of the self-produced heat from solar thermal energy, which can be compared with other systems. Instead of a solar thermal system, the heating can also be provided with a heat pump in combination with a photovoltaic system. The photovoltaic electrical energy is "multiplied" by the heat pump (e.g. annual performance factor 3.0: one kWh of electricity becomes three kWh of heat).
The comparison provides a rough orientation for deciding which system type a roof or facade surface should be used for.
More precise calculations are required in individual cases. *[Comparison with gas heating not shown; solar thermal is definitely better here!]*

Environmental parameters for useful heat from solar thermal energy (worse than / equal to / better than benchmark)

Collector type and application	Placement	Primary energy non-renewable: kWh oil-eq/kWh, for different orientations									Greehouse gas emissions: g CO2-eq/kWh, for different orientations								
		horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°	horizontal	0° south	45°	90° west	135°	180° north	-135°	-90° east	-45°
Flat-plate collector for hot water, MFH	Roof, horizontal	0.07	–	–	–	–	–	–	–	–	17	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.04	0.05	0.06	0.10	0.13	0.10	0.07	0.05	–	11	11	16	25	33	26	17	12
	Facade	–	0.07	0.07	0.10	0.15	0.20	0.16	0.12	0.08	–	17	18	26	37	50	41	29	20
Flat-plate collector for hot water, SFH	Roof, horizontal	0.11	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.08	0.08	0.11	0.17	0.22	0.18	0.11	0.08	–	21	22	29	47	60	49	31	23
	Facade	–	0.12	0.12	0.17	0.32	0.46	0.35	0.20	0.13	–	32	32	47	86	125	94	54	36
Flat-plate collector for hot water and space heating, SFH	Roof, horizontal	0.13	–	–	–	–	–	–	–	–	34	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.08	0.09	0.12	0.22	0.31	0.23	0.13	0.09	–	20	23	32	57	80	60	35	24
	Facade	–	0.13	0.14	0.21	0.44	0.62	0.49	0.25	0.15	–	33	35	53	114	161	127	64	39
Tube collector for hot water and space heating, SFH	Roof, horizontal	0.12	–	–	–	–	–	–	–	–	32	–	–	–	–	–	–	–	–
	Roof, inclined	–	0.07	0.08	0.12	0.20	0.26	0.20	0.12	0.09	–	19	22	30	51	67	53	33	23
	Facade	–	0.11	0.13	0.19	0.35	0.45	0.37	0.21	0.14	–	29	33	48	92	117	96	55	36
Benchmark hot water / space heating and hot water heat pump with PV electricity		variable									variable								

Calculation of benchmarks for useful heat, generated with a heat pump on PV electricity: environmental parameters for electricity ÷ annual performance factor of the heat pump (APF)
Environmental parameters of PV Electricity: See calculations for monocrystalline silicon modules in table "Comparison: Photovoltaic vs. Swiss grid electricity"
APF hot water: 2.0 (because of the high temperatures required for hot water)
APF space heating and hot water: 3.0 (mean value from APF 2.0 for hot water and APF 4.0 for space heating)

Example flat-plate collector for hot water, MFH, flat roof: Primary energy non-renewable 22.3 kWh oil-eq/(m²×a) ÷ yield 340 kWh/(m²×a) = 0.07 kWh oil-eq/kWh useful heat.
This is better than the benchmark (primary energy non-renewable 0.18 kWh oil-eq/kWh PV electricity ÷ APF heat pump 2.0 = 0.09 kWh oil-eq/kWh useful heat).
Storage and distribution are not taken into account here (embodied energy and emissions, and efficiency losses), as are the embodied energy and emissions of the heat pump.

KBOB LCA DATA TABLES (MARCH 2022, EXCERPT)

Karin Sander, XML-SVG/ Sourcecode, Datascape Laboral, 2014, Photo: ©Marcos Morilla

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

••• AUSZUG •••
gelb unterlegt: Fokus auf Kennwerte im Kontext Architektur und Entwurf
Professur Annette Gigon / Mike Guyer, D-ARCH, ETH Zürich, zum Herbstsemester 2022

Die Ökobilanz-Kennwerte wurden mit aktualisierten Hintergrunddaten (UVEK Ökobilanzdatenbestand DQRv2:2022) gerechnet. Neu werden in der Excel-Datei die Indikatoren "Primärenergie, stofflich genutzt" (differenziert nach erneuerbar und nicht erneuerbar) sowie der Gehalt an biogenem Kohlenstoff (in kg C) aufgeführt. Zudem wurden die Sachbilanzen einzelner Baumaterialien (Durchschnitt und herstellerspezifische), Gebäudetechnikelemente, Energiesysteme, Transportsysteme und Entsorgung aktualisiert beziehungsweise neu hinzugefügt.

Legende:
schwarz:
aktualisierte Hintergrunddaten (Sachbilanzdaten unverändert)
rot:
- Zahlen in rot: Sachbilanz- und Hintergrunddaten bei bestehenden Datensätzen aktualisiert (z.B. ID-Nr. 00.001)
- ganze Zeile rot: Datensatz neu in die KBOB-Empfehlung 2009/1:2022 aufgenommen (z.B. ID-Nr. 03.021)
blau schattiert (nur in der Excel-Datei verfügbar):
hersteller- oder herstellerregionenspezifische Datensätze

Sortierkriterien für die KBOB-Ökobilanzdaten 2022:
1. Gruppe gemäss vorderem Teil der ID-Nummer (z.B. ID-Nr. 06.xxx)
2. innerhalb Gruppe alphabetisch nach Name in deutscher Sprache

Auf www.kbob.ch > Publikationen > Nachhaltiges Bauen, sind zwei Dateien platziert:

Die pdf-Datei «Ökobilanzdaten im Baubereich 2009/1:2022» soll den Planenden den Einstieg in diese Thematik erleichtern. Sie enthält für die Schweiz repräsentative Daten für Baumaterialien und Gebäudetechnik (Herstellung, Entsorgung), Energie sowie Transporte (Betrieb, Fahrzeug, Infrastruktur).

Die Excel-Datei «Ökobilanzdaten im Baubereich 2009/1:2022» enthält zusätzlich die Ergebnisse des Indikators "Primärenergie, gesamt", "Primärenergie, gesamt, stofflich genutzt", "Primärenergie, erneuerbar, stofflich genutzt", Primärenergie, nicht erneuerbar, stofflich genutzt", "biogener Kohlenstoff im Produkt", herstellerspezifische Daten sowie die Daten zu den bauspezifischen Entsorgungsprozessen. Die Excel-Datei stellt ein Arbeitsinstrument dar.

Gesamtbewertung	Teilbewertung			
UBP'21	**Primärenergie (PE)**		**Treibhausgasemissionen (THG-E)**	**biogener Kohlenstoffgehalt**
	erneuerbar	**nicht erneuerbar (Graue Energie)**		
Die Umweltbelastungspunkte 2021 (UBP'21) gemäss der Methode der ökologischen Knappheit quantifizieren die Umweltbelastungen durch die Nutzung von Energie- und stofflichen Ressourcen, von Land und Süsswasser, durch Emissionen in Luft, Gewässer und Boden, durch die Ablagerung von Rückständen aus der Abfallbehandlung sowie durch Verkehrslärm.	Die erneuerbare Primärenergie quantifiziert den kumulierten Energieaufwand der erneuerbaren Energieträger. Die erneuerbaren Energieträger umfassen Wasserkraft, Holz / Biomasse (ohne Kahlschlag von Primärwäldern), Sonnen-, Wind-, geothermische Energie und Umgebungswärme. Primärenergie erneuerbar und nicht erneuerbar bilden addiert die Primärenergie gesamt. Stofflich und energetisch genutzte Primärenergie werden separat ausgewiesen (in der Excel-Version).	Die nicht erneuerbare Primärenergie (Graue Energie) quantifiziert den kumulierten Energieaufwand der fossilen und nuklearen Energieträger sowie Holz aus Kahlschlag von Primärwäldern. Primärenergie erneuerbar und nicht erneuerbar bilden addiert die Primärenergie gesamt. Stofflich und energetisch genutzte Primärenergie werden separat ausgewiesen (in der Excel-Version).	Die Treibhausgasemissionen quantifizieren die kumulierten Wirkungen verschiedener Treibhausgase bezogen auf die Leitsubstanz CO_2. Die Treibhauswirkung wird auf Basis der Treibhauspotenziale des 5. Sachstandberichts des IPCC (2013) quantifiziert. Biogenes CO_2 wird als nicht klimawirksam betrachtet. Sein Treibhauspotenzial ist 0 kg CO_2-eq/kg. Von Verkehrsflugzeugen emittiertes CO_2 hat ein Treibhauspotenzial von 2.5 kg CO_2-eq/kg (RFI-Faktor 2.5).	Der biogene Kohlenstoffgehalt quantifiziert den in den Baumaterialien und Bauelementen (z.B. Fensterrahmen) enthaltenen biogenen Kohlenstoff, ausgedrückt in "kg C".
Die Umweltauswirkungen der Teilbewertungen sind in der Gesamtbewertung UBP enthalten.	Diese Kenngrösse ist Teil der Betrachtung gemäss 2000 Watt Gesellschaft. Mit der Summe aus Primärenergie erneuerbar und nicht erneuerbar wird die dem Gebäude zugeführte Energiemenge (Endenergie) gemäss Merkblatt SIA 2031 «Energieausweis für Gebäude» bewertet.	Mit dieser Kenngrösse wird die Bezugsgrösse gemäss Merkblatt SIA 2032 «Graue Energie von Gebäuden» und gemäss Merkblatt SIA 2040 „SIA-Effizienzpfad Gebäude" bewertet.	Mit dieser Kenngrösse werden die dem Gebäude zugeführte Energiemenge gemäss Merkblatt SIA 2031 «Energieausweis für Gebäude», die Bezugsgrösse gemäss Merkblatt SIA 2032 «Graue Energie von Gebäuden» sowie der Energieverbrauch gemäss Merkblatt SIA 2040 «SIA-Effizienzpfad Energie» bewertet.	Mit dieser Kenngrösse wird der in Holz, Stroh und weiteren nachwachsenden Rohstoffen enhaltene Kohlenstoff quantifiziert. Diese Kenngrösse basiert auf der europäischen Norm EN 15804:2012+A2:2019 zu den Grundregeln von Umweltproduktdeklarationen für die Produktkategorie Baumaterialien.
Die Beurteilung mit den Ökofaktoren Schweiz 2021 gemäss der Methode der ökologischen Knappheit zeigt in Umweltbelastungspunkten (UBP'21) ein vollständiges Bild der Umweltauswirkungen auf und basiert auf der Schweizerischen Umweltpolitik. Sie entspricht den Anforderungen eines „true and fair view" bezüglich Umweltinformationen.		**Die nicht erneuerbare Primärenergie (Graue Energie) ist ein im Baubereich etablierter Kennwert. Die Instrumente des Vereins ecobau (ecoDevis, ecoBKP-Merkblätter, ecoProdukte) sowie die Tools für die Berechnung der Erstellungsenergie für das Gebäudelabel Minergie-ECO stützen sich für eine gesamtheitliche Beurteilung neben zusätzlichen ökologischen Merkmalen auf diese Teilbewertung ab.**	**Die in dieser Empfehlung ausgewiesenen Treibhausgasemissionen sind ein Kennwert für die Klimaerwärmung. Sie sind nicht gleichbedeutend mit dem standortgebundenen CO_2-Ausstoss, welcher Gegenstand von Zielvereinbarungen zwischen Emittenten und der Eidgenossenschaft im Rahmen des CO_2-Gesetzes ist.**	**Der in dieser Empfehlung ausgewiesene biogene Kohlenstoffgehalt ist ein Kennwert für die Menge der in Gebäuden verbauten Baumaterialien auf Basis nachwachsender Rohstoffe.**

Ökobilanzen basieren auf Modellen, die von Wertvorstellungen geprägt sind. Somit sind die Ergebnisse nicht wertfrei. In dieser Empfehlung wurde für alle Materialien dieselbe Modellierungsmethode verwendet.
Werden andere Modellierungsmethoden verwendet, können die Ergebnisse anders aussehen.
Diese Informationen stammen aus zuverlässigen Quellen. Die Autoren oder ihre Organisationen lehnen jedoch jegliche Haftung für Schäden oder Verluste ab, die durch die Verwendung dieser Angaben entstehen könnten.
Die Verantwortung für die Nutzung der Informationen liegt ausschliesslich bei den sie Verwendenden

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	BAUMATERIALIEN	Rohdichte/ Flächen-masse	Bezug	UBP'21			Primärenergie										Treibhausgas-emissionen			Biogener Kohlenstoff
				UBP			erneuerbar					nicht erneuerbar (Graue Energie)								
				Total	Herstellung	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung	Entsorgung	im Produkt enthalten
				UBP	UBP	UBP	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg C
00	**Vorbereitungsarbeiten**	-																		
00.001	Baugrubensicherung, Bohrpfahlwand, gespriesst	-	m^2	1'390'000	1'230'000	169'000	134	125	125	0	9.15	2'230	1'980	1'980	0	249	911	850	61.1	0
00.002	Baugrubensicherung, Bohrpfahlwand, unverankert	-	m^2	1'320'000	1'160'000	169'000	120	110	110	0	9.15	2'040	1'800	1'800	0	249	872	810	61.1	0
00.003	Baugrubensicherung, Bohrpfahlwand, verankert	-	m^2	1'000'000	889'000	111'000	111	105	105	0	6.04	1'570	1'410	1'410	0	164	620	579	40.4	0
00.004	Baugrubensicherung, Nagelwand	-	m^2	222'000	198'000	24'500	24.3	23.0	23.0	0	1.33	336	300	300	0	36.1	140	131	8.87	0
00.005	Baugrubensicherung, Rühlwand, auskragend	-	m^2	447'000	407'000	39'300	108	106	106	0	2.15	886	828	828	0	57.9	276	262	14.4	0
00.006	Baugrubensicherung, Rühlwand, gespriesst	-	m^2	317'000	294'000	23'000	47.3	46.1	46.1	0	1.25	651	617	617	0	33.9	193	185	8.34	0
00.007	Baugrubensicherung, Rühlwand, verankert	-	m^2	340'000	313'000	26'600	46.5	45.1	45.1	0	1.44	665	626	626	0	39.2	208	199	9.63	0
00.008	Baugrubensicherung, Schlitzwand, 400 mm	-	m^2	913'000	828'000	84'800	96.2	91.6	91.6	0	4.60	1'320	1'190	1'190	0	125	497	467	30.6	0
00.009	Baugrubensicherung, Schlitzwand, 800 mm	-	m^2	1'650'000	1'480'000	167'000	182	173	173	0	9.07	2'400	2'150	2'150	0	246	957	897	60.4	0
00.010	Baugrubensicherung, Spundwand, auskragend	-	m^2	289'000	287'000	1'710	44.4	44.3	44.3	0	0.089	733	729	729	0	4.18	170	169	1.07	0
00.011	Baugrubensicherung, Spundwand, gespriesst	-	m^2	163'000	162'000	935	24.4	24.4	24.4	0	0.048	413	411	411	0	2.29	96.3	95.7	0.585	0
00.012	Baugrubensicherung, Spundwand, verankert	-	m^2	327'000	321'000	5'500	53.7	53.4	53.4	0	0.294	800	789	789	0	10.0	190	188	2.52	0
00.013	Tiefgründung, Mikrobohrpfahl	-	m	59'800	59'800	0	8.68	8.68	8.68	0	0	118	118	118	0	0	35.4	35.4	0	0
00.014	Tiefgründung, Ortbetonbohrpfahl, 700 mm	-	m	296'000	296'000	0	30.4	30.4	30.4	0	0	411	411	411	0	0	184	184	0	0
00.015	Tiefgründung, Ortbetonbohrpfahl, 900 mm	-	m	435'000	435'000	0	46.9	46.9	46.9	0	0	572	572	572	0	0	275	275	0	0
00.016	Tiefgründung, Ortbetonbohrpfahl, 1200 mm	-	m	670'000	670'000	0	74.1	74.1	74.1	0	0	856	856	856	0	0	428	428	0	0
00.017	Tiefgründung, Ortbetonverdrängungspfahl 560/480 mm	-	m	149'000	149'000	0	14.9	14.9	14.9	0	0	246	246	246	0	0	91.0	91.0	0	0
00.018	Tiefgründung, Ortbetonverdrängungspfahl 660/580 mm	-	m	187'000	187'000	0	19.5	19.5	19.5	0	0	296	296	296	0	0	115	115	0	0
00.019	Tiefgründung, Rüttelstopfsäule	-	m	30'900	30'900	0	1.53	1.53	1.53	0	0	28.9	28.9	28.9	0	0	6.82	6.82	0	0
00.020	Tiefgründung, Vorgefertigter Betonpfahl	-	m	51'400	51'400	0	5.62	5.62	5.62	0	0	66.5	66.5	66.5	0	0	32.9	32.9	0	0
00.021	Wasserhaltung, Pumphöhe 2.5 m	-	m^3	21.0	21.0	0	0.022	0.022	0.022	0	0	0.084	0.084	0.084	0	0	0.005	0.005	0	0
00.022	Wasserhaltung, Pumphöhe 5 m	-	m^3	24.6	24.6	0	0.026	0.026	0.026	0	0	0.098	0.098	0.098	0	0	0.006	0.006	0	0
00.023	Wasserhaltung, Pumphöhe 7.5 m	-	m^3	28.6	28.6	0	0.031	0.031	0.031	0	0	0.114	0.114	0.114	0	0	0.007	0.007	0	0
00.024	Wasserhaltung, Pumphöhe 10 m	-	m^3	32.9	32.9	0	0.035	0.035	0.035	0	0	0.132	0.132	0.132	0	0	0.008	0.008	0	0
01	**Beton**	kg/m^3																		
01.001	Magerbeton (ohne Bewehrung)	2'150	kg	105	68.9	35.6	0.010	0.008	0.008	0	0.002	0.129	0.077	0.077	0	0.052	0.063	0.050	0.013	0
01.002	Hochbaubeton (ohne Bewehrung)	2'300	kg	154	118	35.4	0.015	0.013	0.013	0	0.002	0.175	0.124	0.124	0	0.052	0.101	0.089	0.013	0
01.003	Tiefbaubeton (ohne Bewehrung)	2'350	kg	164	128	35.4	0.016	0.014	0.014	0	0.002	0.189	0.138	0.138	0	0.052	0.109	0.096	0.013	0
01.004	Bohrpfahlbeton (ohne Bewehrung)	2'325	kg	175	139	35.3	0.017	0.015	0.015	0	0.002	0.198	0.146	0.146	0	0.051	0.119	0.107	0.013	0
01.041	Betonfertigteil, hochfester Beton, ab Werk	2'770	kg	589	558	31.2	0.082	0.080	0.080	0	0.002	0.871	0.825	0.825	0	0.046	0.358	0.347	0.011	0
01.042	Betonfertigteil, Normalbeton, ab Werk	2'500	kg	330	296	34.2	0.096	0.095	0.095	0	0.002	0.489	0.439	0.439	0	0.050	0.204	0.191	0.012	0
01.043	Hanfbeton	600	kg	665	663	1.69	0.899	0.899	0.061	0.839	0.000	0.959	0.959	0.959	0	0.000	0.324	0.324	0.000	0.065
Betonsortenrechner: Mit dem Betonsortenrechner (https://treeze.ch/de/rechner) können die Umweltkennwerte von spezifischen Betonen mit verschiedenen Zementtypen und Gesteinskörnungen berechnet werden.																				
02	**Mauersteine**	kg/m^3																		
02.001	Backstein	900	kg	372	329	42.7	0.080	0.078	0.078	0	0.002	0.788	0.735	0.735	0	0.053	0.267	0.254	0.013	0
02.002	Kalksandstein	1'400	kg	259	216	42.7	0.039	0.037	0.037	0	0.002	0.390	0.337	0.337	0	0.053	0.162	0.149	0.013	0
02.003	Leichtlehmstein	700	kg	354	311	42.7	0.793	0.790	0.790	0	0.002	0.764	0.712	0.712	0	0.053	0.180	0.167	0.013	0
02.004	Leichtzementstein, Blähton	1'200	kg	610	568	42.7	0.055	0.053	0.053	0	0.002	1.43	1.37	1.37	0	0.053	0.429	0.416	0.013	0
02.005	Leichtzementstein, Naturbims	1'200	kg	323	280	42.7	0.036	0.034	0.034	0	0.002	0.364	0.311	0.311	0	0.053	0.213	0.200	0.013	0
02.006	Porenbetonstein	500	kg	574	531	42.7	0.070	0.067	0.067	0	0.002	0.860	0.807	0.807	0	0.053	0.427	0.414	0.013	0
02.007	Zementstein	1'700	kg	215	172	42.7	0.026	0.024	0.024	0	0.002	0.226	0.173	0.173	0	0.053	0.127	0.114	0.013	0
03	**Andere Massivbaustoffe**	kg/m^3																		
03.021	Betongranulat	2'500	kg	43.6	3.18	40.4	0.004	0.001	0.001	0	0.002	0.062	0.009	0.009	0	0.053	0.014	0.001	0.013	0
03.001	Betonziegel	2'300	kg	327	284	42.7	0.037	0.035	0.035	0	0.002	0.469	0.416	0.416	0	0.053	0.209	0.196	0.013	0
03.002	Faserzement-Dachschindel	1'800	kg	1'100	1'040	68.0	0.490	0.489	0.489	0	0.002	2.16	2.11	2.11	0	0.053	0.700	0.687	0.013	0
03.003	Faserzementplatte gross	1'800	kg	1'520	1'450	68.0	0.614	0.613	0.613	0	0.002	2.93	2.87	2.87	0	0.053	1.04	1.02	0.013	0
03.004	Faserzement-Wellplatte	1'800	kg	1'060	992	68.0	0.552	0.550	0.550	0	0.002	1.78	1.73	1.73	0	0.053	0.650	0.636	0.013	0
03.005	Flachglas beschichtet	2'500	kg	2'000	1'930	69.2	0.255	0.243	0.243	0	0.012	4.64	4.53	4.53	0	0.109	1.20	1.19	0.019	0
03.006	Flachglas unbeschichtet	2'500	kg	1'790	1'720	69.2	0.139	0.127	0.127	0	0.012	4.08	3.97	3.97	0	0.109	1.14	1.12	0.019	0
03.007	Gipsfaserplatte	1'200	kg	875	803	71.8	0.098	0.094	0.094	0	0.004	2.47	2.40	2.40	0	0.079	0.553	0.534	0.019	0.045
03.008	Gipskartonplatte	850	kg	525	453	72.1	0.089	0.085	0.085	0	0.004	1.33	1.26	1.26	0	0.078	0.302	0.283	0.019	0.018
03.016	Gips-Wandbauplatte / Vollgipsplatte	1'000	kg	531	459	71.7	0.032	0.028	0.028	0	0.004	1.45	1.37	1.37	0	0.079	0.317	0.298	0.019	0
03.009	Hartsandsteinplatte	2'500	kg	113	70.0	42.7	0.045	0.043	0.043	0	0.002	0.276	0.223	0.223	0	0.053	0.041	0.028	0.013	0
03.017	Kalksteinplatte	2'500	kg	141	98.3	42.7	0.026	0.024	0.024	0	0.002	0.339	0.286	0.286	0	0.053	0.074	0.061	0.013	0
03.010	Keramik-/Steinzeugplatte	2'600	kg	4'110	4'060	42.7	0.208	0.206	0.206	0	0.002	3.73	3.67	3.67	0	0.053	0.796	0.783	0.013	0
03.011	Kies gebrochen	2'000	kg	65.2	24.8	40.4	0.008	0.005	0.005	0	0.002	0.085	0.032	0.032	0	0.053	0.018	0.005	0.013	0
03.022	Mischgranulat	2'400	kg	41.3	0.829	40.4	0.002	0.000	0.000	0	0.002	0.053	0.000	0.000	0	0.053	0.014	0.001	0.013	0
03.012	Rundkies	2'000	kg	59.7	19.3	40.4	0.004	0.002	0.002	0	0.002	0.069	0.016	0.016	0	0.053	0.016	0.003	0.013	0
03.013	Sand	2'000	kg	59.7	19.3	40.4	0.004	0.002	0.002	0	0.002	0.069	0.016	0.016	0	0.053	0.016	0.003	0.013	0
03.014	Sanitärkeramik	2'000	kg	4'690	4'650	42.7	0.355	0.353	0.353	0	0.002	11.1	11.1	11.1	0	0.053	2.38	2.37	0.013	0
03.020	Stampflehm	2'000	kg	80.1	32.0	48.2	0.005	0.005	0.005	0	0.000	0.080	0.075	0.075	0	0.005	0.019	0.018	0.001	0
03.015	Tonziegel	1'700	kg	515	480	35.9	0.035	0.033	0.033	0	0.002	1.12	1.06	1.06	0	0.052	0.386	0.373	0.013	0

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	BAUMATERIALIEN	Rohdichte/ Flächen-masse	Bezug	UBP'21			Primärenergie										Treibhausgas-emissionen			Biogener Kohlenstoff
				UBP			erneuerbar					nicht erneuerbar (Graue Energie)								
				Total	Herstellung	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung	Entsorgung	im Produkt enthalten
				UBP	UBP	UBP	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg C
04	**Mörtel und Putze**	kg/m³																		
04.008	Baukleber/Einbettmörtel mineralisch	1'400	kg	634	591	42.7	0.173	0.171	0.171	0	0.002	1.53	1.47	1.47	0	0.053	0.406	0.393	0.013	0
04.010	Baukleber/Einbettmörtel mineralisch Leichtzuschlag	1'100	kg	639	596	42.7	0.153	0.150	0.150	0	0.002	1.61	1.56	1.56	0	0.053	0.427	0.414	0.013	0
04.002	Baukleber/Einbettmörtel organisch	1'670	kg	1'400	1'350	42.7	0.161	0.159	0.159	0	0.002	4.15	4.10	4.10	0	0.053	0.779	0.766	0.013	0
04.017	Gips-Kalk-Putz	925	kg	251	209	42.7	0.065	0.063	0.063	0	0.002	0.675	0.622	0.622	0	0.053	0.158	0.145	0.013	0
04.001	Gips-/Weissputz	1'100	kg	242	199	42.7	0.063	0.061	0.061	0	0.002	0.681	0.628	0.628	0	0.053	0.151	0.138	0.013	0
04.003	Kunststoffputz (Dispersionsputz)	1'540	kg	1'740	1'700	42.7	0.236	0.234	0.234	0	0.002	5.20	5.15	4.37	0.779	0.053	0.972	0.959	0.013	0
04.013	Kalk-Zement/Zement-Kalk-Putz	1'550	kg	396	354	42.7	0.135	0.133	0.133	0	0.002	0.716	0.663	0.663	0	0.053	0.264	0.251	0.013	0
04.004	Lehmputz	1'800	kg	96.5	53.8	42.7	0.019	0.017	0.017	0	0.002	0.173	0.120	0.120	0	0.053	0.033	0.020	0.013	0
04.015	Leichtputz mineralisch	1'000	kg	575	533	42.7	0.163	0.161	0.161	0	0.002	1.23	1.18	1.18	0	0.053	0.373	0.360	0.013	0
04.011	Silikatputz (Dispersionssilikatputz)	1'880	kg	1'880	1'840	42.7	0.275	0.273	0.273	0	0.002	5.49	5.44	5.44	0	0.053	1.08	1.07	0.013	0
04.012	Silikonharzputz	1'670	kg	2'010	1'970	42.7	0.358	0.355	0.355	0	0.002	6.09	6.04	6.04	0	0.053	1.14	1.13	0.013	0
04.016	Sumpfkalkputz	1'350	kg	747	704	42.7	0.129	0.127	0.127	0	0.002	1.77	1.72	1.72	0	0.053	0.511	0.498	0.013	0
04.005	Unterlagsboden Anhydrit, 60 mm	2'000	kg	216	173	42.7	0.032	0.030	0.030	0	0.002	0.430	0.377	0.377	0	0.053	0.092	0.079	0.013	0
04.006	Unterlagsboden Zement, 85 mm	1'850	kg	206	163	42.7	0.036	0.034	0.034	0	0.002	0.232	0.179	0.179	0	0.053	0.120	0.108	0.013	0
04.007	Wärmedämmputz EPS	250	kg	965	922	42.7	0.149	0.147	0.147	0	0.002	1.79	1.74	1.31	0.424	0.053	0.727	0.715	0.013	0
04.014	Weisszementputz	1'550	kg	508	465	42.7	0.139	0.137	0.137	0	0.002	0.902	0.849	0.849	0	0.053	0.354	0.341	0.013	0
04.009	Zementputz	1'550	kg	392	349	42.7	0.127	0.125	0.125	0	0.002	0.655	0.602	0.602	0	0.053	0.261	0.249	0.013	0
05	**Fenster, Sonnenschutz, Fassadenverkleidungen**	kg/m²																		
05.008	Fassade, Pfosten-Riegel, Alu/Glas [1]	-	m²	349'000	334'000	15'500	74.3	73.8	73.8	0	0.481	723	718	718	0	5.24	193	180	13.1	0
05.022	Fassadenplatte, Aluverbund, 4 mm	7.1	m²	74'900	66'700	8'270	23.9	23.8	23.8	0	0.050	192	192	192	0	0.874	43.4	35.7	7.65	0
05.023	Fassadenplatte, Hochdrucklaminatplatte (HPL), 8.1 mm	11.6	m²	73'400	58'400	15'000	83.7	83.5	46.7	36.7	0.202	198	195	168	26.5	3.07	46.0	33.4	12.6	3.28
05.025	Fassadenplatte, Kalkstein, 30 mm	78	m²	11'000	7'670	3'330	2.04	1.87	1.87	0	0.171	26.4	22.3	22.3	0	4.12	5.75	4.75	1.00	0
05.024	Fassadenplatte, Kunststoff glasfaserverstärkt (GFK), 1.6 mm	2.4	m²	31'700	25'700	6'010	3.55	3.52	3.52	0	0.029	75.4	74.8	65.8	9.02	0.657	22.2	16.6	5.51	0
05.004	Fensterrahmen Aluminium [2]	-	m²	247'000	230'000	16'200	77.1	77.0	77.0	0	0.105	554	552	552	0	1.99	133	118	14.9	0
05.005	Fensterrahmen Holz [2]	-	m²	78'000	70'800	7'130	190	190	104	85.7	0.037	172	170	160	9.80	2.01	36.4	30.5	5.89	7.50
05.006	Fensterrahmen Holz-Metall [2]	-	m²	134'000	126'000	8'240	179	179	107	71.4	0.038	300	298	286	12.2	1.91	65.9	58.8	7.12	6.25
05.007	Fensterrahmen Kunststoff/PVC [2]	-	m²	115'000	103'000	11'800	15.4	14.9	14.9	0	0.485	328	323	242	81.1	5.32	63.5	53.3	10.2	0
05.001	Isolierverglasung 2-fach, Ug-Wert 1.1 W/m²K, Dicke 24 mm [3]	-	m²	70'800	65'900	4'910	10.3	9.98	9.98	0	0.272	167	165	165	0	2.67	44.4	40.8	3.61	0
05.009	Isolierverglasung 2-fach, Ug-Wert 1.1 W/m²K, Dicke 18 mm [3]	-	m²	79'000	74'900	4'100	12.8	12.6	12.6	0	0.267	195	192	192	0	2.58	48.6	45.8	2.85	0
05.010	Isolierverglasung 2-fach, ESG, Ug-Wert 1.1 W/m²K [3]	-	m²	87'100	82'200	4'910	18.5	18.2	18.2	0	0.272	216	214	214	0	2.67	52.2	48.5	3.61	0
05.002	Isolierverglasung 2-fach, VSG, Ug-Wert 1.1 W/m²K [3]	-	m²	128'000	120'000	8'740	21.2	20.7	20.7	0	0.416	324	320	320	0	4.14	79.4	72.7	6.68	0
05.011	Isolierverglasung 2-fach, ESG/VSG, Ug-Wert 1.1 W/m²K [3]	-	m²	145'000	136'000	8'740	29.4	29.0	29.0	0	0.416	373	369	369	0	4.14	87.2	80.5	6.68	0
05.003	Isolierverglasung 3-fach, Ug-Wert 0.5 W/m²K, Dicke 36 mm [3]	-	m²	128'000	121'000	6'840	22.6	22.1	22.1	0	0.404	320	316	316	0	3.95	78.4	73.4	4.92	0
05.012	Isolierverglasung 3-fach, Ug-Wert 0.6 W/m²K, Dicke 40 mm [3]	-	m²	110'000	103'000	7'690	16.1	15.7	15.7	0	0.410	255	251	251	0	4.03	67.9	62.2	5.71	0
05.013	Isolierverglasung 3-fach, ESG/ESG, Ug-Wert 0.6 W/m²K [3]	-	m²	143'000	135'000	7'690	32.7	32.3	32.3	0	0.410	353	349	349	0	4.03	83.4	77.7	5.71	0
05.014	Isolierverglasung 3-fach, ESG/ESG/ESG, Ug-Wert 0.6 W/m²K [3]	-	m²	159'000	151'000	7'690	40.9	40.5	40.5	0	0.410	402	398	398	0	4.03	91.2	85.5	5.71	0
05.015	Isolierverglasung 3-fach, VSG, Ug-Wert 0.6 W/m²K [3]	-	m²	168'000	156'000	11'500	26.9	26.3	26.3	0	0.554	412	406	406	0	5.50	103	94.2	8.79	0
05.016	Isolierverglasung 3-fach, ESG/VSG, Ug-Wert 0.6 W/m²K [3]	-	m²	186'000	174'000	11'500	35.4	34.9	34.9	0	0.554	465	459	459	0	5.50	112	103	8.79	0
05.020	Putzträgerplatte kunstharzgebunden 13 mm	6.3	m²	16'700	16'400	269	3.58	3.57	3.57	0	0.014	44.3	44.0	44.0	0	0.333	8.12	8.04	0.081	0
05.021	Putzträgerplatte mineralisch gebunden 12.5 mm	14.4	m²	9'940	9'320	615	2.44	2.40	2.40	0	0.032	19.1	18.3	18.3	0	0.761	6.32	6.13	0.185	0
05.026	Rahmenverbreiterung, PVC	15.0	m²	99'800	66'500	33'300	41.8	40.8	32.9	7.87	1.04	306	294	206	87.6	12.5	69.7	39.6	30.1	0.778
05.027	Rahmenverbreiterung, Spanplatte	17.8	m²	43'600	36'000	7'600	94.4	94.2	35.1	59.2	0.121	124	121	91.9	28.8	3.53	26.1	19.5	6.59	6.68
05.018	Sonnenschutz, Ausstellstoren motorisiert [4]	-	m²	151'000	149'000	2'110	35.5	35.4	35.4	0	0.029	283	282	278	4.13	0.544	67.9	66.0	1.91	0
05.017	Sonnenschutz, Lamellenstoren motorisiert [4]	-	m²	133'000	131'000	1'620	31.9	31.9	31.9	0	0.025	249	249	249	0	0.435	60.0	58.6	1.47	0
05.019	Sonnenschutz, Rollladen motorisiert [4]	-	m²	168'000	167'000	801	43.9	43.9	43.9	0	0.021	314	313	313	0	0.408	74.8	74.1	0.695	0
06	**Metallbaustoffe**	kg/m³																		
06.001	Aluminiumblech, blank	2'690	kg	12'500	12'500	19.9	5.22	5.22	5.22	0	0.001	24.8	24.8	24.8	0	0.032	5.59	5.58	0.008	0
06.002	Aluminiumprofil, blank	2'690	kg	11'500	11'400	19.9	5.24	5.24	5.24	0	0.001	25.6	25.6	25.6	0	0.032	5.70	5.69	0.008	0
06.003	Armierungsstahl	7'850	kg	2'930	2'910	19.7	0.422	0.420	0.420	0	0.002	4.99	4.94	4.94	0	0.051	1.52	1.50	0.012	0
06.014	Blei	11'340	kg	3'810	3'790	19.9	0.240	0.240	0.240	0	0.001	3.84	3.81	3.81	0	0.032	1.02	1.01	0.008	0
06.004	Chromnickelstahlblech 18/8 blank	7'900	kg	9'710	9'700	11.2	2.39	2.39	2.39	0	0.001	14.6	14.5	14.5	0	0.027	4.12	4.12	0.007	0
06.005	Chromnickelstahlblech 18/8 verzinnt	7'900	kg	13'000	13'000	11.2	2.65	2.65	2.65	0	0.001	22.3	22.3	22.3	0	0.027	5.88	5.88	0.007	0
06.006	Chromstahlblech blank	7'700	kg	7'080	7'070	11.2	0.961	0.960	0.960	0	0.001	8.54	8.51	8.51	0	0.027	2.74	2.73	0.007	0
06.007	Chromstahlblech verzinnt	7'700	kg	10'400	10'400	11.2	1.22	1.22	1.22	0	0.001	16.2	16.2	16.2	0	0.027	4.50	4.49	0.007	0
06.008	Kupferblech, blank	8'900	kg	24'500	24'500	19.9	1.62	1.62	1.62	0	0.001	8.91	8.88	8.88	0	0.032	2.21	2.20	0.008	0
06.009	Messing-/Baubronzeblech	8'300	kg	25'500	25'500	19.9	1.88	1.88	1.88	0	0.001	11.1	11.1	11.1	0	0.032	2.72	2.71	0.008	0
06.010	Stahlblech, blank	7'850	kg	5'270	5'260	11.2	0.613	0.612	0.612	0	0.001	7.80	7.78	7.78	0	0.027	2.80	2.79	0.007	0
06.011	Stahlblech, verzinkt	7'850	kg	15'200	15'200	11.2	1.38	1.37	1.37	0	0.001	15.6	15.6	15.6	0	0.027	4.49	4.49	0.007	0
06.012	Stahlprofil, blank	7'850	kg	1'300	1'280	11.2	0.246	0.245	0.245	0	0.001	3.38	3.35	3.35	0	0.027	0.738	0.731	0.007	0
06.013	Titanzinkblech	7'200	kg	27'800	27'800	19.9	2.60	2.59	2.59	0	0.001	17.5	17.4	17.4	0	0.032	4.03	4.02	0.008	0

[1] Bezugsgrösse Fassade: Glas- und Rahmenfläche
[2] Bezugsgrösse Fensterrahmen: Maueröffnung
[3] Bezugsgrösse Isolierverglasung: Glasfläche
[4] Bezugsgrösse Sonnenschutz: Fensterlichtmass

Fensterrechner: Mit dem Fensterrechner (https://treeze.ch/de/rechner) können Umweltkennwerte von Fenstern mit projektspezifischen Abmessungen und Eigenschaften berechnet werden.

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	BAUMATERIALIEN	Rohdichte/ Flächen-masse	Bezug	UBP'21			Primärenergie										Treibhausgas-emissionen			Biogener Kohlenstoff
				UBP			erneuerbar					nicht erneuerbar (Graue Energie)								
				Total	Herstellung	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung total	Herstellung energetisch genutzt	Herstellung stofflich genutzt	Entsorgung	Total	Herstellung	Entsorgung	im Produkt enthalten
				UBP	UBP	UBP	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg C
07	**Holz und Holzwerkstoffe**	kg/m³																		
07.001	3- und 5-Schicht Massivholzplatte	453	kg	1'020	935	80.7	13.3	13.2	8.30	4.95	0.006	2.18	2.09	1.75	0.337	0.093	0.471	0.415	0.056	0.433
07.021	Balkenschichtholz	439	kg	792	718	74.2	8.59	8.58	3.49	5.09	0.006	1.56	1.47	1.38	0.097	0.091	0.343	0.294	0.049	0.446
07.003	Brettschichtholz	439	kg	772	698	74.2	8.14	8.13	3.07	5.06	0.006	1.54	1.45	1.30	0.142	0.091	0.336	0.287	0.049	0.446
07.020	Brettsperrholz	436	kg	884	777	107	8.12	8.11	2.99	5.12	0.006	1.82	1.73	1.64	0.089	0.098	0.397	0.317	0.080	0.449
07.022	Furniersperrholz	823	kg	1'980	1'870	107	9.24	9.24	4.72	4.52	0.006	5.08	4.98	4.05	0.933	0.098	1.02	0.944	0.080	0.410
07.004	Hartfaserplatte	955	kg	1'770	1'700	68.8	7.04	7.03	1.85	5.18	0.006	4.13	4.04	3.78	0.260	0.090	1.07	1.03	0.044	0.455
07.005	Holzwolle-Leichtbauplatte, zementgebunden	400	kg	773	687	86.5	2.04	2.03	0.491	1.54	0.010	1.28	1.10	1.10	0	0.171	0.536	0.499	0.036	0.138
07.023	Konstruktionsvollholz	436	kg	691	622	68.8	8.28	8.27	3.13	5.15	0.006	1.25	1.15	1.14	0.011	0.090	0.290	0.245	0.044	0.450
07.008	Massivholz Buche / Eiche, kammergetrocknet, gehobelt	675	kg	438	375	63.3	7.28	7.27	2.32	4.95	0.006	0.664	0.575	0.575	0	0.089	0.153	0.114	0.039	0.451
07.007	Massivholz Buche / Eiche, kammergetrocknet, rau	675	kg	393	330	63.3	7.11	7.11	2.16	4.95	0.006	0.569	0.480	0.480	0	0.089	0.136	0.097	0.039	0.451
07.006	Massivholz Buche / Eiche, luftgetrocknet, rau	705	kg	324	261	63.3	6.21	6.20	1.66	4.54	0.006	0.480	0.390	0.390	0	0.089	0.121	0.082	0.039	0.413
07.011	Massivholz Fichte / Tanne / Lärche, kammergetr., gehobelt	465	kg	478	415	63.3	6.05	6.04	0.889	5.15	0.006	0.779	0.690	0.690	0	0.089	0.174	0.135	0.039	0.451
07.010	Massivholz Fichte / Tanne / Lärche, luftgetr., gehobelt	485	kg	402	339	63.3	5.21	5.21	0.484	4.72	0.006	0.674	0.585	0.585	0	0.089	0.157	0.118	0.039	0.413
07.009	Massivholz Fichte / Tanne / Lärche, luftgetrocknet, rau	485	kg	318	255	63.3	4.98	4.97	0.249	4.72	0.006	0.511	0.421	0.421	0	0.089	0.130	0.091	0.039	0.413
07.012	Mitteldichte Faserplatte (MDF), UF-gebunden	685	kg	1'550	1'420	129	5.85	5.84	1.23	4.61	0.006	4.48	4.37	3.20	1.17	0.102	0.956	0.856	0.100	0.396
07.013	OSB Platte, PF-gebunden, Feuchtbereich	605	kg	1'030	925	107	8.26	8.25	3.16	5.09	0.006	2.71	2.61	2.08	0.535	0.098	0.565	0.485	0.080	0.444
07.024	Röhrenspanplatte	272	kg	1'350	1'240	107	6.89	6.88	1.96	4.92	0.006	3.65	3.56	2.91	0.647	0.098	0.815	0.735	0.080	0.429
07.015	Spanplatte, PF-gebunden, Feuchtbereich	640	kg	889	782	107	4.36	4.36	0.778	3.58	0.006	2.56	2.46	1.61	0.856	0.098	0.531	0.451	0.080	0.417
07.016	Spanplatte, UF-gebunden, beschichtet, Trockenbereich	640	kg	1'210	1'090	122	4.69	4.68	1.22	3.46	0.006	3.70	3.60	2.47	1.13	0.099	0.737	0.642	0.095	0.417
07.014	Spanplatte, UF-gebunden, Trockenbereich	640	kg	889	782	107	4.36	4.36	0.778	3.58	0.006	2.56	2.46	1.61	0.856	0.098	0.531	0.451	0.080	0.417
07.018	Sperrholz/Multiplex, PF-gebunden, Feuchtbereich	500	kg	2'880	2'770	107	10.0	10.0	5.90	4.15	0.006	6.95	6.85	6.11	0.741	0.098	1.43	1.35	0.080	0.410
07.017	Sperrholz/Multiplex, UF-gebunden, Trockenbereich	500	kg	2'150	2'040	107	9.99	9.99	5.84	4.15	0.006	4.70	4.61	3.87	0.741	0.098	0.951	0.871	0.080	0.410
08	**Klebstoffe und Fugendichtungsmassen**	kg/m³																		
08.001	2-Komponenten Klebstoff	1'500	kg	10'100	9'910	236	0.354	0.352	0.352	0	0.002	24.3	24.2	24.2	0	0.056	4.84	4.65	0.187	0
08.002	Heissbitumen	1'000	kg	2'050	1'810	236	0.066	0.063	0.063	0	0.002	15.0	14.9	3.42	11.5	0.056	1.10	0.911	0.187	0
08.003	Kautschukdichtungsmasse	1'500	kg	6'880	6'640	236	0.288	0.286	0.286	0	0.002	24.4	24.4	16.2	8.14	0.056	2.42	2.24	0.187	0
08.004	Polysulfiddichtungsmasse	1'600	kg	2'890	2'660	236	0.413	0.411	0.411	0	0.002	7.81	7.75	6.51	1.24	0.056	1.72	1.53	0.187	0
08.005	Silicon-Fugenmasse	1'000	kg	4'580	4'340	236	1.86	1.86	1.86	0	0.002	14.5	14.4	6.27	8.14	0.056	2.91	2.72	0.187	0
09	**Dichtungsbahnen und Schutzfolien**	kg/m³																		
09.001	Dampfbremse bituminös	1'100	kg	5'230	2'790	2'430	0.661	0.646	0.646	0	0.015	13.5	13.2	5.64	7.57	0.268	3.64	1.31	2.33	0
09.002	Dampfbremse Polyethylen (PE)	920	kg	6'930	4'120	2'810	0.855	0.844	0.844	0	0.011	24.8	24.6	13.4	11.2	0.210	5.42	2.75	2.67	0
09.003	Dichtungsbahn bituminös	1'100	kg	4'360	1'930	2'430	0.271	0.256	0.256	0	0.015	12.3	12.0	4.66	7.37	0.268	3.34	1.01	2.33	0
09.004	Dichtungsbahn Gummi (EPDM)	1'100	kg	8'110	4'870	3'240	0.826	0.813	0.813	0	0.013	24.7	24.5	16.3	8.14	0.225	5.84	2.74	3.10	0
09.005	Dichtungsbahn Polyolefin (FPO)	1'000	kg	7'880	5'070	2'810	0.421	0.410	0.410	0	0.011	23.2	22.9	11.0	11.9	0.210	5.19	2.52	2.67	0
09.006	Kraftpapier	650	kg	3'460	3'250	207	13.0	13.0	8.38	4.61	0.013	7.74	7.56	7.56	0	0.173	1.67	1.62	0.059	0.404
09.007	Polyethylenfolie (PE)	920	kg	6'930	4'120	2'810	0.855	0.844	0.844	0	0.011	24.8	24.6	12.8	11.8	0.210	5.42	2.75	2.67	0
09.008	Polyethylenvlies (PE)	920	kg	7'100	4'290	2'810	0.544	0.533	0.533	0	0.011	26.0	25.7	13.9	11.8	0.210	5.63	2.96	2.67	0
10	**Wärmedämmstoffe**	kg/m³																		
10.014	Aerogel-Vlies	150	kg	73'600	73'200	409	12.1	12.1	12.1	0	0.012	230	229	229	0	0.175	48.8	48.5	0.289	0
10.012	Blähperlit	65-140	kg	1'460	1'420	42.7	0.164	0.162	0.162	0	0.002	4.46	4.41	4.41	0	0.053	1.06	1.04	0.013	0
10.011	Blähvermiculit	65-140	kg	690	647	42.7	0.050	0.048	0.048	0	0.002	1.56	1.51	1.51	0	0.053	0.396	0.383	0.013	0
10.016	Flachsfasern	30	kg	2'950	2'570	372	5.97	5.96	0.956	5.00	0.012	5.32	5.17	5.17	0	0.155	1.01	0.777	0.235	0.440
10.017	Flachsfasern, feuerfest	30	kg	3'530	3'160	372	5.47	5.46	0.456	5.00	0.012	7.52	7.36	7.36	0	0.155	1.45	1.22	0.235	0.440
10.001	Glaswolle	20-100	kg	1'960	1'850	116	2.35	2.34	2.34	0	0.011	5.46	5.33	5.33	0	0.133	1.10	1.04	0.060	0
10.002	Korkplatte	120	kg	2'170	2'000	173	7.94	7.92	3.77	4.15	0.012	6.24	6.09	5.09	1.00	0.149	1.11	1.07	0.039	0.496
10.003	Phenolharz (PF)	40	kg	10'000	6'740	3'280	0.598	0.586	0.586	0	0.012	33.5	33.3	26.3	7.00	0.203	7.27	4.17	3.09	0
10.004	Polystyrol expandiert (EPS)	15-40	kg	9'800	6'520	3'280	0.513	0.502	0.502	0	0.012	30.0	29.8	20.6	9.22	0.203	7.60	4.51	3.09	0
10.005	Polystyrol extrudiert (XPS)	30-35	kg	19'700	16'500	3'280	0.655	0.643	0.643	0	0.012	29.4	29.2	20.0	9.22	0.203	14.4	11.3	3.09	0
10.006	Polyurethan (PUR/PIR)	30	kg	10'400	7'500	2'930	0.824	0.807	0.807	0	0.017	30.1	29.5	20.9	8.58	0.683	7.45	4.80	2.65	0
10.007	Schaumglas	100-165	kg	1'760	1'720	42.7	1.88	1.88	1.88	0	0.002	5.17	5.12	5.12	0	0.053	1.19	1.18	0.013	0
10.013	Schaumglasschotter	125-150	kg	499	457	42.7	0.262	0.260	0.260	0	0.002	1.74	1.69	1.69	0	0.053	0.160	0.148	0.013	0
10.008	Steinwolle	32-160	kg	1'790	1'670	116	0.511	0.500	0.500	0	0.011	4.46	4.32	4.32	0	0.133	1.19	1.13	0.060	0
10.015	Strohballenwand	215	kg	586	586	0	4.87	4.87	0.095	4.78	0	0.229	0.229	0.229	0	0	0.096	0.096	0	0.368
10.009	Weichfaserplatte	148	kg	1'400	1'180	228	7.11	7.09	1.92	5.17	0.013	3.43	3.28	2.74	0.530	0.152	0.727	0.634	0.093	0.436
10.010	Zellulosefasern	35-60	kg	558	396	163	0.258	0.245	0.245	0	0.014	1.05	0.883	0.883	0	0.166	0.281	0.210	0.072	0.404
11	**Bodenbeläge**	kg/m²																		
11.001	2K-Fliessbelag Industrie (Epoxidharz), 2.25 mm	4.55	m²	41'800	33'500	8'250	1.52	1.44	1.44	0	0.081	65.1	62.8	53.7	9.12	2.27	18.4	11.2	7.24	0
11.002	2K-Fliessbelag Wohnen/Verwaltung (Epoxidharz, PU), 2 mm	3.6	m²	25'800	21'300	4'540	2.05	1.99	1.99	0	0.061	62.0	60.5	58.2	2.31	1.45	13.9	10.0	3.87	0
11.003	Gummigranulat versiegelt, 7.5 mm	8.25	m²	38'800	25'400	13'400	2.53	2.39	2.39	0	0.139	113	110	91.7	18.1	2.74	26.9	14.9	11.9	0
11.004	Gussasphalt, 27.5 mm	63.3	m²	33'800	24'700	9'080	3.40	3.25	3.25	0	0.154	126	120	62.2	58.2	5.42	16.0	14.7	1.23	0
11.005	Hartbeton einschichtig, 27.5 mm	57.8	m²	26'600	24'100	2'470	2.26	2.14	2.14	0	0.127	46.6	43.6	43.6	0	3.05	16.5	15.7	0.741	0
11.006	Hartbeton zweischichtig, 35 mm	73.5	m²	27'300	24'100	3'140	2.29	2.13	2.13	0	0.161	41.9	38.0	38.0	0	3.88	16.4	15.5	0.942	0
11.007	Kautschuk, 2 mm	3.36	m²	24'200	20'400	3'760	9.79	9.72	9.72	0	0.066	60.8	59.8	52.5	7.30	0.930	14.2	11.0	3.19	0
11.008	Keramik-/Steinzeugplatte, 9 mm	18	m²	87'000	73'100	13'800	4.41	3.70	3.70	0	0.709	83.3	66.1	66.1	0	17.1	18.2	14.1	4.15	0
11.009	Kork Fertigparkett, 10.5 mm	7.8	m²	15'600	13'400	2'140	39.1	39.0	7.73	31.3	0.099	45.2	43.8	38.1	5.72	1.37	9.08	7.78	1.30	2.73
11.010	Kork PVC-beschichtet, 3.2 mm	2.7	m²	12'000	7'900	4'060	8.35	8.25	2.56	5.69	0.095	34.7	33.3	28.9	4.37	1.43	8.28	4.76	3.53	0.604
11.011	Korkparkett geölt/versiegelt, 5.3 mm	2.7	m²	5'980	3'840	2'140	12.3	12.2	4.72	7.48	0.099	12.1	10.7	10.7	0	1.37	3.26	1.96	1.30	0.921

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	BAUMATERIALIEN	Rohdichte/ Flächen-masse	Bezug	UBP'21 UBP Total	UBP Herstellung	UBP Entsorgung	Primärenergie erneuerbar Total	erneuerbar Herstellung total	erneuerbar Herstellung energetisch genutzt	erneuerbar Herstellung stofflich genutzt	erneuerbar Entsorgung	nicht erneuerbar (Graue Energie) Total	nicht erneuerbar Herstellung total	nicht erneuerbar Herstellung energetisch genutzt	nicht erneuerbar Herstellung stofflich genutzt	nicht erneuerbar Entsorgung	Treibhausgas-emissionen Total	Treibhausgas Herstellung	Treibhausgas Entsorgung	Biogener Kohlenstoff im Produkt enthalten
				UBP	UBP	UBP	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq	kg C
11.012	Kunststeinplatte zementgebunden, 10 mm	21.5	m^2	25'900	6'110	19'800	1.76	0.750	0.750	0	1.01	30.5	6.05	6.05	0	24.4	10.4	4.51	5.92	0
11.013	Laminat, 8.5 mm	8.5	m^2	16'600	13'600	2'980	38.2	38.1	2.72	35.4	0.107	42.8	41.3	28.2	13.1	1.46	10.4	8.12	2.30	2.42
11.014	Linoleum, 2.5 mm	2.9	m^2	15'800	15'100	731	19.3	19.2	8.96	10.3	0.036	26.3	25.9	25.9	0	0.440	6.37	5.85	0.517	0.786
11.015	Natursteinplatte geschliffen, 15 mm	40.5	m^2	42'100	40'400	1'730	19.4	19.3	19.3	0	0.089	118	116	116	0	2.14	17.0	16.5	0.519	0
11.018	Parkett 2-Schicht werkversiegelt, 11 mm	6.1	m^2	16'100	15'700	493	87.5	87.5	58.3	29.2	0.037	42.3	41.7	40.6	1.18	0.566	7.83	7.49	0.338	2.69
11.019	Parkett 3-Schicht werkversiegelt, 15 mm	7.9	m^2	18'200	17'600	638	145	145	106	38.8	0.048	40.4	39.7	39.0	0.681	0.732	8.13	7.70	0.438	3.54
11.020	Parkett Mosaik werkversiegelt, 8 mm	5.6	m^2	9'050	8'700	355	89.9	89.9	65.2	24.7	0.034	23.3	22.8	22.8	0	0.499	3.59	3.37	0.219	2.23
11.021	PVC homogen, 2 mm	3.1	m^2	20'600	13'500	7'140	2.22	1.92	1.92	0	0.297	58.2	55.0	46.6	8.43	3.20	14.4	8.17	6.22	0
11.022	Steinholz versiegelt, 16.5 mm	22	m^2	16'400	15'500	940	0.961	0.913	0.913	0	0.048	25.2	24.0	24.0	0	1.16	13.0	12.7	0.282	0
11.023	Synthetische thermoplastische Beläge (TPO), 2 mm	3.4	m^2	20'000	9'520	10'500	3.17	3.14	3.14	0	0.030	43.3	42.6	30.2	12.4	0.642	16.0	5.88	10.1	0
11.024	Teppich Kunstfaser getuftet	2.1	m^2	21'200	14'700	6'470	0.585	0.566	0.566	0	0.019	50.0	49.6	38.3	11.3	0.396	16.7	10.5	6.25	0
11.025	Teppich Nadelfilz	1.3	m^2	12'700	8'700	4'010	0.596	0.584	0.584	0	0.012	34.3	34.0	23.6	10.4	0.245	9.85	5.98	3.87	0
11.026	Teppich Naturfaser	2.7	m^2	15'300	13'200	2'070	10.9	10.8	1.42	9.43	0.024	15.5	15.1	12.8	2.26	0.417	5.08	3.23	1.86	1.01
11.027	Terrazzo versiegelt, 40 mm	95	m^2	28'200	24'200	4'060	4.13	3.92	3.92	0	0.208	40.6	35.6	35.6	0	5.02	17.3	16.1	1.22	0
12	**Türen**	-																		
12.005	Aussentüre, Aluminium, Glaseinsatz	-	m^2	395'000	378'000	17'400	117	116	116	0	0.481	912	906	906	0	5.36	216	201	14.8	0
12.006	Aussentüre, Aluminium, Paneelfüllung	-	m^2	385'000	375'000	10'500	142	142	142	0	0.026	838	837	837	0	0.796	193	183	10.0	0
12.008	Aussentüre, Holz	-	m^2	125'000	116'000	9'290	283	283	102	181	0.138	265	261	234	26.3	4.19	62.3	54.7	7.65	15.5
12.001	Aussentüre, Holz, aluminiumbeplankt	-	m^2	231'000	222'000	9'290	328	328	147	181	0.138	506	502	475	26.3	4.19	116	108	7.65	15.5
12.002	Aussentüre, Holz, Glaseinsatz	-	m^2	161'000	149'000	12'200	246	246	92.6	153	0.316	359	353	331	21.2	6.33	85.9	76.2	9.71	13.0
12.007	Innentüre, Aluminium, Glaseinsatz	-	m^2	316'000	306'000	10'500	103	103	103	0	0.333	723	719	719	0	3.61	166	158	8.71	0
12.009	Innentüre, Funktionstüre, Holz, Holzrahmen	-	m^2	88'000	79'400	8'550	279	279	88.4	191	0.179	190	185	158	27.5	4.89	44.4	37.5	6.87	17.3
12.012	Innentüre, Funktionstüre, Holz, Stahlzarge	-	m^2	181'000	173'000	7'930	231	231	93.3	138	0.171	357	353	326	26.3	4.36	97.0	90.5	6.47	13.7
12.004	Innentüre, Zimmertüre, Holz, Glaseinsatz, Holzrahmen	-	m^2	109'000	100'000	8'900	200	200	72.6	127	0.275	255	250	235	14.9	5.25	59.8	52.9	6.93	11.0
12.011	Innentüre, Zimmertüre, Holz, Glaseinsatz, Stahlzarge	-	m^2	202'000	194'000	8'290	152	152	77.4	74.4	0.266	421	417	403	13.7	4.73	112	106	6.54	7.46
12.003	Innentüre, Zimmertüre, Holz, Holzrahmen	-	m^2	64'600	57'900	6'710	206	206	66.8	139	0.124	141	137	118	18.9	3.46	32.4	27.0	5.40	12.4
12.010	Innentüre, Zimmertüre, Holz, Stahlzarge	-	m^2	158'000	152'000	6'100	158	158	71.7	86.2	0.116	307	304	287	17.7	2.93	85.0	80.0	5.00	8.83
Türrechner: mit dem Türrechner (https://treeze.ch/de/rechner) können Umweltkennwerte von Türen mit projektspezifischen Abmessungen und Eigenschaften berechnet werden.																				
13	**Rohre**	kg/m^3																		
13.001	Acrylnitril-Butadien-Styrol (ABS)	1'050	kg	9'780	6'790	2'980	0.429	0.408	0.408	0	0.021	30.0	29.2	20.6	8.58	0.741	7.67	4.92	2.75	0
13.005	Gusseisen	7'850	kg	5'670	5'660	11.2	0.268	0.268	0.268	0	0.001	5.48	5.45	5.45	0	0.027	2.10	2.09	0.007	0
13.002	Polyethylen (PE)	960	kg	6'020	3'570	2'450	0.537	0.523	0.523	0	0.014	23.2	23.0	11.1	11.9	0.210	4.75	2.38	2.37	0
13.003	Polypropylen (PP)	910	kg	6'050	3'600	2'450	0.421	0.407	0.407	0	0.014	22.7	22.5	10.6	11.9	0.210	4.78	2.40	2.37	0
13.004	Polyvinylchlorid (PVC)	1'390	kg	6'250	3'880	2'370	0.637	0.536	0.536	0	0.101	19.5	18.4	12.4	6.02	1.10	4.49	2.38	2.10	0
14	**Anstrichstoffe, Beschichtungen**	kg/m^2																		
14.002	Anstrich, lösemittelverdünnbar, 2 Anstriche	0.300	m^2	2'270	2'200	70.8	0.450	0.449	0.449	0	0.001	6.57	6.56	5.65	0.905	0.017	0.976	0.920	0.056	0
14.001	Anstrich, wasserverdünnbar, 2 Anstriche	0.300	m^2	1'220	1'150	70.8	0.141	0.140	0.140	0	0.001	4.17	4.15	3.25	0.905	0.017	0.702	0.646	0.056	0
14.003	Bitumenemulsion, 1 Anstrich	0.250	m^2	429	370	59.0	0.017	0.016	0.016	0	0.001	1.85	1.84	0.706	1.13	0.014	0.181	0.135	0.047	0
14.004	Emaillieren, Metall	-	m^2	16'400	16'400	0	3.98	3.98	3.98	0	0	43.5	43.5	43.5	0	0	8.12	8.12	0	0
14.005	Pulverbeschichten, Aluminium	-	m^2	6'270	6'270	0	0.576	0.576	0.576	0	0	16.6	16.6	16.6	0	0	3.65	3.65	0	0
14.006	Pulverbeschichten, Stahl	-	m^2	6'760	6'760	0	0.695	0.695	0.695	0	0	21.1	21.1	21.1	0	0	4.39	4.39	0	0
14.007	Verchromen, Stahl	-	m^2	6'320	6'320	0	0.855	0.855	0.855	0	0	4.45	4.45	4.45	0	0	0.612	0.612	0	0
14.008	Verzinken, Stahl	-	m^2	29'500	29'500	0	2.63	2.63	2.63	0	0	25.6	25.6	25.6	0	0	6.10	6.10	0	0
15	**Kunststoffe**	kg/m^3																		
15.001	Plexiglas (PMMA, Acrylglas)	1'180	kg	14'800	11'700	3'090	0.385	0.371	0.371	0	0.014	40.2	40.0	32.4	7.60	0.211	11.6	8.68	2.92	0
15.002	Polyamid (PA) glasfaserverstärkt	1'360	kg	15'200	12'300	2'920	0.979	0.960	0.960	0	0.020	40.3	39.6	35.6	3.96	0.688	11.5	8.89	2.62	0
15.003	Polycarbonat (PC)	1'200	kg	15'900	12'800	3'090	0.419	0.405	0.405	0	0.014	31.8	31.6	25.6	6.00	0.211	11.4	8.49	2.92	0
15.004	Polyester (UP) glasfaserverstärkt	1'500	kg	13'800	10'700	3'090	1.48	1.47	1.47	0	0.014	31.4	31.2	27.4	3.76	0.211	9.85	6.93	2.92	0
15.005	Polystyrol (PS)	1'050	kg	8'170	4'880	3'290	0.110	0.097	0.097	0	0.013	24.6	24.4	13.6	10.8	0.209	6.73	3.64	3.08	0
21	**Kücheneinbauten und -möbel**	-																		
21.001	Abfalltrennsystem	-	Stk.	35'300	26'600	8'770	16.8	16.7	16.7	0	0.052	113	112	109	3.62	0.877	24.2	16.1	8.13	0
21.002	Arbeitsplatte Chromstahl, high-end	-	m^2	838'000	837'000	715	450	450	450	0	0.037	1'260	1'260	1'260	0	1.75	333	333	0.447	0
21.003	Arbeitsplatte Chromstahl, Standard	-	m^2	137'000	136'000	1'430	88.9	88.8	45.1	43.7	0.082	225	223	213	10.6	1.47	56.9	55.9	1.05	5.09
21.004	Arbeitsplatte Kompositwerkstoff (auf Aluminiumhydroxidbasis)	-	m^2	137'000	116'000	20'800	6.30	6.06	6.06	0	0.235	355	350	297	53.4	4.52	95.6	76.3	19.3	0
21.005	Arbeitsplatte kunstharzbeschichtet	-	m^2	34'300	32'800	1'550	148	148	48.9	99.0	0.079	102	101	75.0	25.8	1.26	20.2	19.0	1.20	11.6
21.006	Arbeitsplatte Massivholz	-	m^2	27'600	26'100	1'490	335	335	206	129	0.142	60.8	58.7	49.8	8.81	2.10	12.6	11.7	0.920	6.36
21.007	Arbeitsplatte Naturstein	-	m^2	159'000	155'000	3'530	71.5	71.4	71.4	0	0.181	356	352	352	0	4.36	41.3	40.3	1.06	0
21.008	Dampfabzug	-	Stk.	357'000	339'000	17'700	69.3	69.3	69.3	0	0.039	598	597	597	0	1.32	151	134	17.1	0
21.009	Küche, Massivholz, 16-teilig	-	Stk.	1'010'000	944'000	62'800	5'040	5'040	3'140	1'900	2.46	1'980	1'940	1'810	129	38.4	471	419	51.4	160
21.010	Küche, Metall, 16-teilig	-	Stk.	6'620'000	6'560'000	54'300	683	683	615	67.3	0.261	10'300	10'300	10'300	0	5.16	2'770	2'720	51.0	3.45
21.011	Küche, Spanplatte, 16-teilig	-	Stk.	1'200'000	1'110'000	91'300	2'530	2'520	599	1'930	3.48	2'870	2'820	2'280	531	56.4	633	558	74.9	223
21.012	Spüle Chromstahl	-	Stk.	110'000	105'000	5'340	40.9	40.8	40.8	0	0.035	214	213	213	0	0.714	48.6	43.7	4.93	0
21.013	Spüle Kompositwerkstoff (auf Gesteinsmehlbasis)	-	Stk.	46'700	46'100	598	16.4	16.4	16.4	0	0.031	144	143	126	16.8	0.740	30.7	30.6	0.179	0
Mobiliarrechner: mit dem Mobiliarrechner können Umweltkennwerte von verschiedenen Möbel berechnet werden.																				

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	GEBÄUDETECHNIK	Bezug Grösse	Bezug Einheit	UBP'21 UBP Total	UBP Herstellung	UBP Entsorgung	Primärenergie erneuerbar Total	erneuerbar Herstellung	erneuerbar Entsorgung	nicht erneuerbar Total	nicht erneuerbar Herstellung	nicht erneuerbar Entsorgung	Treibhausgasemissionen Total	Treibhausgas Herstellung	Treibhausgas Entsorgung
				UBP	UBP	UBP	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kWh oil-eq	kg CO_2-eq	kg CO_2-eq	kg CO_2-eq
31	**Heizungsanlagen**														
31.001	Wärmeerzeuger, spez. Leistungsbedarf 10 W/m^2	EBF	m^2	1'810	1'770	36.5	0.296	0.295	0.000	3.17	3.16	0.007	0.860	0.850	0.010
31.002	Wärmeerzeuger, spez. Leistungsbedarf 30 W/m^2	EBF	m^2	5'430	5'320	110	0.887	0.886	0.001	9.51	9.49	0.021	2.58	2.55	0.029
31.003	Wärmeerzeuger, spez. Leistungsbedarf 50 W/m^2	EBF	m^2	9'040	8'860	183	1.48	1.48	0.001	15.8	15.8	0.035	4.30	4.25	0.048
31.027	Elektrospeicherofen 5kW	Masse	kg	7'080	6'740	349	0.969	0.951	0.018	10.7	10.5	0.191	2.88	2.59	0.297
31.021	Wärmeverteilung Wohngebäude	EBF	m^2	7'040	5'640	1'410	1.54	1.17	0.366	13.2	11.1	2.14	3.47	2.77	0.696
31.022	Wärmeverteilung Bürogebäude	EBF	m^2	18'100	16'100	2'020	2.77	2.34	0.430	29.9	27.3	2.57	9.16	8.07	1.09
31.023	Wärmeabgabe über Heizkörper	EBF	m^2	12'800	12'100	700	1.67	1.66	0.003	21.1	21.0	0.027	6.51	6.49	0.022
31.024	Wärmeabgabe über Fussbodenheizung	EBF	m^2	7'390	5'300	2'090	1.44	1.44	0.002	21.9	21.8	0.087	5.06	3.02	2.04
31.025	Wärmeabgabe über Heizkühldecke (ohne Gips- oder Metalldecke)	EBF	m^2	24'400	24'200	141	4.39	4.39	0.002	25.0	25.0	0.026	5.79	5.66	0.134
31.015	Wärmeverteilung und Abgabe, Luftheizung	EBF	m^2	4'350	3'730	613	0.470	0.470	0.000	7.57	7.57	0.004	2.07	2.00	0.067
31.016	Erdsonden, für Sole-Wasser-Wärmepumpe	Sondenlänge	m	85'800	80'500	5'220	3.97	3.69	0.278	167	166	1.29	42.4	39.9	2.56
31.026	Förder- und Schluckbrunnen für Grundwasser Wärmepumpe	Gerät	Stk.	952'000	845'000	107'000	48.2	44.1	4.08	1'790	1'740	44.9	664	568	95.7
31.017	Sole-Wasser Wärmepumpe 7 kW	Gerät	Stk.	4'690'000	4'200'000	486'000	489	486	3.05	4'460	4'430	35.0	2'400	1'930	473
31.018	Sole-Wasser Wärmepumpe 7 kW	Masse	kg	29'700	26'600	3'080	3.09	3.07	0.019	28.3	28.0	0.222	15.2	12.2	2.99
31.019	Luft-Wasser Wärmepumpe 7 kW	Gerät	Stk.	7'440'000	6'600'000	845'000	1'010	1'000	4.97	7'130	7'080	57.4	4'000	3'180	824
31.020	Luft-Wasser Wärmepumpe 7 kW	Masse	kg	29'100	25'800	3'300	3.94	3.92	0.019	27.9	27.6	0.224	15.6	12.4	3.22
31.007	Flachkollektor für Warmwasser EFH	Kollektorfläche	m^2	689'000	689'000	inkl.	146	146	inkl.	1'070	1'070	inkl.	290	290	inkl.
31.008	Flachkollektor für Raumheizung und Warmwasser EFH	Kollektorfläche	m^2	484'000	484'000	inkl.	105	105	inkl.	784	784	inkl.	204	204	inkl.
31.009	Flachkollektor für Warmwasser MFH	Kollektorfläche	m^2	412'000	412'000	inkl.	81.6	81.6	inkl.	668	668	inkl.	169	169	inkl.
31.010	Röhrenkollektor für Raumheizung und Warmwasser EFH	Kollektorfläche	m^2	494'000	494'000	inkl.	103	103	inkl.	886	886	inkl.	231	231	inkl.
31.028	Hybridkollektor Schrägdach mit Erdsondenregeneration	Kollektorfläche	m^2	717'000	717'000	inkl.	152	152	inkl.	1'300	1'300	inkl.	344	344	inkl.
31.029	Hybridkollektor Schrägdach mit Warmwasserspeicher	Kollektorfläche	m^2	771'000	771'000	inkl.	167	167	inkl.	1'380	1'380	inkl.	371	371	inkl.
32	**Lüftungsanlagen**														
32.011	Lüftungsanlage, spez. Luftmenge 1 m^3/hm^2 EBF	EBF	m^2	34'200	33'600	592	4.43	4.43	0.010	50.5	50.4	0.144	15.0	14.7	0.339
32.005	Lüftungsanlage, spez. Luftmenge 2 m^3/hm^2 EBF	EBF	m^2	46'100	45'300	829	5.96	5.95	0.013	68.2	68.0	0.199	20.2	19.7	0.475
32.006	Lüftungsanlage, spez. Luftmenge 4 m^3/hm^2 EBF	EBF	m^2	69'900	68'600	1'300	9.01	8.99	0.020	104	103	0.307	30.6	29.9	0.749
32.007	Lüftungsanlage, spez. Luftmenge 6 m^3/hm^2 EBF	EBF	m^2	93'800	92'000	1'780	12.1	12.0	0.027	139	139	0.416	41.0	40.0	1.02
32.012	Lüftungsanlage, spez. Luftmenge 8 m^3/hm^2 EBF	EBF	m^2	118'000	115'000	2'250	15.1	15.1	0.034	175	174	0.524	51.4	50.1	1.30
32.001	Lüftungsanlage Wohnen, Blechkanäle, inkl. Küchenabluft	EBF	m^2	41'700	41'300	361	4.22	4.21	0.005	50.0	49.9	0.068	14.3	14.0	0.298
32.002	Lüftungsanlage Wohnen, PE-Kanäle, inkl. Küchenabluft	EBF	m^2	21'600	20'900	782	2.50	2.50	0.003	31.0	30.9	0.062	8.40	7.68	0.723
32.003	Abluftanlage Küche und Bad	EBF	m^2	12'300	12'100	175	1.23	1.23	0.000	14.5	14.5	0.008	4.05	3.92	0.125
32.004	Erdregister zu Lüftungsanlage Wohnen	EBF	m^2	6'880	4'600	2'280	0.600	0.528	0.071	15.3	14.2	1.06	4.43	2.81	1.62
32.008	Erdregister kurz zu Lüftungsanlage Büro (0.27 m/m^2 EBF)	EBF	m^2	11'900	7'970	3'960	1.04	0.916	0.124	26.5	24.7	1.84	7.68	4.87	2.81
32.009	Erdregister lang zu Lüftungsanlage Büro (0.67 m/m^2 EBF)	EBF	m^2	29'800	19'900	9'900	2.60	2.29	0.310	66.3	61.7	4.61	19.2	12.2	7.03
32.010	Einzelraumlüfer Fenstermodell 10-30 m^3/h, ohne Montage	Gerät	Stk.	84'300	78'200	6'140	106	106	0.077	214	213	1.34	43.7	38.2	5.49
33	**Sanitäranlagen**														
33.001	Sanitäranlagen, Büro, einfach, inkl. Apparate und Leitungen	EBF	m^2	8'490	7'290	1'200	1.19	1.18	0.007	19.1	19.0	0.115	4.73	3.58	1.15
33.002	Sanitäranlagen, Büro, aufwändig, inkl. Apparate und Leitungen	EBF	m^2	21'000	17'000	3'950	3.32	3.30	0.020	45.6	45.1	0.428	12.3	8.53	3.76
33.003	Sanitäranlagen, Wohnen, inkl. Apparate und Leitungen	EBF	m^2	26'300	24'700	1'670	3.91	3.88	0.023	46.1	45.9	0.284	12.6	11.0	1.54
34	**Elektroanlagen**														
34.001	Elektroanlagen Wohnen	EBF	m^2	37'100	33'500	3'630	4.69	4.63	0.061	54.0	53.3	0.720	13.0	9.57	3.42
34.002	Elektroanlagen Büro	EBF	m^2	83'400	81'700	1'660	76.9	76.8	0.052	106	105	0.813	24.2	22.7	1.48
34.024	Solarstromanlage[1]	Max. Leistung	kWp	2'240'000	2'240'000	inkl.	417	417	inkl.	3'820	3'820	inkl.	1'070	1'070	inkl.
34.025	Solarstromanlage Schrägdach[1]	Max. Leistung	kWp	2'100'000	2'100'000	inkl.	392	392	inkl.	3'580	3'580	inkl.	1'000	1'000	inkl.
34.026	Solarstromanlage Flachdach[1]	Max. Leistung	kWp	2'370'000	2'370'000	inkl.	440	440	inkl.	4'060	4'060	inkl.	1'140	1'140	inkl.
34.027	Solarstromanlage Fassade[1]	Max. Leistung	kWp	2'890'000	2'890'000	inkl.	490	490	inkl.	4'430	4'430	inkl.	1'220	1'220	inkl.
34.028	Solarstromanlage Schrägdach Mono-Si[1]	Max. Leistung	kWp	2'940'000	2'940'000	inkl.	506	506	inkl.	4'530	4'530	inkl.	1'260	1'260	inkl.
34.029	Solarstromanlage Schrägdach Multi-Si[1]	Max. Leistung	kWp	2'990'000	2'990'000	inkl.	523	523	inkl.	4'560	4'560	inkl.	1'250	1'250	inkl.
34.030	Solarstromanlage Schrägdach CdTe[1]	Max. Leistung	kWp	2'050'000	2'050'000	inkl.	319	319	inkl.	3'250	3'250	inkl.	794	794	inkl.
34.031	Solarstromanlage Schrägdach CIS[1]	Max. Leistung	kWp	2'600'000	2'600'000	inkl.	503	503	inkl.	4'610	4'610	inkl.	1'080	1'080	inkl.
34.032	Wechselrichter 2.5 kW[1]	Max. Leistung	kWp	534'000	534'000	inkl.	63.1	63.1	inkl.	622	622	inkl.	144	144	inkl.
34.033	Wechselrichter 5 kW[1]	Max. Leistung	kWp	428'000	428'000	inkl.	50.5	50.5	inkl.	498	498	inkl.	116	116	inkl.
34.034	Wechselrichter 10 kW[1]	Max. Leistung	kWp	343'000	343'000	inkl.	40.5	40.5	inkl.	399	399	inkl.	92.7	92.7	inkl.
34.035	Wechselrichter 20 kW[1]	Max. Leistung	kWp	275'000	275'000	inkl.	32.4	32.4	inkl.	320	320	inkl.	74.3	74.3	inkl.
34.036	Elektroinstallation, Photovoltaikanlage[1]	Max. Leistung	kWp	167'000	167'000	inkl.	10.2	10.2	inkl.	170	170	inkl.	42.1	42.1	inkl.

[1] Umweltkennwerte «Herstellung» inklusive Umweltbelastung durch Rücknahme und Recycling

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	ENERGIE	Bezug: Grösse	Bezug: Einheit	UBP'21 (UBP)	Primärenergie erneuerbar (kWh oil-eq)	Primärenergie nicht erneuerbar (kWh oil-eq)	Treibhausgas-emissionen (kg CO_2-eq)
41	**Brennstoffe[1]**						
41.001	Heizöl EL	Endenergie	kWh	409	0.014	1.25	0.324
41.002	Erdgas	Endenergie	kWh	274	0.003	1.05	0.230
41.003	Propan/Butan	Endenergie	kWh	368	0.006	1.21	0.293
41.004	Kohle Koks	Endenergie	kWh	597	0.014	1.43	0.435
41.005	Kohle Brikett	Endenergie	kWh	726	0.009	1.18	0.398
41.006	Stückholz	Endenergie	kWh	175	1.01	0.044	0.023
41.010	Stückholz mit Partikelfilter	Endenergie	kWh	175	1.01	0.044	0.023
41.007	Holzschnitzel	Endenergie	kWh	115	1.03	0.031	0.011
41.011	Holzschnitzel mit Partikelfilter	Endenergie	kWh	115	1.03	0.031	0.011
41.008	Pellets	Endenergie	kWh	111	1.05	0.128	0.028
41.012	Pellets mit Partikelfilter	Endenergie	kWh	111	1.05	0.128	0.028
41.009	Biogas	Endenergie	kWh	155	0.028	0.293	0.124
	[1]Oberer Heizwert						
42	**Fernwärme**						
42.018	Atomkraftwerk	Endenergie	kWh	13.7	0.011	0.059	0.003
42.001	Heizzentrale Oel	Endenergie	kWh	509	0.021	1.56	0.402
42.002	Heizzentrale Gas	Endenergie	kWh	365	0.015	1.40	0.302
42.003	Heizzentrale Holz	Endenergie	kWh	165	1.46	0.145	0.025
42.004	Heizkraftwerk Holz	Endenergie	kWh	82.8	1.19	0.111	0.022
42.006	Heizzentrale EWP Abwasser (JAZ 3.4)	Endenergie	kWh	176	0.183	0.691	0.046
42.007	Heizzentrale EWP Grundwasser (JAZ 3.1)	Endenergie	kWh	208	0.326	0.795	0.056
42.008	Heizzentrale EWP Erdsonde (JAZ 3.1)	Endenergie	kWh	225	0.327	0.829	0.064
42.009	Heizzentrale Geothermie	Endenergie	kWh	88.5	1.26	0.146	0.020
42.010	Heizkraftwerk Geothermie	Endenergie	kWh	63.2	0.432	0.112	0.015
42.011	Kehrichtverbrennung	Endenergie	kWh	11.4	0.011	0.042	0.003
42.012	Blockheizkraftwerk Diesel	Endenergie	kWh	184	0.013	0.534	0.131
42.013	Blockheizkraftwerk Gas	Endenergie	kWh	134	0.012	0.495	0.106
42.014	Blockheizkraftwerk Biogas	Endenergie	kWh	83.4	0.023	0.171	0.061
42.016	Fernwärme Durchschnitt Netze CH	Endenergie	kWh	126	0.490	0.339	0.067
42.017	Fernwärme mit Nutzung Kehrichtwärme, Durchschnitt Netze CH	Endenergie	kWh	126	0.490	0.339	0.067
43	**Nutzwärme**						
43.013	Elektrospeicherofen (Strom CH)	Nutzwärme[2]	kWh	519	0.557	2.09	0.127
43.014	Elektrospeicherofen (Strom CH zertifiziert)	Nutzwärme[2]	kWh	87.0	1.16	0.041	0.017
43.001	Heizkessel Heizöl EL	Nutzwärme[2]	kWh	438	0.011	1.31	0.343
43.002	Heizkessel Erdgas	Nutzwärme[2]	kWh	279	0.003	1.06	0.234
43.003	Heizkessel Propan / Butan	Nutzwärme[2]	kWh	364	0.006	1.20	0.289
43.004	Heizkessel Kohle Koks	Nutzwärme[2]	kWh	886	0.022	1.99	0.643
43.005	Heizkessel Kohle Brikett	Nutzwärme[2]	kWh	1'080	0.014	1.49	0.588
43.006	Heizkessel Stückholz	Nutzwärme[2]	kWh	239	1.35	0.069	0.033
43.010	Heizkessel Stückholz mit Partikelfilter	Nutzwärme[2]	kWh	239	1.35	0.069	0.033
43.007	Heizkessel Holzschnitzel	Nutzwärme[2]	kWh	164	1.33	0.056	0.021
43.011	Heizkessel Holzschnitzel mit Partikelfilter	Nutzwärme[2]	kWh	164	1.33	0.056	0.021
43.008	Heizkessel Pellets	Nutzwärme[2]	kWh	143	1.28	0.166	0.038
43.012	Heizkessel Pellets mit Partikelfilter	Nutzwärme[2]	kWh	143	1.28	0.166	0.038
43.009	Heizkessel Biogas	Nutzwärme[2]	kWh	159	0.029	0.300	0.127
44	**Nutzwärme am Standort erzeugt, inkl. erneuerbare Energien**						
44.001	Elektrowärmepumpe Luft / Wasser (15kW, Altbau, JAZ 2.7, Strom CH)	Nutzwärme2	kWh	214	0.837	0.783	0.058
44.012	Elektrowärmepumpe Luft / Wasser (15kW, Altbau, JAZ 2.7, Strom CH zertifiziert)	Nutzwärme[2]	kWh	54.5	1.06	0.025	0.017
44.009	Elektrowärmepumpe Luft / Wasser (15kW, Neubau, JAZ 4.4, Strom CH)	Nutzwärme[2]	kWh	142	0.901	0.485	0.040
44.015	Elektrowärmepumpe Luft / Wasser (15kW, Neubau, JAZ 4.4, Strom CH zertifiziert)	Nutzwärme[2]	kWh	44.2	1.04	0.020	0.015
44.002	Elektrowärmepumpe Erdsonden (15kW, Altbau, JAZ 3.2, Strom CH)	Nutzwärme[2]	kWh	195	0.863	0.690	0.054
44.013	Elektrowärmepumpe Erdsonden (15kW, Altbau, JAZ 3.2, Strom CH zertifiziert)	Nutzwärme[2]	kWh	59.8	1.05	0.051	0.020
44.010	Elektrowärmepumpe Erdsonden (15kW, Neubau, JAZ 5.3, Strom CH)	Nutzwärme[2]	kWh	132	0.918	0.433	0.039
44.016	Elektrowärmepumpe Erdsonden (15kW, Neubau, JAZ 5.3, Strom CH zertifiziert)	Nutzwärme[2]	kWh	51.0	1.03	0.046	0.018
44.003	Elektrowärmepumpe Grundwasser (15kW, Altbau, JAZ 3.2, Strom CH)	Nutzwärme[2]	kWh	181	0.918	0.662	0.047
44.014	Elektrowärmepumpe Grundwasser (15kW, Altbau, JAZ 3.2, Strom CH zertifiziert)	Nutzwärme[2]	kWh	46.4	1.11	0.022	0.013
44.011	Elektrowärmepumpe Grundwasser (15kW, Neubau, JAZ 5.3, Strom CH)	Nutzwärme[2]	kWh	118	0.917	0.404	0.032
44.017	Elektrowärmepumpe Grundwasser (15kW, Neubau, JAZ 5.3, Strom CH zertifiziert)	Nutzwärme[2]	kWh	37.0	1.03	0.018	0.011

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	ENERGIE	Bezug: Grösse	Bezug: Einheit	UBP'21 (UBP)	Primärenergie erneuerbar (kWh oil-eq)	Primärenergie nicht erneuerbar (kWh oil-eq)	Treibhausgas-emissionen (kg CO_2-eq)
44.004	Flachkollektor für Warmwasser EFH	Nutzwärme[2]	kWh	121	1.33	0.244	0.042
44.005	Flachkollektor für Raumheizung und Warmwasser EFH	Nutzwärme[2]	kWh	110	1.61	0.200	0.038
44.006	Flachkollektor für Warmwasser MFH	Nutzwärme[2]	kWh	50.0	1.15	0.079	0.015
44.007	Röhrenkollektor für Raumheizung und Warmwasser EFH	Nutzwärme[2]	kWh	93.7	1.54	0.177	0.035
44.008	Kleinblockheizkraftwerk, Erdgas	Nutzwärme[2]	kWh	131	0.002	0.470	0.107
44.018	Solarthermieanlage Schrägdach mit Erdsondenregeneration	Nutzwärme[2]	kWh	39.1	1.14	0.058	0.014
44.019	Solarthermieanlage Schrägdach mit Warmwasserspeicher	Nutzwärme[2]	kWh	45.2	1.14	0.067	0.017
	[2] inkl. Verteilverluste (Wärme am Ausgang Wärmeerzeuger)						
45	**Elektrizität vom Netz**						
45.001	Atomkraftwerk	Endenergie	kWh	675	0.005	4.21	0.024
45.002	Erdgaskombikraftwerk GuD	Endenergie	kWh	622	0.008	2.23	0.480
45.024	Erdgaskraftwerk	Endenergie	kWh	945	0.014	3.37	0.743
45.023	Braunkohlekraftwerk	Endenergie	kWh	1'610	0.011	3.93	1.36
45.003	Steinkohlekraftwerk	Endenergie	kWh	1'530	0.036	3.88	1.23
45.004	Kraftwerk Schweröl	Endenergie	kWh	1'570	0.021	3.73	1.07
45.005	Kehrichtverbrennung	Endenergie	kWh	55.6	0.002	0.014	0.007
45.006	Heizkraftwerk Holz	Endenergie	kWh	172	1.93	0.125	0.038
45.007	Blockheizkraftwerk Diesel	Endenergie	kWh	1'180	0.020	3.22	0.841
45.008	Blockheizkraftwerk Gas	Endenergie	kWh	826	0.011	2.83	0.648
45.009	Blockheizkraftwerk Biogas	Endenergie	kWh	511	0.078	0.820	0.364
45.011	Photovoltaik	Endenergie	kWh	151	1.20	0.159	0.048
45.012	Photovoltaik Schrägdach	Endenergie	kWh	176	1.21	0.192	0.055
45.013	Photovoltaik Flachdach	Endenergie	kWh	161	1.20	0.177	0.053
45.014	Photovoltaik Fassade	Endenergie	kWh	221	1.21	0.251	0.072
45.027	Photovoltaik Schrägdach Mono-Si	Endenergie	kWh	177	1.20	0.185	0.055
45.028	Photovoltaik Schrägdach Multi-Si	Endenergie	kWh	179	1.21	0.187	0.055
45.029	Photovoltaik Schrägdach CdTe	Endenergie	kWh	144	1.20	0.137	0.037
45.030	Photovoltaik Schrägdach CIS	Endenergie	kWh	164	1.20	0.188	0.048
45.015	Windkraft	Endenergie	kWh	110	1.20	0.087	0.028
45.016	Wasserkraft	Endenergie	kWh	77.0	1.17	0.025	0.012
45.017	Pumpspeicherung	Endenergie	kWh	666	0.722	2.71	0.169
45.018	Heizkraftwerk Geothermie	Endenergie	kWh	143	3.17	0.191	0.031
45.020	CH-Verbrauchermix	Endenergie	kWh	513	0.556	2.08	0.125
45.019	CH-Produktionsmix	Endenergie	kWh	329	0.678	1.68	0.032
45.022	Mix Stromprodukte aus erneuerbaren Energien	Endenergie	kWh	81.8	1.16	0.033	0.015
45.025	CH-Lieferantenmix HKN	Endenergie	kWh	265	0.902	1.08	0.054
45.021	ENTSO-E-Mix (ehemals UCTE-Mix)	Endenergie	kWh	935	0.275	2.87	0.523
46	**Elektrizität am Standort erzeugt, inkl. erneuerbare Energien**						
46.001	Photovoltaik	Endenergie	kWh	86.7	1.09	0.131	0.037
46.002	Photovoltaik Schrägdach	Endenergie	kWh	110	1.09	0.161	0.044
46.003	Photovoltaik Flachdach	Endenergie	kWh	96.0	1.09	0.148	0.042
46.004	Photovoltaik Fassade	Endenergie	kWh	149	1.09	0.214	0.059
46.009	Photovoltaik Schrägdach Mono-Si	Endenergie	kWh	111	1.09	0.155	0.043
46.010	Photovoltaik Schrägdach Multi-Si	Endenergie	kWh	112	1.09	0.157	0.043
46.011	Photovoltaik Schrägdach CdTe	Endenergie	kWh	80.0	1.08	0.112	0.027
46.012	Photovoltaik Schrägdach CIS	Endenergie	kWh	98.8	1.09	0.158	0.037
46.013	Photovoltaik Mono-Si in Hybridkollektor	Endenergie	kWh	111	1.09	0.173	0.049
46.005	Windkraft	Endenergie	kWh	49.8	1.09	0.067	0.019
46.006	Biogas	Endenergie	kWh	411	0.068	0.728	0.322
46.007	Biogas, Landwirtschaft	Endenergie	kWh	232	0.034	0.108	0.155
46.008	Kleinblockheizkraftwerk, Erdgas	Endenergie	kWh	943	0.013	3.37	0.768
46.014	Kleinblockheizkraftwerk, Biogas	Endenergie	kWh	569	0.092	1.00	0.432

Strommixrechner: Mit dem Strommixrechner (https://treeze.ch/de/rechner) können Umweltkennwerte von spezifischen Strommixen berechnet werden.
Fernwärmerechner: Mit dem Fernwärmerechner (https://treeze.ch/de/rechner) können Umweltkennwerte von spezifischen Fernwärmemixen berechnet werden.
Wärmepumpenrechner: Mit dem Wärmepumpenrechner (https://treeze.ch/de/rechner) können Umweltkennwerte pro kWh gelieferte Wärme und pro kWh Strom, der von der Wärmepumpe verbraucht wird, berechnet werden.

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	TRANSPORTE	Bezug		UBP'21				Primärenergie erneuerbar				Primärenergie nicht erneuerbar				Treibhausgasemissionen und Klimaeffekte Flugzeugemissionen, RFI=2.5			
		Grösse	Einheit	Total UBP	Betrieb UBP	Fahrzeug UBP	Infrastruktur UBP	Total kWh oil-eq	Betrieb kWh oil-eq	Fahrzeug kWh oil-eq	Infrastruktur kWh oil-eq	Total kWh oil-eq	Betrieb kWh oil-eq	Fahrzeug kWh oil-eq	Infrastruktur kWh oil-eq	Total kg CO_2-eq	Betrieb kg CO_2-eq	Fahrzeug kg CO_2-eq	Infrastruktur kg CO_2-eq
61	**Treibstoffe**																		
61.003	Benzin in Personenwagen	Endenergie	kWh	**478**	478			**0.024**	0.024			1.25	1.25			0.338	0.338		
61.009	Benzin in Scooter	Endenergie	kWh	**814**	814			**0.024**	0.024			1.26	1.26			0.397	0.397		
61.005	Biogas in Personenwagen	Endenergie	kWh	**188**	188			**0.036**	0.036			0.321	0.321			0.114	0.114		
61.001	Diesel in Baumaschine	Endenergie	kWh	**513**	513			**0.007**	0.007			1.23	1.23			0.325	0.325		
61.002	Diesel in Lastwagen	Endenergie	kWh	**566**	566			**0.051**	0.051			1.19	1.19			0.321	0.321		
61.004	Diesel in Personenwagen	Endenergie	kWh	**487**	487			**0.005**	0.005			1.20	1.20			0.329	0.329		
61.006	Erdgas in Personenwagen	Endenergie	kWh	**326**	326			**0.011**	0.011			1.12	1.12			0.237	0.237		
61.007	Kerosin in Flugzeug	Endenergie	kWh	**776**	776			**0.005**	0.005			1.22	1.22			0.665	0.665		
61.008	Strom CH-Verbrauchermix in Personenwagen	Endenergie	kWh	**628**	628			**0.556**	0.556			2.08	2.08			0.158	0.158		
61.010	Mix Stromprodukte aus erneuerbaren Energien in Personenwagen	Endenergie	kWh	**197**	197			**1.16**	1.16			0.033	0.033			0.048	0.048		
62	**Güter-Transporte**																		
62.001	Aushub maschinell, Durchschnitt	Aushubvolumen	m3	**700**	613	87.1		**0.019**	0.008	0.011		**1.64**	1.47	0.175		**0.438**	0.388	0.050	
62.014	Aushub maschinell, mit PF	Aushubvolumen	m3	**700**	613	87.1		**0.019**	0.008	0.011		**1.65**	1.47	0.175		**0.438**	0.388	0.050	
62.015	Aushub maschinell, ohne PF	Aushubvolumen	m3	**702**	615	87.1		**0.019**	0.008	0.011		**1.60**	1.43	0.175		**0.427**	0.377	0.050	
62.002	Binnenschiff	Transportleistung	tkm	**70.1**	56.2	1.04	12.8	**0.009**	0.005	0.000	0.003	**0.157**	0.120	0.002	0.035	**0.040**	0.032	0.001	0.007
62.011	Flugzeug, Durchschnitt	Transportleistung	tkm	**1'950**	1'930	1.63	18.3	**0.016**	0.012	0.000	0.004	**2.88**	2.82	0.004	0.055	**1.67**	1.66	0.001	0.011
62.012	Flugzeug, Kurzstrecke	Transportleistung	tkm	**2'600**	2'470	4.42	129	**0.047**	0.020	0.001	0.026	**4.95**	4.55	0.011	0.383	**2.12**	2.04	0.003	0.077
62.018	Flugzeug, Mittelstrecke	Transportleistung	tkm	**1'880**	1'840	1.14	34.5	**0.019**	0.012	0.000	0.007	**2.89**	2.79	0.003	0.103	**1.60**	1.57	0.001	0.021
62.013	Flugzeug, Langstrecke	Transportleistung	tkm	**1'930**	1'910	1.02	12.3	**0.015**	0.012	0.000	0.002	**2.79**	2.75	0.003	0.037	**1.66**	1.65	0.001	0.007
62.003	Güterzug	Transportleistung	tkm	**32.6**	11.3	9.11	12.2	**0.046**	0.042	0.001	0.003	**0.054**	0.015	0.018	0.021	**0.012**	0.002	0.005	0.005
62.004	Helikopter	Einsatzzeit	h	**1'010'000**	1'000'000	7'510		**14.0**	12.3	1.66		**2'850**	2'830	19.4		**759**	754	4.41	
62.005	Hochseeschiff	Transportleistung	tkm	**17.4**	15.2	0.347	1.79	**0.001**	0.000	0.000	0.001	**0.029**	0.023	0.000	0.006	**0.007**	0.006	0.000	0.001
62.006	Hochseetanker	Transportleistung	tkm	**20.4**	19.2	0.188	1.02	**0.000**	0.000	0.000	0.000	**0.025**	0.021	0.000	0.003	**0.006**	0.006	0.000	0.001
62.007	Kleintransporter (<3.5 t)	Transportleistung	tkm	**2'920**	1'960	676	282	**0.313**	0.032	0.135	0.145	**7.29**	4.94	1.43	0.913	**1.77**	1.33	0.344	0.093
62.016	Lastwagen, Durchschnitt	Transportleistung	tkm	**266**	205	25.2	36.3	**0.029**	0.018	0.004	0.007	**0.604**	0.428	0.062	0.113	**0.144**	0.115	0.013	0.016
62.017	Lastwagen 3.5t-7.5 t	Transportleistung	tkm	**1'070**	838	125	111	**0.128**	0.071	0.020	0.038	**2.31**	1.65	0.311	0.353	**0.553**	0.445	0.065	0.043
62.009	Lastwagen 7.5-16 t	Transportleistung	tkm	**424**	336	37.3	51.3	**0.049**	0.031	0.006	0.013	**0.967**	0.712	0.093	0.162	**0.232**	0.192	0.020	0.021
62.008	Lastwagen 16-32 t	Transportleistung	tkm	**344**	274	30.4	39.8	**0.037**	0.024	0.004	0.008	**0.759**	0.561	0.074	0.125	**0.183**	0.150	0.016	0.017
62.010	Lastwagen 32-40 t	Transportleistung	tkm	**214**	160	21.4	33.4	**0.023**	0.015	0.003	0.005	**0.499**	0.341	0.054	0.104	**0.118**	0.092	0.011	0.015
63	**Personen-Transporte**																		
63.003	Autobus	Transportleistung	pkm	**258**	228	12.9	17.9	**0.012**	0.002	0.005	0.004	**0.627**	0.537	0.033	0.056	**0.156**	0.143	0.006	0.007
63.001	Fernreisezug Schweiz	Transportleistung	pkm	**30.1**	13.6	3.32	13.2	**0.072**	0.067	0.001	0.004	**0.044**	0.013	0.009	0.023	**0.007**	0.001	0.002	0.005
63.002	Fernreisezug Deutschland, ICE	Transportleistung	pkm	**64.8**	44.0	1.99	18.8	**0.035**	0.032	0.000	0.002	**0.125**	0.096	0.005	0.025	**0.034**	0.025	0.001	0.009
63.004	Flugzeug, Durchschnitt	Transportleistung	pkm	**332**	324	0.661	6.91	**0.004**	0.002	0.000	0.001	**0.533**	0.511	0.002	0.021	**0.283**	0.278	0.000	0.004
63.005	Flugzeug, Kurzstrecke	Transportleistung	pkm	**427**	405	0.729	21.2	**0.008**	0.003	0.000	0.004	**0.816**	0.751	0.002	0.063	**0.350**	0.337	0.000	0.013
63.020	Flugzeug, Mittelstrecke	Transportleistung	pkm	**302**	296	0.184	5.59	**0.003**	0.002	0.000	0.001	**0.468**	0.451	0.000	0.017	**0.259**	0.255	0.000	0.003
63.006	Flugzeug, Langstrecke	Transportleistung	pkm	**303**	301	0.162	1.95	**0.002**	0.002	0.000	0.000	**0.442**	0.436	0.000	0.006	**0.263**	0.261	0.000	0.001
63.018	Helikopter, einmotorig	Einsatzzeit	h	**1'270'000**	1'270'000	7'510		**17.3**	15.6	1.66		**3'610**	3'590	19.4		**968**	964	4.41	
63.019	Helikopter, zweimotorig	Einsatzzeit	h	**1'830'000**	1'830'000	8'750		**24.4**	22.4	1.94		**5'180**	5'160	22.5		**1'410**	1'410	5.14	
63.007	Personenwagen, Durchschnitt	Transportleistung	pkm	**352**	220	96.6	35.3	**0.046**	0.008	0.018	0.020	**0.870**	0.567	0.187	0.115	**0.212**	0.154	0.047	0.011
63.008	Personenwagen, Benzin	Transportleistung	pkm	**365**	237	93.0	34.8	**0.050**	0.012	0.017	0.020	**0.919**	0.624	0.182	0.113	**0.225**	0.168	0.046	0.011
63.014	Personenwagen, Biogas	Transportleistung	pkm	**193**	112	46.7	35.0	**0.051**	0.021	0.008	0.022	**0.417**	0.190	0.112	0.115	**0.103**	0.068	0.024	0.010
63.009	Personenwagen, Diesel	Transportleistung	pkm	**333**	195	102	36.0	**0.042**	0.002	0.019	0.020	**0.793**	0.480	0.196	0.117	**0.192**	0.132	0.049	0.011
63.016	Personenwagen, elektrisch, Strom CH-Verbrauchermix	Transportleistung	pkm	**256**	78.1	143	34.8	**0.108**	0.069	0.019	0.020	**0.640**	0.259	0.268	0.114	**0.093**	0.020	0.062	0.011
63.021	Personenwagen, elektrisch, Mix Stromprodukte aus erneu. Energien	Transportleistung	pkm	**202**	24.5	143	34.8	**0.183**	0.144	0.019	0.020	**0.385**	0.004	0.268	0.114	**0.079**	0.006	0.062	0.011
63.015	Personenwagen, Erdgas	Transportleistung	pkm	**266**	184	46.7	35.0	**0.036**	0.006	0.008	0.022	**0.861**	0.634	0.112	0.115	**0.168**	0.134	0.024	0.010
63.010	Regionalzug	Transportleistung	pkm	**39.0**	19.5	2.79	16.7	**0.144**	0.138	0.001	0.005	**0.060**	0.026	0.005	0.029	**0.009**	0.001	0.001	0.006
63.011	Reisebus	Transportleistung	pkm	**107**	89.5	7.18	10.2	**0.006**	0.001	0.003	0.002	**0.250**	0.200	0.019	0.032	**0.061**	0.054	0.003	0.004
63.017	Scooter, Benzin	Transportleistung	pkm	**257**	234	20.8	2.18	**0.011**	0.007	0.004	0.000	**0.422**	0.361	0.054	0.007	**0.127**	0.114	0.012	0.001
63.012	Tram	Transportleistung	pkm	**123**	69.8	6.47	47.2	**0.090**	0.076	0.003	0.011	**0.395**	0.284	0.017	0.094	**0.043**	0.017	0.003	0.023
63.013	Trolleybus	Transportleistung	pkm	**112**	85.7	10.8	15.5	**0.088**	0.081	0.005	0.003	**0.374**	0.301	0.028	0.044	**0.030**	0.019	0.005	0.006

Ökobilanzdaten im Baubereich — KBOB / ecobau / IPB 2009/1:2022

ID-Nummer	TRANSPORTE	Bezug		UBP'21				Primärenergie erneuerbar				Primärenergie nicht erneuerbar				Treibhausgasemissionen und Klimaeffekte Flugzeugemissionen, RFI=2.5			
		Grösse	Einheit	Total UBP	Betrieb UBP	Fahrzeug UBP	Infrastruktur UBP	Total kWh oil-eq	Betrieb kWh oil-eq	Fahrzeug kWh oil-eq	Infrastruktur kWh oil-eq	Total kWh oil-eq	Betrieb kWh oil-eq	Fahrzeug kWh oil-eq	Infrastruktur kWh oil-eq	Total kg CO_2-eq	Betrieb kg CO_2-eq	Fahrzeug kg CO_2-eq	Infrastruktur kg CO_2-eq
64	**Personen-Transporte**																		
64.003	Autobus	Fahrleistung	km	**2'640**	2'320	131	183	**0.123**	0.024	0.056	0.044	**6.39**	5.48	0.341	0.576	**1.60**	1.46	0.059	0.076
64.001	Fernreisezug Schweiz	Fahrleistung	km	**6'230**	2'810	689	2'730	**15.0**	14.0	0.238	0.776	**9.14**	2.60	1.84	4.71	**1.53**	0.142	0.338	1.05
64.002	Fernreisezug Deutschland, ICE	Fahrleistung	km	**15'300**	10'400	468	4'420	**8.12**	7.61	0.083	0.427	**29.5**	22.5	1.15	5.82	**8.08**	5.80	0.257	2.02
64.004	Flugzeug, Durchschnitt	Fahrleistung	km	**68'400**	66'800	136	1'420	**0.778**	0.458	0.032	0.288	**110**	105	0.347	4.24	**58.2**	57.3	0.079	0.850
64.005	Flugzeug, Kurzstrecke	Fahrleistung	km	**53'700**	51'000	91.8	2'670	**0.973**	0.412	0.020	0.541	**103**	94.6	0.237	7.96	**44.1**	42.5	0.054	1.60
64.020	Flugzeug, Mittelstrecke	Fahrleistung	km	**39'900**	39'100	24.3	737	**0.414**	0.259	0.005	0.149	**61.8**	59.6	0.063	2.20	**34.1**	33.7	0.014	0.440
64.006	Flugzeug, Langstrecke	Fahrleistung	km	**76'100**	75'600	40.7	490	**0.585**	0.477	0.010	0.099	**111**	109	0.104	1.46	**65.9**	65.6	0.024	0.292
64.018	Helikopter, einmotorig	Einsatzzeit	h	**1'270'000**	1'270'000	7'510		**17.3**	15.6	1.66		**3'610**	3'590	19.4		**968**	964	4.41	
64.019	Helikopter, zweimotorig	Einsatzzeit	h	**1'830'000**	1'830'000	8'750		**24.4**	22.4	1.94		**5'180**	5'160	22.5		**1'410**	1'410	5.14	
64.007	Personenwagen, Durchschnitt	Fahrleistung	km	**564**	353	155	56.5	**0.074**	0.013	0.029	0.032	**1.39**	0.908	0.299	0.184	**0.339**	0.246	0.075	0.018
64.008	Personenwagen, Benzin	Fahrleistung	km	**584**	379	149	55.7	**0.079**	0.019	0.028	0.032	**1.47**	0.999	0.291	0.182	**0.359**	0.269	0.073	0.017
64.014	Personenwagen, Biogas	Fahrleistung	km	**310**	179	74.7	56.1	**0.082**	0.034	0.013	0.035	**0.667**	0.304	0.179	0.184	**0.164**	0.109	0.039	0.017
64.009	Personenwagen, Diesel	Fahrleistung	km	**533**	311	164	57.6	**0.067**	0.003	0.031	0.033	**1.27**	0.767	0.313	0.188	**0.307**	0.210	0.079	0.018
64.016	Personenwagen, elektrisch, Strom CH-Verbrauchermix	Fahrleistung	km	**409**	125	228	55.7	**0.173**	0.111	0.030	0.032	**1.02**	0.414	0.428	0.182	**0.148**	0.031	0.100	0.017
64.021	Personenwagen, elektrisch, Mix Stromprodukte aus erneu. Energien	Fahrleistung	km	**323**	39.1	228	55.7	**0.292**	0.230	0.030	0.032	**0.617**	0.007	0.428	0.182	**0.127**	0.010	0.100	0.017
64.015	Personenwagen, Erdgas	Fahrleistung	km	**425**	295	74.7	56.1	**0.058**	0.010	0.013	0.035	**1.38**	1.01	0.179	0.184	**0.269**	0.214	0.039	0.017
64.010	Regionalzug	Fahrleistung	km	**2'540**	1'270	182	1'090	**9.38**	8.99	0.078	0.310	**3.89**	1.68	0.340	1.88	**0.593**	0.095	0.079	0.419
64.011	Reisebus	Fahrleistung	km	**2'240**	1'880	151	214	**0.128**	0.018	0.064	0.046	**5.26**	4.19	0.394	0.671	**1.29**	1.13	0.068	0.090
64.017	Scooter, Benzin	Fahrleistung	km	**282**	257	22.9	2.40	**0.012**	0.008	0.004	0.000	**0.464**	0.397	0.060	0.007	**0.139**	0.125	0.013	0.001
64.012	Tram	Fahrleistung	km	**4'150**	2'350	218	1'590	**3.01**	2.55	0.086	0.374	**13.3**	9.54	0.574	3.16	**1.45**	0.577	0.097	0.778
64.013	Trolleybus	Fahrleistung	km	**2'130**	1'630	205	294	**1.67**	1.53	0.087	0.052	**7.10**	5.72	0.535	0.841	**0.574**	0.366	0.092	0.116

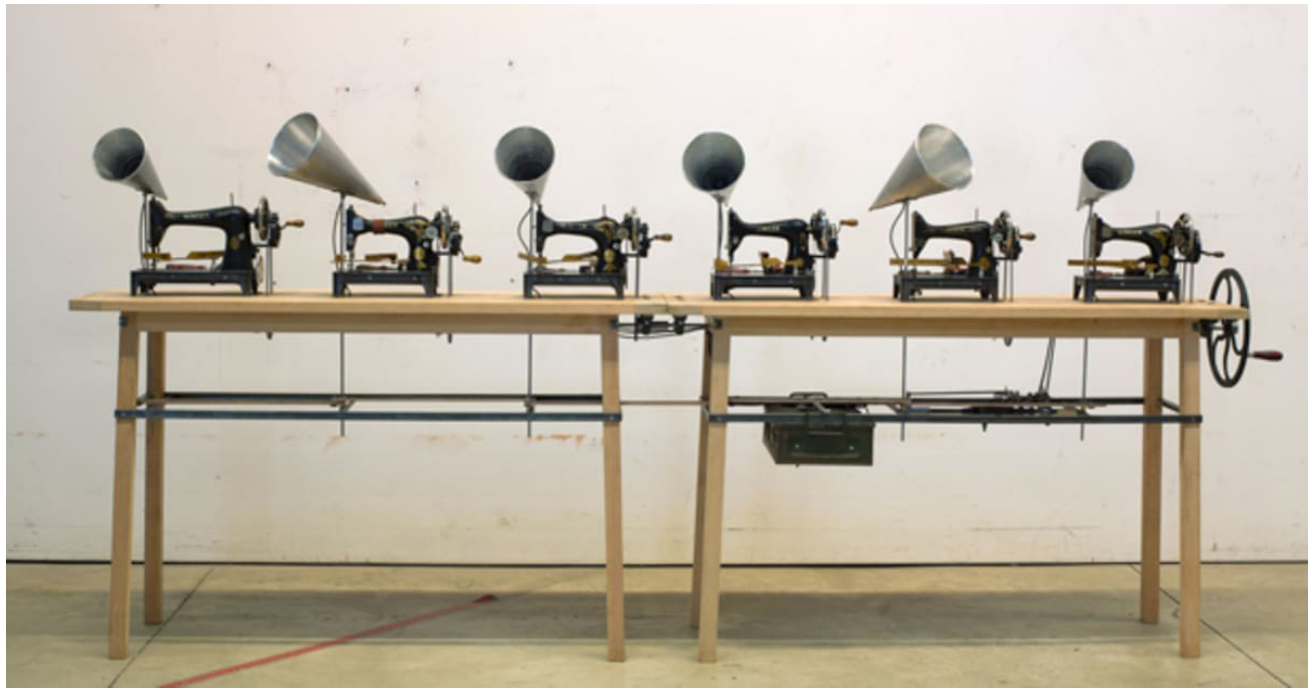
Transportrechner: Mit den mobitool-Faktoren 2.1 (https://mobitool.ch) können die Umweltkennwerte pro Personenkilometer oder pro Tonnenkilometer für spezfische Auslastungen und Transportmittel berechnet werden.

for complete publication see:
https://www.kbob.admin.ch/kbob/de/home/themen-leistungen/nachhaltiges-bauen/oekobilanzdaten_baubereich.html

Information from Dr. Rolf Frischknecht, 11.03.2022:
Changes in greenhouse gas emissions (production and disposal) for some key building materials, in KBOB-Empfehlung 2009/1 version 2022 compared to version 2016:

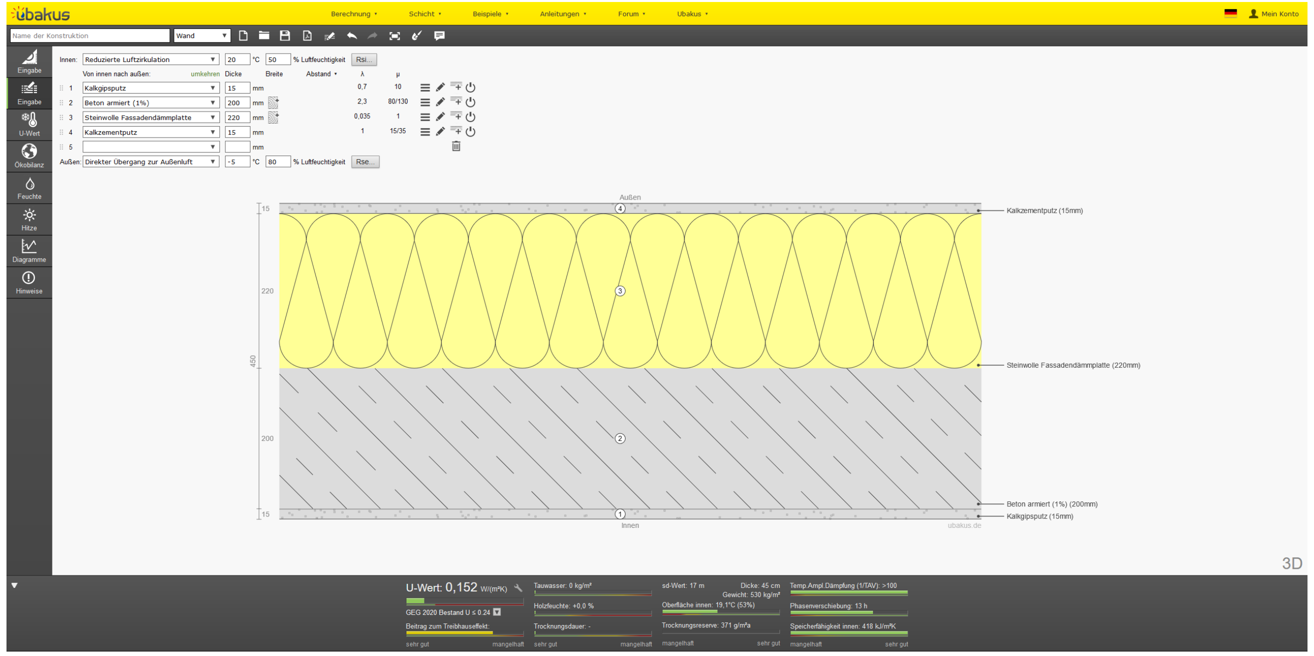
Structural concrete (excl. reinforcement): GHG emissions remain practically the same;
Brick: GHG emissions remain practically the same;
Glazing: GHG emissions remain practically the same;
Reinforcement steel: GHG emissions more than twice as high;
Sheet steel: GHG emissions more than 50% higher;
Structural steel: GHG emissions remain practically the same;
Glue laminated timber: GHG emissions reduced by over 30 %;
Solid timber: GHG emissions increased between 25 and 50 % (mainly due to updated calculation of disposal);
Thermal insulation materials: GHG emissions change inconsistently, but only slightly.

PLANNING TOOLS AND LINKS



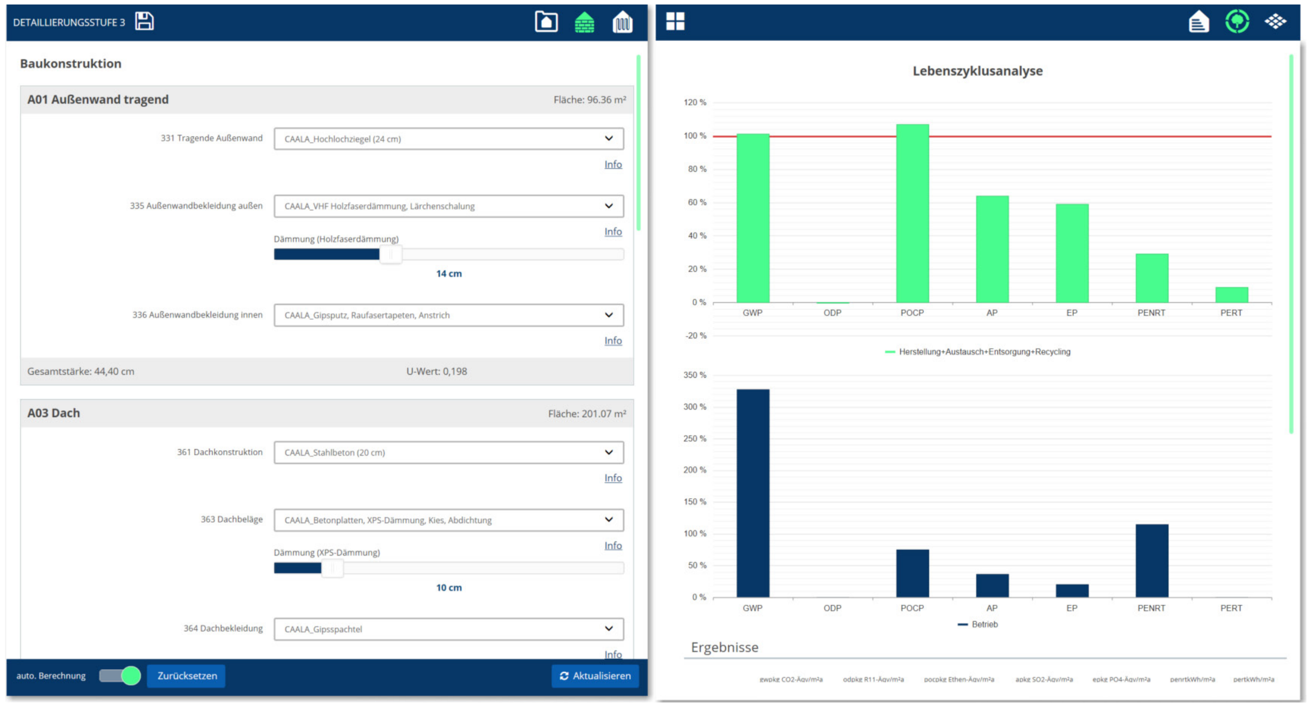
Untitled (Singer Choir/ Chorus), **William Kentridge, 2013**

Ubakus



https://www.ubakus.com, accessed March 2022

CAALA



https://caala.de/blog/alpha-version-0-97, accessed August 2021
Talk by Philipp Hollberg about CAALA for A4F Munich https://www.youtube.com/watch?v=rOKlUu42XLs

SIA 2040 Effizienzpfad Energie

Rechenhilfe SIA 2040: Vorstudie / Vorprojekt ***(mac-fähige Version zu Schulungszwecken)*** **Auswertung**

Projektinformation **0**

Objekteingaben Geschossfläche GF 1 m2 Zone 1 **Wohnen**
Energiebezugsfläche EBF 1 m2 Zone 2 **...**
Zone 3 **...**

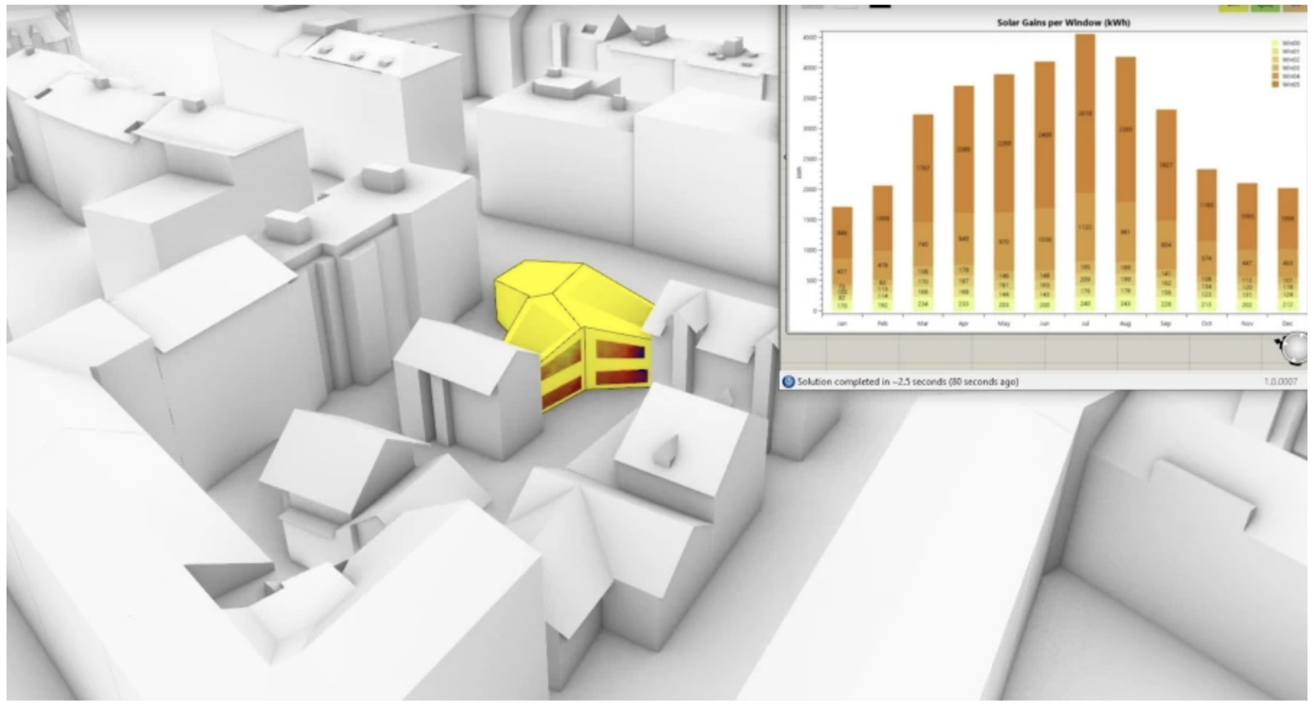
		Primärenergie nicht erneuerbar		Treibhausgas-emissionen		*Primärenergie gesamt (inkl. erneuerbare)*	
		kWh/m²		kg/m²		*kWh/m²*	
Gebäude	**Neubau/Umbau**	Richtwert	Projektwert	Richtwert	Projektwert	*Richtwert*	*Projektwert*
	Erstellung	30	13	9.0	3.3	*35*	*14*
	Betrieb	60	30	3.0	1.5	*140*	*43*
	Mobilität	30	4	4.0	0.7	*35*	*4*
Zielwert	Projektwert	**120**	**47**	**16.0**	**5.6**	***210***	***61***
Zusatzanforderung		*90*	*43*	*12.0*	*4.9*	***175***	***57***

Ihr Projekt ist auf gutem Weg die Vorgaben des SIA-Effizienzpfad Energie zu erfüllen.

Informativ: Nur für den Zusammenhang zur Methodik der 2000-Watt-Gesellschaft relevant. Vgl. Anhang C, SIA 2040

https://www.energytools.ch, accessed August 2021 (Image: Screenshot in Excel)

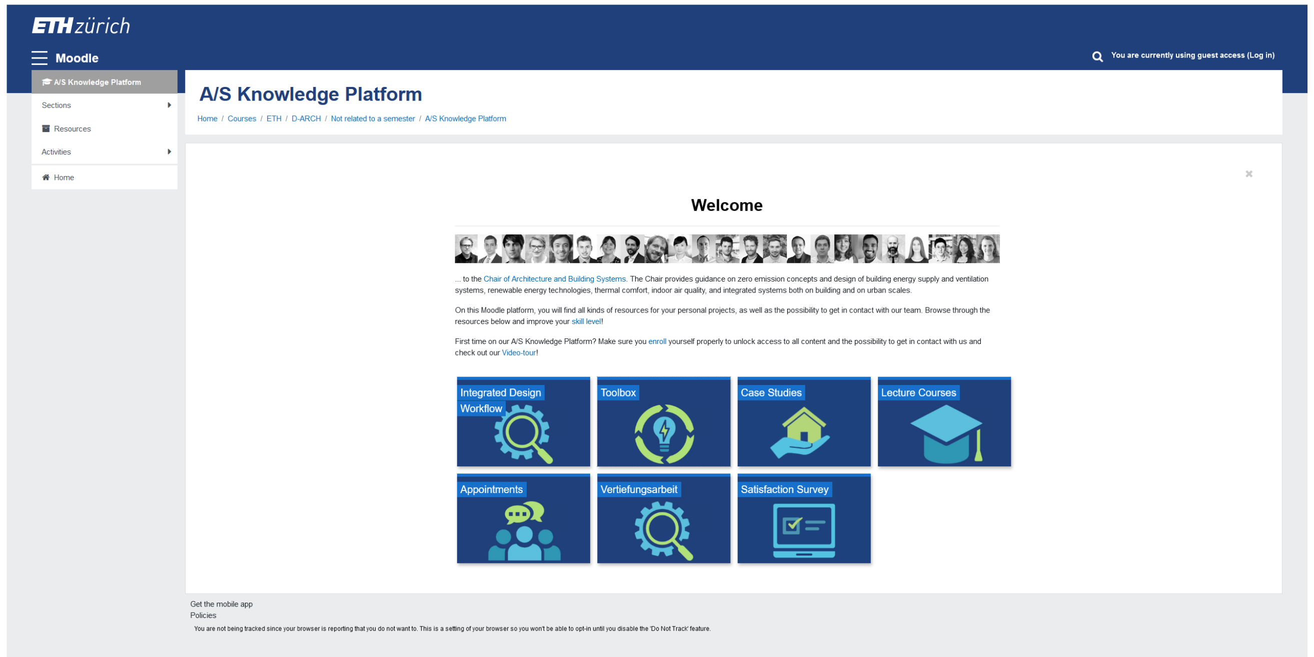
Hive



https://systems.arch.ethz.ch/demonstrators/hive, accessed August 2021

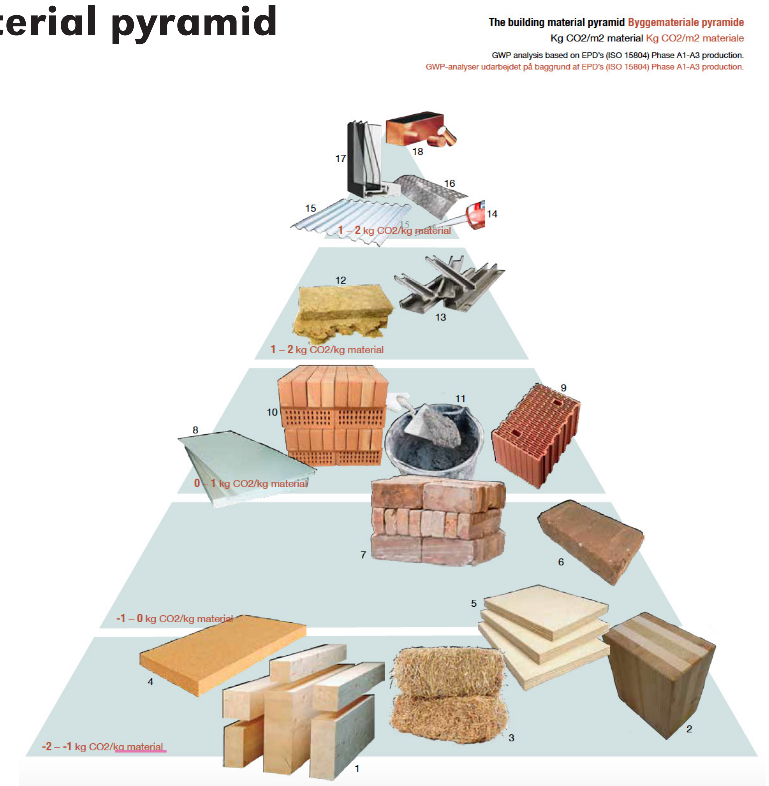
A/S Knowledge Platform

Chair of Architecture and Building Systems ETHZ



Moodle Board, Chair of Architecture and Building Systems, Prof. Dr. Arno Schlüter: https://moodle-app2.let.ethz.ch/course/view.php?id=11917 (retr. March 2022)

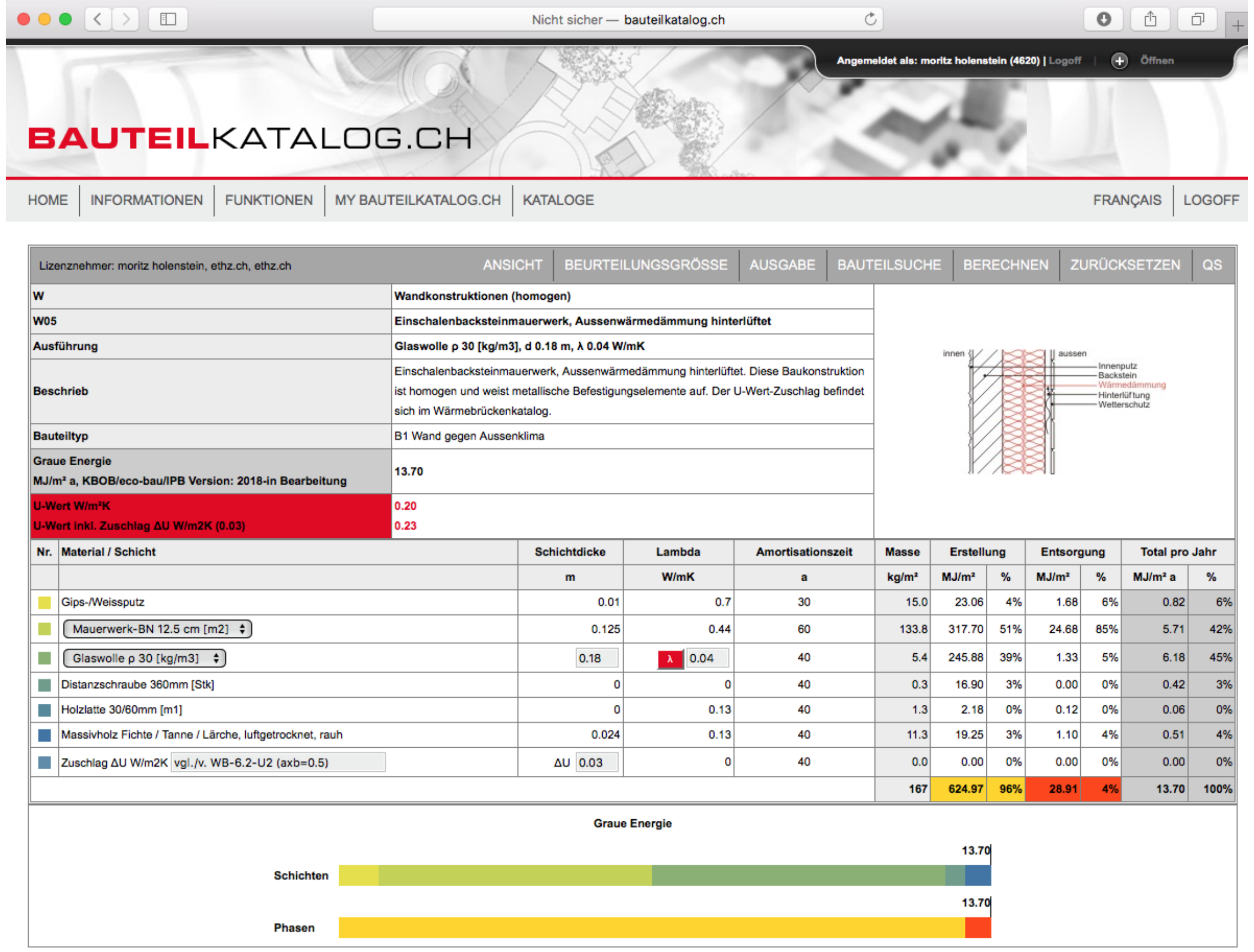
Material pyramid



https://www.materialepyramiden.dk (accessed August 2021)

Comment by chair Gigon / Guyer:
The disposal phase is left out here, which is why biogenic building materials appear as a (permanent) CO_2 sink.
However, the binding of carbon in components ends after the usage phase.
This must be taken into account when comparing to LCA in Swiss context, see KBOB list. See also pp. 48-49.

Building component catalog



www.bauteilkatalog.ch, accessed August 2019

More links und calculators:

https://www.energieschweiz.ch/tools/solarrechner/
https://www.carboncare.org/en/co2-emissions-calculator.html
https://www.wwf.ch/de/nachhaltig-leben/footprintrechner
https://www.atmosfair.de/en/standards/emissions_calculation/
https://www.atmosfair.de/en/offset/flight/
https://www.myclimate.org/

POWER AND ENERGY
(TERMINOLOGY, ORDERS OF MAGNITUDE)

Philips lightbulb 60W

POWER

Power as a physical quantity refers to the energy converted in a period of time in relation to this period of time. Its symbol is usually P, the SI unit is watt with the unit symbol W.

The watt is the unit of measurement used in the International System of Units (SI) for power (energy conversion per period of time). It was named after the Scottish scientist and engineer James Watt. The watt is a derived unit. It can be derived from the basic units kilogram (kg), meter (m) and second (s):

$$1\,\mathrm{W} = 1\,\frac{\mathrm{kg\,m^2}}{\mathrm{s^3}}$$

In the physical and technical context, the term power is used with different meanings:
1. as installed or maximum possible power
(characteristic of a device or system; also called nominal power)
2. as actual performance in an application
(either as the power supplied or as the power delivered in terms of the task).
The power consumption and the useful power output for a specific application can differ significantly depending on the efficiency or amount of waste heat.

Watt – W	1.5 W – power of the human heart 1.5 W – average power of a mobile phone. 70 to 90 W – energy conversion of a person while sleeping in order to maintain their bodily functions (basic metabolic rate) 100 to 130 W – a person's power level while working in an office
Kilowatt – kW	1 kilowatt = 1000 watts 1367 kW – the radiant power received from the sun perpendicular to the direction of radiation, at an average distance between earth and sun, without the influence of the atmosphere, on a square meter of surface (solar constant) 2 to 3.5 kW – power consumption of a typical washing machine 10 to 20 kW – thermal output of a heating system in a single-family home 15 kW – short-term peak performance of a horse (≈ 20 hp, 1 hp ≈ 0.7355 kW) 20 bis 300 kW – typical power output of a passenger car engine with 27-408 hp
Megawatt – MW	1 megawatt = 1000 kilowatts = 1 million watts (10^6) 3 to 9 MW – nominal power of large wind turbines
Gigawatt – GW	1 gigawatt = 1000 megawatts = 1 billion watts (10^9) 1 GW – typical nuclear power plant
Terawatt – TW	1 terawatt = 1000 gigawatts = 1 trillion watts (10^{12}) = 1 billion kilowatts 1.7 TW – average electrical power required worldwide (as of 2001) 44 TW – Power that the earth emits as heat from the mantle and core
Petawatt – PW	1 petawatt = 1000 terawatts = 1 quadrillion watts (10^{15}) = 1000 billion kilowatts 174 PW – portion of the sun's radiant power that reaches the earth (about half of which reaches the earth's surface)

ENERGY

The watt hour (unit symbol: Wh) is a unit of measurement of work or energy. While not part of the International System of Units (SI), it is approved for use with the SI.

A watt-hour corresponds to the energy that a system (e.g. machine, person, light bulb) absorbs or emits with a power of one watt in one hour. So a 50 watt lightbulb that is lit for an hour uses 50 Wh.

In everyday life, the kilowatt-hour (kWh, one thousand watt-hours) is common and widespread. In this unit, mainly electricity, but also heating costs are billed and recorded with measuring devices such as the electricity meter or heat meter.

Unlike the unit kilometers per hour, which is written km/h because it is divided by the hour, no "/" should be written for the kilowatt-hour kWh because it is multiplied by the hour. A spelling "kW/h" is therefore wrong.

The watt-hour is derived from the SI unit joule:

1 joule = 1 Ws (watt-second)

1 Wh = 3600 Ws (watt-seconds) = 3600 joules = 3.6 kilojoules (kJ).

The unit watt-hour is mostly used with the decimal SI prefix kilo (e.g. in electricity bills).

1 kilowatt-hour (kWh) = 1 kW · 1 h = 1000 watts · 1 h = 1000 Wh = 1000 W · 3600 s = 3.6 · 10^6 J = 3.6 megajoules (MJ)

For example, if a photovoltaic system with an output of one kilowatt converts sunlight into electrical energy for one hour, this corresponds to one kilowatt-hour.

To give the electricity production of power plants or the energy needs of entire countries in more manageable numbers, one uses the prefixes mega (M), for one million, giga (G), for one billion, or tera (T), for one trillion of the corresponding unit.
Example: 1000 megawatt-hours correspond to one gigawatt-hour (GWh).

The basic unit of energy in the international system of units is 1 joule (also watt-second).
Named after James Prescott Joule, this unit is used today for all forms of energy, including work and heat. Like any derived unit, the joule can be expressed in SI base units.
With the units kg, m and s the following applies:

$$1\,\mathrm{J} = 1\,\frac{\mathrm{kg\,m^2}}{\mathrm{s^2}}$$

Joule – J

1 joule = 1000 millijoules

1 J = 1 Ws = 1 Nm
1 J = work of the human heart per beat

4.18 J = heats up 1 g of water by 1 K under standard conditions
(formerly used unit: = 1 cal)

Kilojoule – kJ

1 kilojoule = 1000 joules

1 kJ ≈ 0,278 · 10^{-3} kWh ≈ 0,3 Wh
4.18 kJ = heats up 1 kg of water by 1 K = 1 kilocalorie
38 kJ = physiological calorific value, i.e. the energy content of 1 g of fat that can be used by the human body ≙ 9 kcal (kilocalories)

Megajoule – MJ

1 megajoule = 1000 kilojoules = 0.2778 kWh

2.3 MJ = physiological calorific value of 100 g of chocolate ≙ 550kcal
3.6 MJ = 1 kilowatt-hour (kWh) – billing unit for energy such as electricity consumption, heating output
10 to 15 MJ = averate daily energy requirement of humans, varies according to age, gender and other factors = 1430 to 3100 kcal

Gigajoule – GJ

1 gigajoule = 1000 megajoules

1 GJ ≈ 278 kWh
11 GJ ≈ 3.1 MWh, electricity requirement of a two-person household per year

Terajoule – TJ

1 terajoule = 1000 gigajoules

1 TJ ≈ 278 MWh = 278 000 kWh
56 TJ = energy released by the explosion of the Little Boy atomic bomb over Hiroshima (equivalent to 13.4 kt TNT)

Petajoule –PJ

1 petajoule = 1000 terajoules

1 PJ ≈ 278 GWh = 278 million kWh
31.5 PJ = 8760 GWh = 1 gigawatt-year – energy output of a 1 gigawatt power plant in one year (common year with 365 days)
89.9 PJ = complete conversion of 1 kg of matter into energy ($E=m \cdot c^2$)

Prefix	Symbol	Multiplier (trad. notation)	Exponential	English	Deutsch
Exa	E	1'000'000'000'000'000'000	10^{18}	Quintillion	Trillion
Peta	P	1'000'000'000'000'000	10^{15}	Quadrillion	Billiarde
Tera	T	1'000'000'000'000	10^{12}	Trillion	Billion
Giga	G	1'000'000'000	10^{9}	Billion	Milliarde
Mega	M	1'000'000	10^{6}	Million	Million
kilo	k	1'000	10^{3}	Thousand	Tausend
hecto	h	100	10^{2}	Hundred	Hundert
deca	da	10	10^{1}	Ten	Zehn
base	b	1	10^{0}	One	Eins
deci	d	1/10	10^{-1}	Tenth	Zehntel
centi	c	1/100	10^{-2}	Hundredth	Hundertstel
milli	m	1/1'000	10^{-3}	Thousandth	Tausendstel
micro	µ	1/1'000'000	10^{-6}	Millionth	Millionstel
nano	n	1/1'000'000'000	10^{-9}	Billionth	Milliardstel

Kiss #12, John Chamberlain, 1979

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Topic platform for the Master's Thesis HS22
DURABILITY AND/OR CHANGE?

«VADEMECUM» – LCA Data and Parameters

Chair of Annette Gigon / Mike Guyer, D-ARCH, ETH Zurich
March 2022 / Revision 06.06.2022 (English translation)

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Note: The data compiled here has been processed to the best of our knowledge.
The correctness cannot be guaranteed; the application is at your own risk.
If obvious errors are found, please let us know.