Environmental Benchmarks for buildings: Needs, challenges and solutions

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Supplementary information

Main characteristics and ways forward of existing benchmark systems regarding environmental impacts of buildings

Main characteristics of the national benchmarking systems presented during the 71st discussion forum on LCA are summarised in Tables 1 to 8. Most countries apply benchmarking on new and refurbished residential buildings. Germany and Finland cover a very broad spectrum of different building types (see **Table 1**). Most benchmarking systems cover the whole life cycle and only a few of them include benefits and loads beyond the system boundary. The production stage (A1-A3), replacements (B4), operational energy consumption (B6) and end of life stage (modules C1, C2, C3 and/or C4) are covered in most benchmarking systems (see **Table 2**). The Dutch benchmarking system excludes operational energy demand and covers construction, maintenance replacement and end of life. The scope of the assessment (building elements included) comprises the substructure, the superstructure, building services, finishes and balconies in most benchmarking systems. Conveying, data and fire protection systems are often disregarded (see **Table 3**). Operational energy demand covers space heating, hot water demand, ventilation/cooling and lighting (see **Table 4**). In some countries (Belgium, Czechia, France and Switzerland), auxiliary electricity demand is included too. The reference study period applied varies between 50 and 120 years with most countries using 50 years (see **Table 5**). National or global databases adapted to the national context are used in most countries. All benchmarking systems address greenhouse gas emissions while primary energy, acidification, eutrophication, summer smog, and water use are quantified by most of them (see **Table 6**). The Dutch and the Belgian system use a single score indicator to quantify total environmental impacts caused by the buildings. Greenhouse gas emission target values for new residential buildings (construction, operation and end of life) vary between 9 and 11 kg CO_2-eq per m^2 and year (and 20 kg CO_2-eq per m^2 and year for the Czech system, see **Table 7**). The Swiss benchmarking system also includes mobility induced by the building which adds another 5 kg CO_2-eq per m^2 and year. Greenhouse gas emission target values are yet much less common (see **Table 8**). The target value for Swiss refurbished residential buildings is 10 kg CO_2-eq per m^2 and year (excluding induced mobility), compared to 11 kg CO_2-eq per m^2 and year for new residential buildings. The shares of construction and operation are however distinctly different acknowledging the fact that the operational energy demand of refurbished buildings cannot be as low as that of new buildings.

Table 1: Overview of building types covered
N: New buildings; R: Retrofit buildings

	Residential	Office	Schools	Restaurants	Specialist shops	Grocery shops	Universities	Hotel	Retail buildings	Logistics & production	Industrial buildings	Hospitals	Sports facilities
Belgium	N,R												
Czechia	N [1])	N	N										
Denmark [2])	N	N	N										
Finland	N,R	N,R	N,R	N,R	N,R	N,R					N,R	N,R	N,R
France	N [1])	N											
Germany (BNB) [3])		N,R	N,R				N,R						
Germany (DGNB) [4])	N [5]),R	N,R	N,R		N,R	N,R	N,R	N,R	N,R	N,R			
Germany (NaWoh) [6])	N [7])												
Germany (BNK) [8])	N [9])												
Netherlands [10])	N, R	N, R	N, R	N, R	N, R	N, R							
Switzerland	N,R	N,R	N,R	N,R	N,R	N,R							

[1]): distinguishing multi- and single family buildings
[2]): DGNB values based on older benchmarking system methodology are available for those building types, new values are under development and expected by the end of 2019.
[3]): Bewertungssystem Nachhaltiges Bauen
[4]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB
[5]): distinguishing small residential buildings (up to 6 units) and bigger residential buildings
[6]): Bewertungssystem Nachhaltigkeit im Wohnungsbau
[7]): multi-family residential buildings
[8]): Bewertungssystem Nachhaltiger Kleinwohnhausbau
[9]): small residential buildings
[10]): in principle any type of building can be assessed, assessment of civil engineering works is presently being harmonized with the building assessment methodology.

Table 2: Overview of the life cycle stages included in the benchmark system for residential buildings, climate change;

Life cycle stages	A1-A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Belgium	X	X	X		X		X	X	X	X	X	X	X	X	
Czechia	X [1])								X						
Denmark	X						X		X				X	X	
Finland	X	X	X			X	X	X	X		X	X	X	X	X
France	X	X	X	X			X	[2])	X	X	X	X	X	X	X
Germany (NaWoh) [3]) & BNK) [4])	X				X		X		X				X	X	
Germany (DGNB) [5])	X				X		X		X				X	X	X
Netherlands	X	X	X	X	X	X	X	X			X	X	X	X	
Switzerland	X						X		X		X	X	X	X	

[1]): not considered for single-family houses

[2]): refurbishment requires a specific study, e.g. comparing various measures on an existing building. It is possible using the design tool but then no impacts are considered for module A (construction stage).

[3]): Bewertungssystem Nachhaltigkeit im Wohnungsbau

[4]): Bewertungssystem Nachhaltiger Kleinwohnhausbau

[5]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB

Table 3: Overview of the building elements included in the benchmark system for residential buildings, climate change
P: partially included

	Substructure			Superstructure									Building Services									Finishes				External		
Building elements	Foundations	Basement walls	Groundfloor construction	External walls	Frames (pillars and beams)	External doors	Windows	Internal walls	Floors	Ceilings	Roof	Stairs and ramps	Water system	Sewage system	Electrical system	Heating system	Cooling system	Ventilation system	Conveying system	Data system	Fire protection system	External finishes	Internal finishes	Fixed furniture	Furniture	Balcony	Vegetation	Pavements
Belgium	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X				X	X					
Czechia	X	X	X	X	X	X	X	X	X	X	X	X	P	P	P	P	P	P				X	X	X		X		
Denmark	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X		X		
Finland				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				X	X	X		X		
France	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	[1])	[1])	[1])	X	X	[1])		X		
Germany (NaWoh) [2])	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X		
Germany (DGNB) [3, 4])	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X			X		
Germany (BNK) [5])	X	X	X	X	X	X	X	X	X	X	X	X				X						X	X	X		X		
Netherlands [6])	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X		X		
Switzerland	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X				X	X	X		X		

[1]): These systems can be accounted for in specific projects but they are not included in the benchmarks.

[2]): Bewertungssystem Nachhaltigkeit im Wohnungsbau

[3]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB

[4]): Electrical system: photovoltaic systems or solar thermal collectors.
Additional general note: If a simplified system boundary is chosen, a factor of 1.2 on the results of the embodied impacts has to be added (which can be reduced to 1.1 by proving that low tech solutions have been chosen).

[5]): Bewertungssystem Nachhaltiger Kleinwohnhausbau

[6]): In principle all building components which are in some way regulated under the National Building Code.

Table 4: Overview of the energy used in building operation included in the benchmark system for residential buildings, climate change;

Energy use in operation	Space heating	Hot water	Ventilation/cooling	Lighting	Auxiliary electricity demand	Others	PV production [1])	...	...
Belgium	X	X	X	X	X				
Czechia	X	X	X	X	X				
Denmark	X	X	X	X					
Finland	X	X	X	X					
France	X	X	X	X	X	X	X		
Germany (NaWoh) [2])	X	X	X	X [3])			[4])		
Germany (DGNB) [5]) & BNK) [6])	X	X	X						
Netherlands									
Switzerland	X	X	X	X	X		X [7])		

[1]): On-site electricity production for self-consumption and supply to the electricity grid
[2]): Bewertungssystem Nachhaltigkeit im Wohnungsbau
[3]): Only the lighting in the communal areas of the building
[4]): Additional indicator for energy production for tenants and third parties
[5]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB
[6]): Bewertungssystem Nachhaltiger Kleinwohnhausbau
[7]): Only self-consumption share (annual balance)

Table 5: Overview of the reference study period and databases used in the benchmark system for residential buildings;

	Reference study period [years]	**Database**
Belgium	60	ecoinvent v2.2 + adaptations to the Belgian context
Czechia	50	www.envimat.cz
Denmark	120	Oekobau.dat 2016, COWI 2016
Finland	DSL / 50	(national database being developed)
France	100 [1])	ecoinvent v2.2
Germany (NaWoh) [2])	50	Oekobau.dat 2013
Germany (DGNB) [3])	50	Oekobau.dat 2018
Germany (BNK) [4])	50	Oekobau.dat 2011 [5])
Netherlands	75	NMD 2014, ecoinvent data v2.2
Switzerland	60	KBOB LCA data DQRv2:2016

[1]): 200 years for historical buildings
[2]): Bewertungssystem Nachhaltigkeit im Wohnungsbau
[3]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB
[4]): Bewertungssystem Nachhaltiger Kleinwohnhausbau
[5]): New updated version based on Oekobau.dat 2017 may be developed in 2019

Table 6: Environmental indicators covered in the benchmark system for residential buildings
na: not available;

	Primary energy	Greenhouse gas emissions	Acidification	Eutrophication	Ozone depletion	Summer smog	Fine particles	Human toxicity	Ecotoxicity	Water used	Waste	Damage to biodiversity	Damage to health	Depletion of abiotic resources	Depletion of fossil fuels	Odour	Environmental impacts (national approach)
Belgium		X	X	X	X	X	X	X	X	X				X	X		X
Czechia	X [1])	X	X	X	X	X				X			X				na
Denmark	X [1])	X	X	X	X	X											na
Finland		X															na
France	X	X	X	X		X				X	X [2])	X	X	X		X	na
Germany (NaWoh) [3])	X [1])	X	X	X	X	X				X							na
Germany (DGNB) [4])	X [1])	X	X	X	X [5])	X				X							
Germany (BNK) [6])	X [1])	X															
Netherlands	X [1,7])	X	X	X	X	X		X	X	X			X	X [8])	X		X
Switzerland	X [1])	X															

[1]): separately reporting renewable and non-renewable primary energy
[2]): chemical and radioactive waste reported separately
[3]): Bewertungssystem Nachhaltigkeit im Wohnungsbau
[4]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB
[5]): not used as benchmark any more
[6]): Bewertungssystem Nachhaltiger Kleinwohnhausbau
[7]): Indicator is reported but does not contribute to the aggregated impact score (MPG).
[8]): excluding fossil fuels

Table 7: Overview of target values greenhouse gas emissions of new residential buildings
na: not available; nc: not covered; ni: not included in benchmark; tbd: to be defined;

Target value greenhouse gas emissions kg CO_2-eq/m^2.a	Construction	Operation	Induced mobility	End of Life	Total
Belgium [1])	na	na	nc	na	na
Czechia [2])	na	na	nc	na	20
Denmark	na	na	nc	na	[3])
Finland	tbd	tbd	tbd	tbd	tbd
France [4])	na	na	ni	na	9.1 / 10.6
Germany (BNK) [5,6])	na	na	nc	na	9.44
Germany (NaWoh) [7])	na	na	nc	ni	12.0 [8])
Germany (DGNB) [9])	6.58	na [10])	ni	[11])	[12])
Netherlands [13])	na	na	na	na	na
Switzerland	9.0	3.0	4.0	[11])	12.0 [14])

[1]): benchmark defined based on an aggregated score expressed in environmental cost
[2]): multi-family buildings
[3]): DK is in a development phase, with values based on an updated methodology expected by the end of 2019
[4]): best practice performance level for individual (9.1) and collective (10.6) housing. Induced mobility can be accounted for in the design tool, but it is not included in the benchmarks.
[5]): Bewertungssystem Nachhaltiger Kleinwohnhausbau
[6]): small residential buildings
[7]): Bewertungssystem Nachhaltigkeit im Wohnungsbau
[8]): Obsolete value from the year 2016 using an old version of oekobau.dat, revision is forthcoming
[9]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB
[10]): according to energy performance requirements, e.g. 30% better than legal requirements
[11]): included in „Construction“
[12]): specific value resulting of construction and variable operation
[13]): no separate limit value for greenhouse gas emissions; target value for overall environmental impacts: MilieuPrestatie van Gebouwen (MPG) < 1
[14]): without induced mobility

Table 8: Overview of target values greenhouse gas emissions of refurbished residential buildings
na: not available; nc: not covered; ni: not included in benchmark; tbd: to be defined

Target value greenhouse gas emissions kg CO_2-eq/m^2.a	Construction	Operation	Induced mobility	End of Life	Total
Belgium [1])					
Czechia	na	na	nc	na	na
Denmark	na	na	nc	na	
Finland	tbd	tbd	tbd	tbd	tbd
France	na	na	na	na	na
Germany (DGNB) [2])	6.58	na [3])	ni	[4])	[5])
Netherlands [6]):	na	na	nc	na	na
Switzerland	5.0	5.0	5.0	[4])	10.0 [7])

[1]): no preliminary results available yet for refurbishments (ongoing research)
[2]): Deutsches Gütesiegel Nachhaltiges Bauen der DGNB
[3]): according to energy performance requirements, e.g. 30% better than legal requirements
[4]): included in „Construction“
[5]): specific value resulting of construction and variable operation
[6]): no separate limit value for greenhouse gas emissions; target value for overall environmental impacts: MPG < 1
[7]): without induced mobility

An inquiry about the application, the effect and the future plans of national benchmarking systems revealed that most countries are at the beginning. There are hardly any statistics about the share of buildings compliant with the national benchmarks or the share of buildings is still negligible (see **Table 9**). National legislation starts to adopt life cycle based environmental benchmarks and may thus lead to more strict requirements on the environmental performance of buildings (see **Table 10**). Some countries apply or intend to apply top-down emission target values, in particular using the Paris Agreement (UNFCCC 2015) to determine greenhouse gas emission target values (see **Table 11**). Some of the countries with already existing benchmarking systems intend to tighten the target values in the next revisions (see **Table 12**). Others are on the way to introduce a first generation of benchmarks for buildings.

References

UNFCCC (2015) Adoption of the Paris Agreement. vol FCCC/CP/2015/L.9/Rev.1. Paris

Table 9: Share of buildings (surface area-%) that comply with target performance value listed in **Table 7** and **Table 8**

Belgium	The presented benchmarking system is part of a research project. The benchmark values are not yet implemented in building practice.
Czechia	Very limited number of certified buildings so far.
Denmark	There were benchmarks for DGNB based on the German DGNB benchmarks where now 11 residential building projects DGNB are certified and 20 are pre-certified. In 2019 new benchmarks based on slightly different methodology are under development.
Finland	Not yet evaluated. However, we plan to include most buildings, with perhaps the same exceptions as in the nZEB regulations.
France	No survey has been performed at the moment to answer this question in France. The % is probably small.
Germany	In Germany, there are several sustainability certification systems dealing with residential buildings. Specifically, these are: (1) DGNB, which is the rating system developed by the German Green Building; (2) NaWoh, which is a system developed by Federal associations of housing and real estate companies; (3) BNK, which was developed by the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and is currently managed by BiRN GmbH. It should be noted that another building certification system developed by BMUB is BNB (managed by the ministry itself), but it does not include a version for residential buildings. Some figures for DGNB, NaWoh and BNK are provided in the following: DGNB (https://www.dgnb.de/en/council/facts-and-figures/) – In general, DGNB reports 57,7 million square meters of certified floor space for all building types covered by the system. From this 64.947 square meters of GFA belong to "Gold" and "Platinum" certified big apartment buildings, while 1.459 square meters of GFA belong to "Gold" and "Platinum" certified small apartment buildings (up to six units). It can be assumed that these two level of certification comply with the target performance value. NaWoh (Nachhaltiger Wohnungsbau, http://www.nawoh.de/nachhaltiger-wohnungsbau) – In general, 30 quality labels have been so far awarded for sustainable housing. No specific information is available on how many of them have achieved the highest level of fulfilment. BNK (Bewertungssystem Nachhaltiger Kleinwohnhausbau, http://bau-irn.de/zertifizierte-projekte) – In general, 30 small residential buildings have been certified under BNK since 2014. 19 out of these 30 buildings were assessed as "Excellent" (no information on the exact number of square meters is available). It can be assumed that this level of certification complies with the target performance value.
Netherlands	This information is not available: 1) Greenhouse emissions are not reported as such (only aggregated with other impacts), and 2) the share of buildings or m^2 surface area in buildings that have been erected or permitted under the new regulation is not easily established.
Switzerland	**National level:** Because the SIA 2040 energy efficiency path is no label and no legal requirement, no statistics on national level. It is estimated to some 1'000'000 m^2 (personal communication, Dr. Heiri Gugerli, Gugerli Dolder Environment & Sustainability Ltd., 28 May 2019). This is a few per thousand of the energy reference area of the entire building stock in Switzerland. **City owned buildings:** We have a reporting for 3 building groups: *Residential buildings:* The average of all housing developments (new and retrofit, since 2009 including planed buildings) is below the target value. *School buildings:* The average of all schools (new and retrofit, since 2009 including planed buildings) is below the target value. *Centres for elderly:* The average of all centres (new and retrofit, since 2009 including planed buildings) is about 30% over the target value.

Table 10: Did the environmental benchmark system lead to more rigorous legal requirements on the environmental/energy or greenhouse gas emissions performance of buildings?

Belgium	The developed benchmarking system will be the basis for future legal requirements. However, we expect in the short term that the benchmark values will only be indicative to help designers to position their design in the market.
Czechia	It did no lead to compulsory requirements, but SBToolCZ certification is now compulsory for school buildings in Prague that apply for financing.
Denmark	Not relevant (yet). This question can hopefully be answered in few years.
Finland	The benchmarking system goes hand in hand with regulatory development. They cannot be separated from each other, according to our current plans.
France	Not yet, the LCA will be integrated in the next building regulation planned in 2020.
Germany	No, not yet
Netherlands	Yes, from 2013 on an MPG calculation is compulsory for building permit requests for office buildings and new houses larger than 100 m^2. From January 2018, the maximum value of the MPG calculation for building permit requests should not exceed the value of 1.
Switzerland	Currently the legal requirements are in revision and are getting tightened. The intensification affects operation energy and share of renewable energy / energy production. The new requirements are a little bit more comprehensive, but still far away from 2040 requirements (construction, induced mobility…). No direct influence can be observed. Regarding the ongoing political discussion a future influence of course is possible…

Table 11: Is it planned to adapt your current benchmark target values (if any) to the global carbon neutrality target? If yes, only for building operation (only regulated energy consumption or also non-regulated energy consumption?) or also for embodied environmental impacts?

Belgium	The benchmark values derived from a bottom-up approach will be compared with the target values based on a top-down approach. The top-down approach will be based on environmental goals and policy targets. Potential sources are EU greenhouse gases reduction targets, national climate plans, but also the concepts of ecological footprint, planetary boundaries, carbon budget, absolute sustainability and earth carrying capacity factors.
Czechia	We plan to adapt it for operational as well as for embodied environmental impacts.
Denmark	The previous DGNB benchmarks based on the German DGNB system were based on bottom-up approach and therefore not adapted to carbon neutrality targets. The benchmarks under development will probably also be based on bottom-up approach.
Finland	We plan to make the benchmark levels compatible with national energy and climate strategy. This way, we can monitor how well the building stock is performing in respect to the national goals.
France	This idea is welcome but requires to define an appropriate methodology, explaining how to derive building related targets from a global carbon neutrality target, e.g. dividing by 4 greenhouse gases emissions compared to 1990.
Germany	It is currently under discussion. A research activity is ongoing in Germany with the aim to support in a more active way the topic of climate protection in sustainability certification systems. In this context, possibilities for deriving benchmarks for GWP according to the top-down approach are also discussed.
Netherlands	There is a proposal (by W/E) to combine energy performance assessment and LCA assessment of materials into a single Sustainability Performance score (DPG-score). This avoids certain problems if you want to comply with two individual scores (operational energy and materials impacts). However, it will take several years before this can be integrated into building regulations.
Switzerland	In the city of Zurich there is currently a vivid political discussion about the implementation of the Paris Agreement. Given that we yet do have the 2000-Watt-society goals in the city constitution, the discussion is about an intensification of the goals, the velocity of the implementation and on methodical questions. On a city level it is difficult to take embodied environmental impacts into account. For the building sector we see it as fundamental. We (= means city owned buildings) already take operation and environmental impacts into account.

Table 12: Is there already a next version of the provided benchmark target values planned? If yes, when? And will the benchmark values become more rigorous?

Belgium	As part of the research project, a stepwise approach to gradually evolve towards more ambitious benchmark values will be proposed.
Czechia	We are developing the next version in a separate ongoing project RESBy. We have first version of the indicator for new residential buildings. The benchmark is defined per person instead per m^2. There is ongoing testing of the benchmark in several diploma theses and in other case studies made within the project.
Denmark	The benchmarking system is under development. It is not known yet how ambitious the benchmark values will be.
Finland	Not yet.
France	New benchmark values for the design tool EQUER will be provided in autumn 2019, based upon ecoinvent v3.4 instead of v2.2 and using new damage indicators regarding human health and biodiversity. The new regulation should be defined in 2020 but it is not sure if it will impose a reduction of CO_2 emissions compared to the present (2012) regulation.
Germany	It depends on the results of the processes described in the previous answer – see Table 11. The tendency is towards forming more stringent requirements.
Netherlands	Yes, it is at present very easy to comply with the MPG limit value of 1 for new buildings – almost any design will comply with this standard. This was of course done to make the new obligation more acceptable for building developers and builders. For this reason there is now research underway to see whether we can set the limit value at a more lower (i.e. more demanding) value. It is not known if and when such new standards will be published and enforced.
Switzerland	Currently no plans for a next version. However, the top down targets of the 2000-Watt-society (which form the basis for the current benchmarks for buildings) are currently being revised and will likely be more strict.