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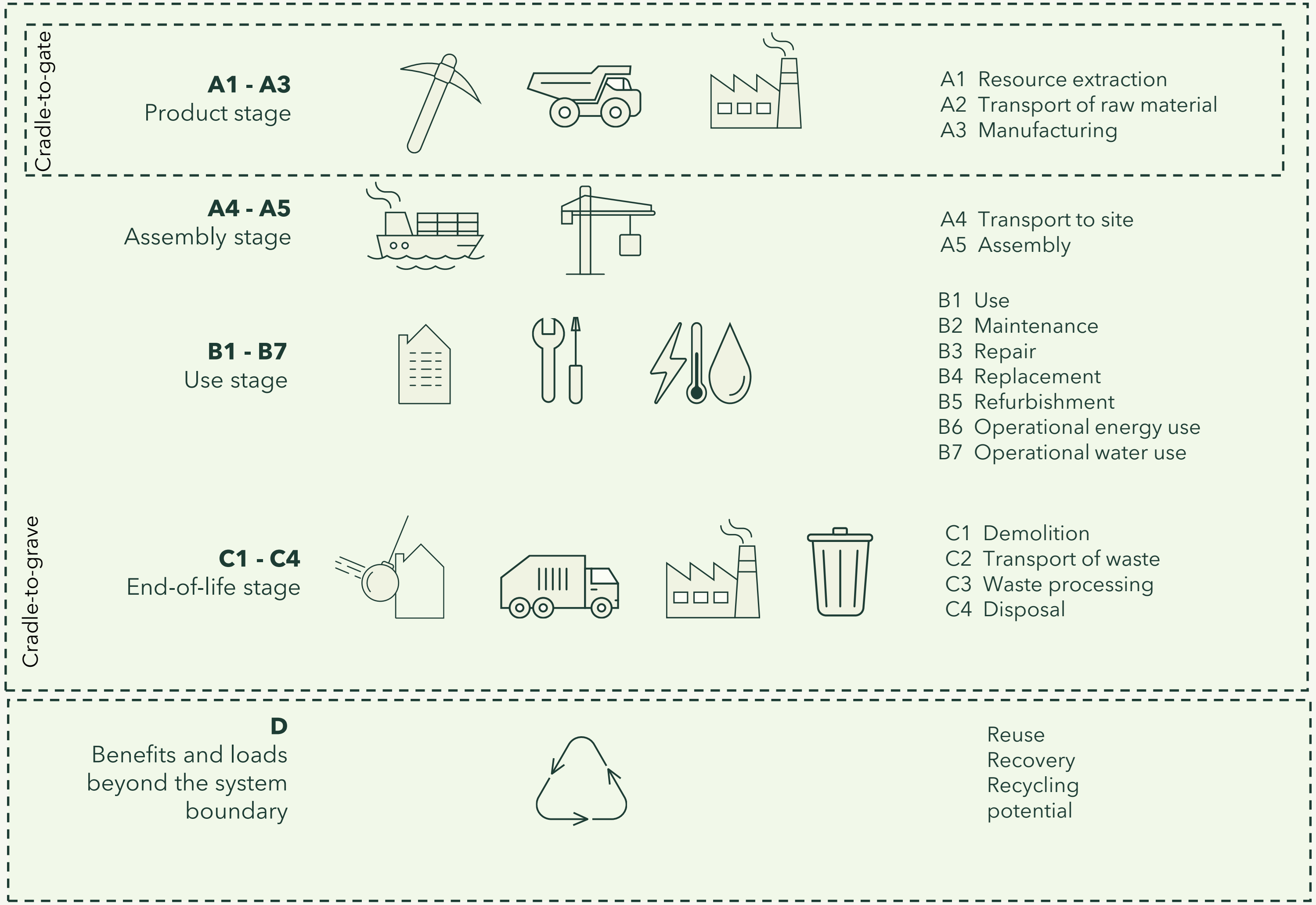
Building LCA in Norway

Background and methodology

Intro

- IEA [1, p. 111] states, "In 2022, buildings sector emissions represent around a third of total energy system emissions, including buildings operations (26%) and embodied emissions (7%) associated with the production of materials used for their construction."
- On the European continent, buildings are responsible for ~40% of final energy use and 36% of indirect GHG emissions [2].
- No scarcity of research and methods for developing low energy buildings using energy saving measures (ESMs) [1, 3].

EN 15978:2011& EN 15804:2012



Aspects that influence LCA results

- The scope of the study
  - Functional unit [7].
  - System boundaries (life cycle stages) [4,6].
  - Methodological choices: attributional vs consequential, LCI and LCIA methods, standardized LCA method, and software [4-7].

3. Attributional and consequential LCA respond to different questions

As clear from the Introduction, we can distinguish between ALCA and CLCA. The distinction between two types of LCA was suggested in the beginning of the 1990s [4, 5]. It was established toward the end of the decade [6] to resolve debates on what type of input data to use in LCAs (cf. Section 4) and on how to deal with the allocation problems that occur when, for example, a process produces more than one type of product (Section 5). Various names were used on the two types of LCA [7], but the terms attributional/consequential have been used since 2001 [8].

Several different definitions of attributional and consequential LCA have been suggested [9, 10]. I prefer the definitions of Finnveden et al., in what is probably the most cited scientific paper on LCA [11]:

- Attributional LCA: LCA aiming to describe the environmentally relevant physical flows to and from a life cycle and its subsystems
- Consequential LCA: LCA aiming to describe how environmentally relevant flows will change in response to possible decisions

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COMMENTARY AND DISCUSSION ARTICLE

CrossMark

Digesting the alphabet soup of LCA

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1 Introduction

One of the most pertinent and enduring debates within the life-cycle assessment (LCA) community is on consequential (CLCA) and attributional LCA (ALCA), see for example, Weidema et al. (1999), Guinée et al.(2002), Ekvall and Andræ (2006), Schmidt (2010), Zamagni et al. (2012), Rehl et al. (2012), Anex and Lifset (2014), Brandão et al. (2014), Suh and Yang (2014), Dale and Kim (2014), Hertwich (2014), Plevin et al. (2014a), Plevin et al. (2014b), Ekvall et al. (2016), and Weidema et al. (2018). Amongst other things, the debate focuses on similarities and differences between these two modes and on which mode is more appropriate for which case or question. Some authors claimed superiority of one of these modes over the other (Plevin et al. 2014a; Weidema et al. 2018). Here, we refrain from further dwelling on this discussion, but rather discuss the more recent emergence of other modes of LCA. These new modes have been developed by independent scholars, outside the ISO standards (International Organization for Standardisation 2006) and outside national and continental guidelines (e.g., European Commission—Joint Research Centre—Institute for Environment and Sustainability 2010). They all focus on estimating life-cycle impacts of future systems and we argue that they are all varieties of analysis fitting under the umbrella of "explorative" LCA. To substantiate this, we first look into the definitions of ALCA, CLCA, and some of the newer modes of LCA. We then briefly discuss similarities and differences between these different LCA modes, and conclude that rather than discussing different modes, the LCA community should focus on discussing their underlying real differences.

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Assessing the greenhouse gas mitigation potential of urban precincts with hybrid life cycle assessment

- The difference between process-based and hybrid LCA is enlarged from 16% to 23%.

Problem

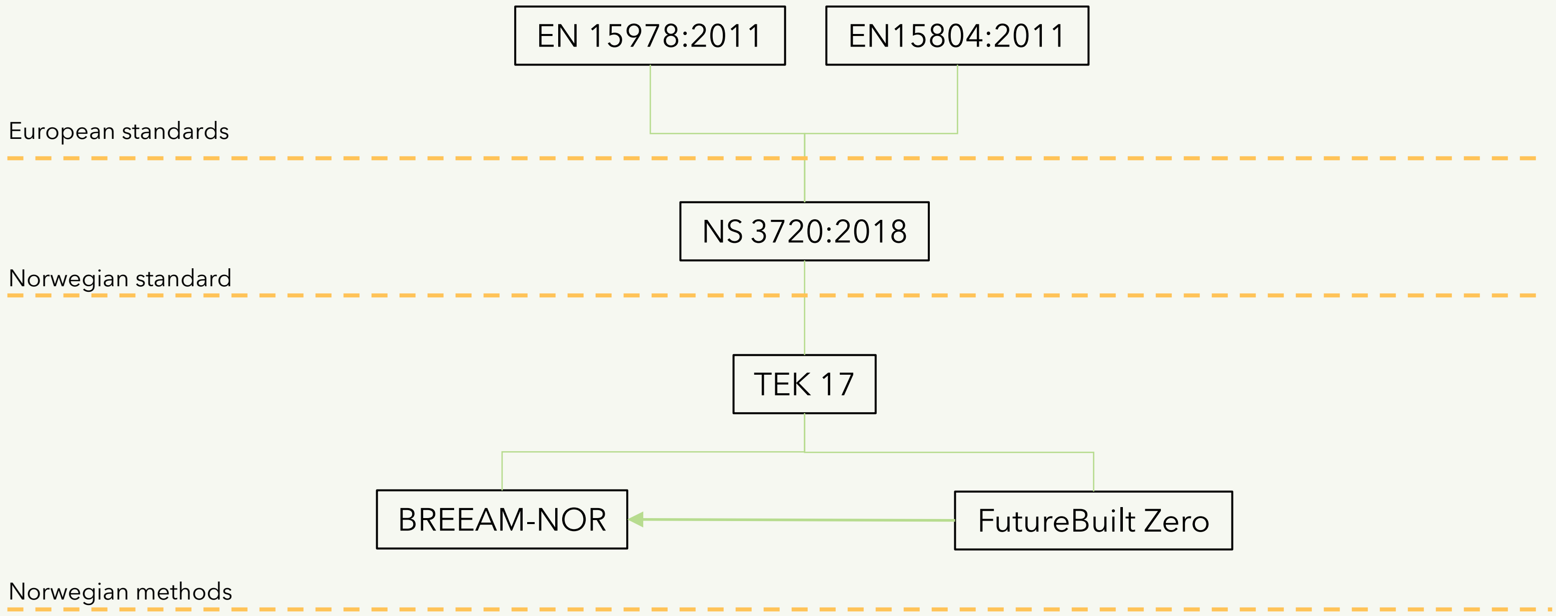
- Despite a standardized and recognized method for calculating environmental burdens derived from the life cycle of buildings, there are inconsistencies in how the LCA methodology is utilized [4, 6, 7, 8].

- The standard leaves many aspects open to interpretation for practitioners.

- Thus, variable use of the LCA method can be identified in scientific research and methods used by the industry [6-7].

- The inconsistent use of the method hampers comparability of results both within the same region and across different regions [6, 8].

Development of building LCA methodologies in Norway:



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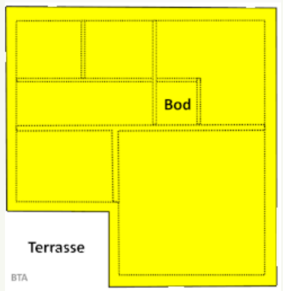
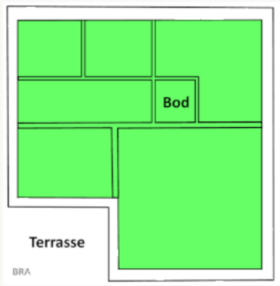
NS 3720 – Method for greenhouse gas calculations for buildings

- Based on the EN 15978 standard albeit with a streamlined focus on greenhouse gas (GHG) emissions.

- Provides a standardized method for calculating GHG emission based on the LCA methodology (EN 15978).

  - The functional unit should at least include:
    - Building typology
    - Technical and functional demand
    - Total gross floor area (GFA)
    - Total internal floor area (GIA)
    - Total heated GIA
    - Use profile/patterns
    - Functional lifetime (60 years)





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Scope – life cycle modules NS 3720:2018

Building Assessment Information																	
Building Life Cycle Information																	Supplementary information beyond the building life cycle
Product stage A1-A3			Construction process stage A4-A5		Use stage B1-B8								End of life stage C1-C4				Benefits and loads beyond the system boundary D
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	B8	C1	C2	C3	C4	D
Raw material supply	Transport	Manufacturing	Transport to site	Construction – installation process	Use, installed products	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	~~Operational water use~~	Transportation in use	Deconstruction	Transport	Waste processing	Disposal	Recovery, Reuse, recycling potential

Differences in LC-modules between NS 3720:2018 and EN 15978 and EN 15804

- Modul A5: "Construction, building, and installation work" is divided into consequences of site preparation, preparatory work, and building erection.

- Modul B7: "Water consumption during operation" is not covered by this standard, but the energy use required for distributing and heating domestic hot water in the building is included in module B6.

- Modul B8: "Transport during operation" (more information on the next slide)

- Modul D: Consequences related to reuse, recycling, and energy recovery outside the system boundary of the analysis can be calculated in module D, and the result in module D should be reported separately (more information later in the presentation)

Module B8

- Total emissions from transportation per year during the operational phase of the building consist of emissions from passenger cars and the group of collective transport modes, including buses, boats, airplanes, and rail vehicles, as well as the company's goods and waste transport.

  The steps in the calculation method are as follows:

  a) Determine the building type and business type at the three-digit level as defined in NS3457,3.
  b) Determine the type of users and the number of individuals associated with different user types (employees, residents, visitors/other users).
  c) Determine the service and goods transport for the business type.
  d) Determine the average number of trips per day for the year.
  e) Determine the mode share (percentages) of transportation modes.
  f) Calculate the travel distance per trip for each type of transportation mode (person km, tonne km).
  g) Choose the emissions factor for the different transportation modes (kgCO2-eq per person km or tonne km).
  h) Sum over all individuals, trips, travel distances, and transportation modes.

- Emission factors and functions should be life cycle-based.
- Bicycling and walking have negligible emissions and therefore are not included in the calculation.

Table 1 – Estimating number of building users for different building typologies. Adapted from and available in [11].

Building type/function	Number of users per day	Number of open days per year	Annual average number of trips per day per user
Educational	The number of students the building has capacity for, with 80% present daily	190	0,83
Hospital	0,5 day patients + 0,5 visits per "warm bed"	365	2

Table 2 - Example of available values for estimating life cycle transport emissions. Adapted from [11].

	Direct emissions	Fuel production	Production and maintenance of vehicles	Other indirect emissions	Total emissions
Norwegian average car	0,17	0,037	0,072	0,008	0,29
Electric car, average size, EU el-mix	0	0,028	0,12	0,011	0,16

Module D - NS 3720:2018

- Where a material flow crosses the system boundary and has an economic value or has reached the stage where the material ceases to be waste, thus replacing another product, greenhouse gas emissions can be calculated.
- Consequences of using waste as energy sources for heat or power production for use in other objects are assigned to module D.
- Consequences of exported self-produced energy crossing the system boundaries are assigned to module D.
- To calculate the consequences of reuse, recycling, and exported energy, the quantity and type of materials and exported energy crossing the system boundaries between different objects or other systems must be provided. Consequences are calculated using current relevant substitution processes.
- Module D calculations are performed as described in EN 18978 and EN 15804.

Other – NS3720:2018

- Details on building component specification (according to NS 3451) [11, 12].
- Data quality in two levels:
  - Level 1: Calculated or measured data for a product or service within a given period. Data extracted from EPDs must be verified by a third party in accordance with EN 18804:2011.
  - Level 2: Generic, average or proxy-data.
- The starting point for greenhouse gas calculations from energy use during operation is the building's energy demand related to heating, cooling, ventilation, hot water, and lighting.
- Calculations should be performed according to SN-NPEK 3031.2023 or measurements of actual energy use for buildings that are operational [11, 13].

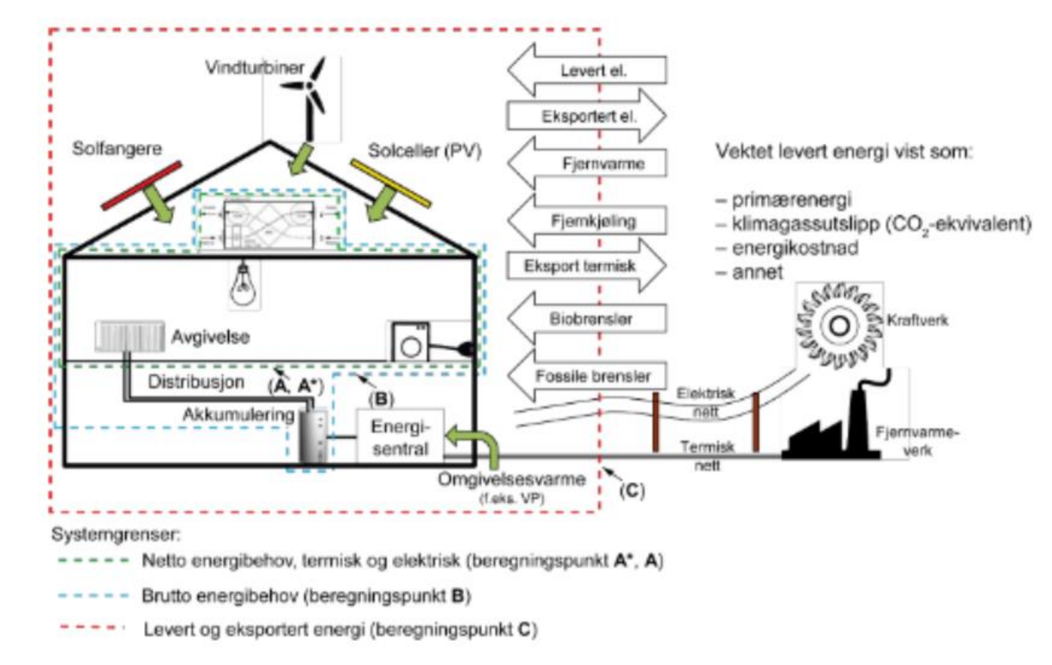

Figure 1 – System boundaries, energy calculations according to NS 3720:2018 [11].

Greenhouse gas calculations for energy use during the operation of the building throughout its lifetime – NS 3720:2018

Carbon content for electricity from the grid, two scenarios:

- **Scenario 1:** Norwegian consumption mix (average per year over the lifespan of the object). The starting point should be the average of the Norwegian consumption mix over the past 3 years. For the lifespan of the object, the factor is calculated using a linear function towards near-zero emissions in 2050, which is then maintained at this level until the end of the period.

- **Scenario 2:** European (EU28+NO) consumption mix (average per year over the lifespan of the object). The requirements are the same as described above but applied to a European consumption mix.

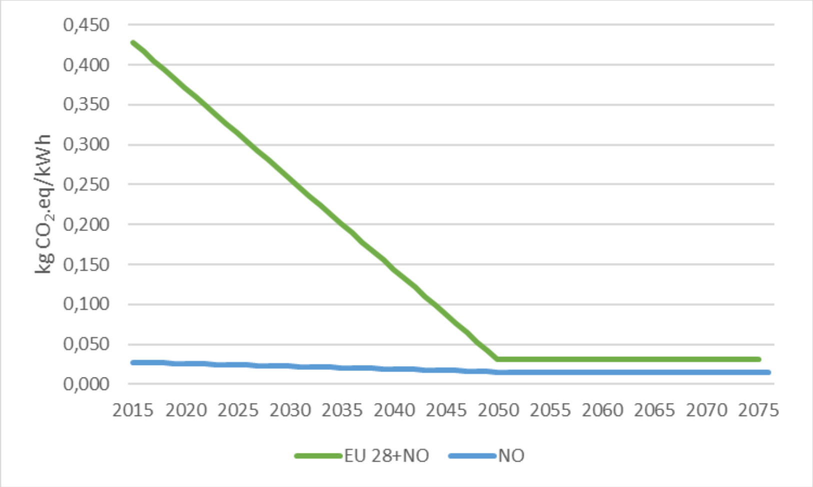

Figure 2 – Predicted carbon content electricity mix.

Table 3 – Carbon factors for different energy production technologies. Adapted from [11] .

Production technology	CO_{2-eq} factor (g/kWh)
Hydropower	2-20
Wind power	3-41
Coal power	660-1300
Natural gas	380-1000
PV	13-190
Biothermal	8,5-130
Nuclear power	3-35
CHP from NaGas with CCS	~100
Thermal power (NO)	450
Thermal power (EU)	800

Table 4 – Calculated and predicted energy mix for Norway and Europe. Adapted from [11].

Production technology	2015		2050	
Production technology	**NO**	**EU28+ NO**	**NO**	**EU28+NO**
Hydropower	95 %	18%	85%	8%
Wind power	1%	8%	15%	33%
Thermal power (NO)	4%		0%	
Thermal power (EU)		43%		0%
PV		3%		10%
Geo/biothermal		0,4%		10%
Nuclear power		28%		19%
CHP from NaGas with CCS		0		20%
Tot	100%	100%	100%	100%

Comparison between EN15978:2011, NS3720:2018, and Level(s)

Table 5 – Building LCA standards [9, 12, 14-15].

	EN 15978:2011	NS 3720:2018	Level(s) (GWP)
Building elements to include (scope of the assessment)	Unspecified. Example of building elements to include in Annex A.	Specified list of elements based on NS 3451. Depending on the calculation level and the specification of the site location.	From user manual 2, Table 11: shell (substructure and superstructure), core (fittings, furnishings and services), and external works.
Cut-off rules for the exclusion of processes in the LCI	As in EN 15804:2012.	***Rules for exclusion of products per element of the building.***	As in EN 15804:2012.
Allocation of parts that can be later reused or recycled in another building	As in EN 15804:2012.	As in EN 15804:2012.	As in EN EN 15804:2012.
Life cycle stages to report at minimum	Unspecified. It is recommended to cover all life cycle stages for new buildings and all life cycle stages representing the remaining service life and end of life stages of the existing building.	It depends on the calculation level and the specification of the building location. For basic and advanced without location: A1-A5, B1-B5, B6, and C1-C4, and possibly D. For basic and advanced with location, same with inclusion of B8.	Standard calculation: all stages. Simplified reporting option 1: A1-3 + B4-6, Simplified reporting option 2: A1-3+B6+C3-4+D
Reference units	***kgCO_2-eq/m²*** ***kgCO_2-eq/yr*** ***kgCO_2-eq/employee*** ***kgCO_2-eq/room/yr*** ***kgCO_2-eq/m²/yr***	***kg CO_2-eq*** ***kg CO_2-eq/yr*** ***kgCO_2-eq/m² (GFA)*** ***kgCO_2-eq/m² (GFA)/year*** ***kg CO_2-eq/person/year***	***kg CO2 equivalents per m2 of useful internal floor area for a reference study period of 50 years (kg CO2 eq./m²/yr).***
Required service life (ReqSL) for the building	Defined by the building client.	60 years (unless otherwise specified by the client).	Defined by the building client.
Reference study period	The default value should be the building ReqSL.	The GHG calculation must be carried out based on the ReqSL" ***(60 years by default).***	***50 years.***
Inventory data	Preferred data type for each life cycle module and per project stage.	At conceptual stage and detailed project stage, minimum data quality **level 2**. In detailed analysis, when choosing between products, and in as-built phase, data quality **level 1** should be used.	Data quality hierarchy: specific data derived from specific production processes, average data from specific production processes, data from other appropriate sources, (when the producer of the building cannot influence performance) average data.

	EN 15978:2011	NS 3720:2018	Level(s) (GWP)
Impact categories to include at minimum	Optionally, the indicators listed in EN 15804.	GWP.	GWP. ***Optionally, full set of EN15978 environmental impact categories.***
Data reliability rating	No rating specified. However, data quality requirements are specified.	No rating specified. Two levels of data quality: level 1 third party validated data or and/or measured. Level 2 generic, average or proxy-data.	***The Data Quality Index*** is to be calculated according to the guideline for each hot spot and overall. Minimum value for overall data quality index.
Module A	For A1-3, as in EN 15804. For A4-, list of processes to include.	General suggestions for scenarios (e.g., material choices). Refer to requirements for scenarios in EN 15978:2011.	Suggests comparing various levels of renovation to demolition-reconstruction, and different construction processes.
Module B2-5	Suggested processes to include. B2-5 scenarios as in ISO 15686-5. Calculation rules for material replacements.	Suggested scenarios (e.g., for maintenance). Requirements for B2-B5 scenarios as in EN 15978:2011.	B2-5 scenarios as in ISO 15686-5. The default service lives for building parts. Potential of the building to adapt to changing needs and influence on the A stage must be assessed based on Level(s) Indicator 2.3 (Adaptability) and the local property market.
Module B6 (and B8)	General information for B6. Operational transportation (B8) is not covered.	***Building energy demand should be calculated based on delivered and exported energy (kWh)*** using SN-NPEK 3031.2023 or measurements of actual energy use. Impacts from exported energy per energy carrier is reported in module D. ***Introduces another life cycle module (B8).***	Calculation method for each component of a building's energy demand is provided by the EN ISO 52000 series of standards. However, the national energy method for calculating the energy performance and obtain the ***Energy Performance Certificate of the building (EPC) is the main method*** *that* should be used for reporting this indicator. Other methodologies may also be used, as described in the User Manual 3. Indicator 1.1 Guidance section L2.2. Unit of measurement: ***primary energy of a building in kilowatt hours per square meter per year (kWh/m2/year)***
Modules C and D	List of processes to include in the scenario.	Refer to requirements for scenarios in EN15978:2011.	General guidelines for end-of-life scenarios.
Reporting of the results	***Per life cycle stage and per environmental indicator. Stages A1-A3 and A4-A5 can be aggregated. Module D reported separately. No distinction between types of GWP.***	***Per life cycle stage and per type of GWP. Only stages A1 to A3 can be aggregated. Materials and energy flows that can be assigned to module D are reported separately.***	***Results presented in five groups of modules (A1-3, A4-5, B1-7, C1-4, and D) and per type of GWP.***

Norwegian Building Acts and Regulations - TEK 17

As of July 1, 2022, it's ***legally required to calculate greenhouse gas (GHG)*** emissions for materials used in constructing or refurbishing ***multi-family homes*** and ***commercial buildings***.

Calculations should ***adhere to*** the NS 3720:2018 standard.

As built calculation (with recommendation to perform this earlier in the project)

50 year functional lifetime (recently changed)

Functional unit = ***kg CO2eq / m2 GFA***

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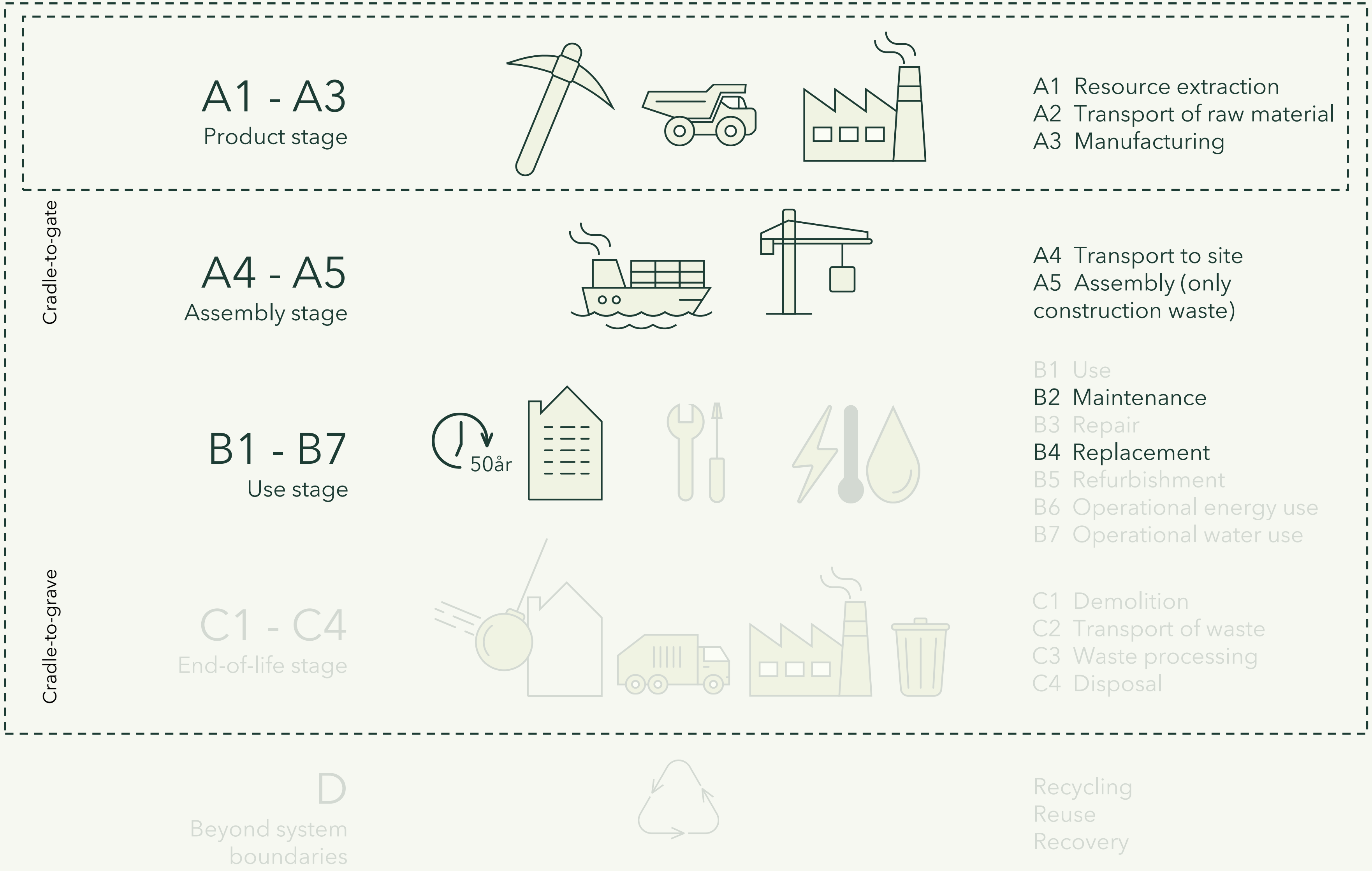
TEK17 - Calculation methodology and requirements

Calculation must include
215 Pile foundations
216 Direct foundations
22 Structural system
23 Outer walls
24 Inner walls
25 Slabs (floors / ceilings)
26 Roof

Inventory data should primarily reflect the actual usage of materials

Environmental data ***should be based on EPDs*** (+ 25% allowance if using generic inventory data)

Exclusion criteria
Components weighing less than 5% of the total weight of an element (consistent with NS 3720:2018)



TEK 17 – Biogenic carbon

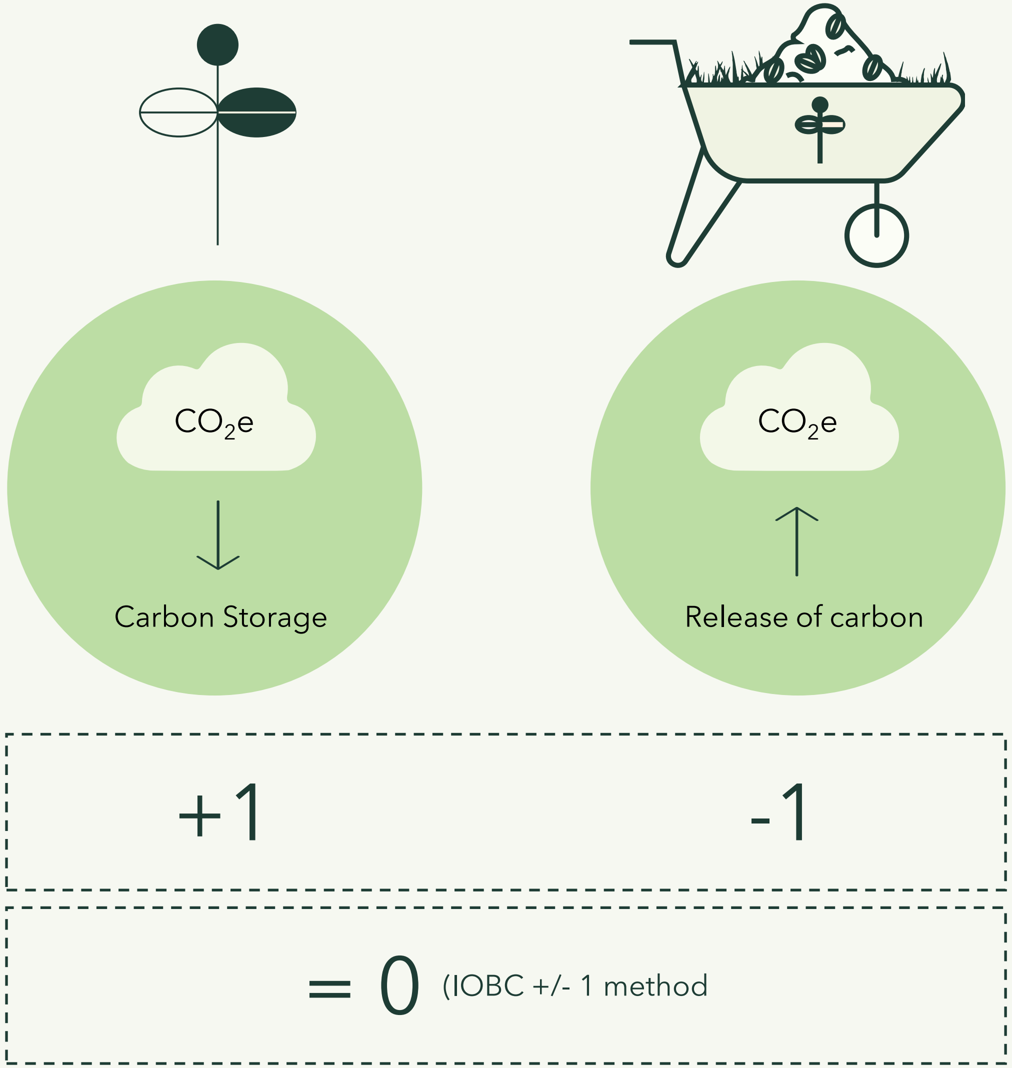
Biogenic carbon ***should not be included*** in the GHG calculations.

Since TEK17 requirements excludes C1-C4, uptake in A1 will not be nulled.

Use values for ***GWP-IOBC*** (IOBC = Instantaneous Oxidation of Biogenic Carbon) given in the additional information.

When information is unavailable in the additional information, the modeller needs to perform manual calculations:

- Use information of bound carbon in packaging and product (kg C).
- Atomic weight: C = 12, O = 16
- Each kg of biogenic carbon: (12+16+16)/12 = 44/12 = 3,67 kg CO_2
- 1 kg $C/m^2_{product}$ x 3,67 kg CO_2-eq/C = 3,67 kg CO_2-eq/m² → GWP_{EPD} + 3,67 kg CO_2-eq/m²



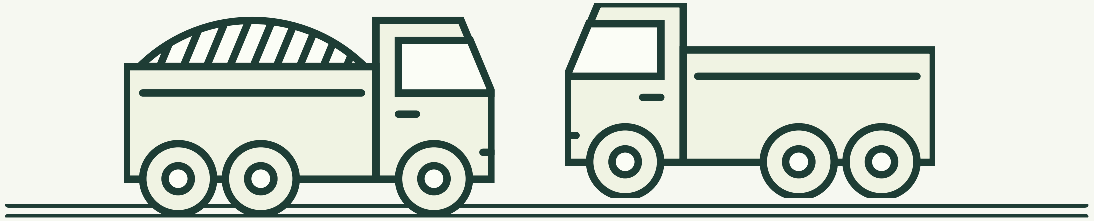
TEK 17 – Transport

Simplified assumption for distances 300 km (within Norway), except for concrete (50 km).

Transportation to Norway must also be considered for imported building materials, ***from the place of production*** (not the supplier warehouse)

Euro 5 trucks weighing 16 – 32 tons with a 50% fill rate can be assumed.

Detailed calculations based on known modes of transport and distances will be performed



TEK 17 – Material reuse

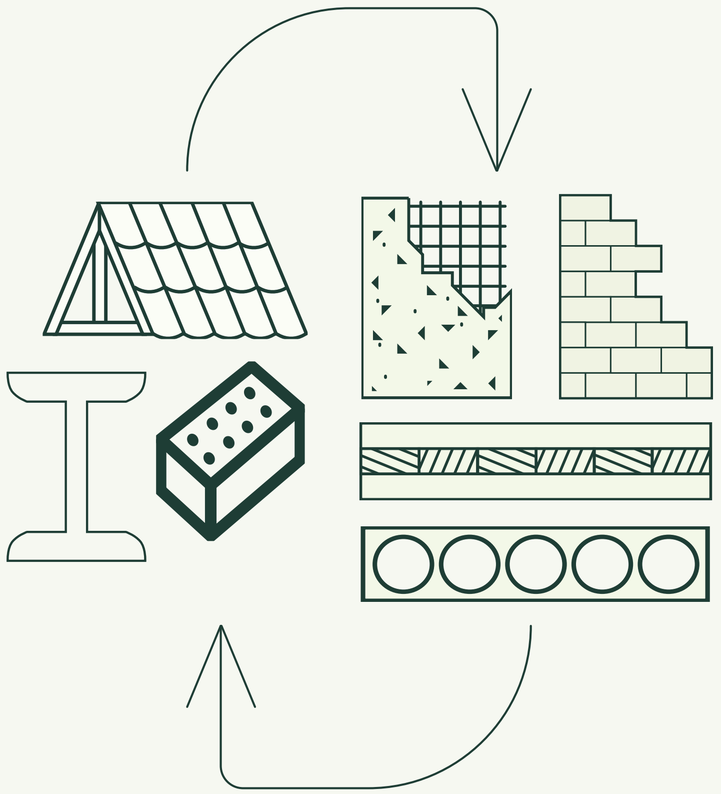
Greenhouse gas emissions for reused building materials only include:

- ***Processing emissions for reuse (in A1-A3)***
- ***Transportation (in A4)***

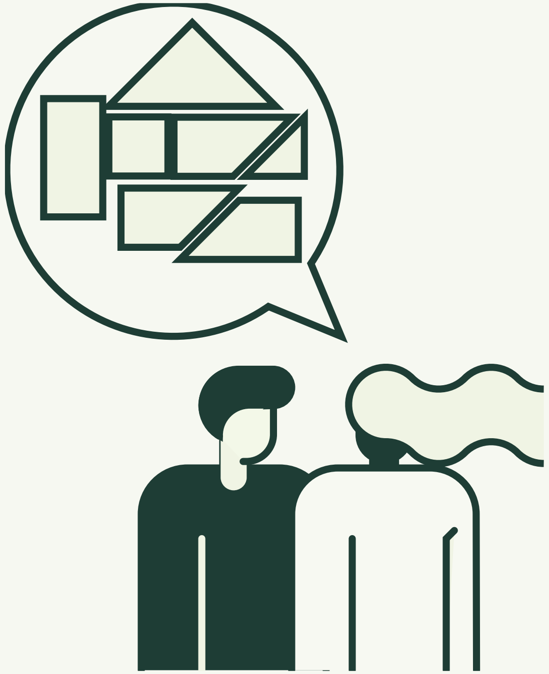
Transportation emissions are ***calculated similarly to newly produced materials***, using standard or actual distances.

Surplus new building materials from other sites are treated similarly to reused materials.

For example: wrongly ordered goods utilized in another project - the ***emissions for wrongly ordered goods are included in the original project's*** greenhouse gas inventory.



Other points regarding TEK17 methodology



A5: Assembly

Values in EPDs directly.
Simplified A5 = $\text{Share}_{\text{material loss}}$ x (A1-A3+A4)

B2: Maintenance

EPDs or third party verified and standardized documentation.
Own calculations (document process).
Embedded values in recognized LCA tools

B4: Replacement
Same as B2

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Required reporting + documentation

Results are reported in ***kg CO2eq / m2 GFA / year***

The greenhouse gas account must not be sent to the municipality together with the framework application, ***but must be available*** upon completion together with all other design and execution documentation

The documentation for the greenhouse gas accounts must be verifiable and can be presented by, for example, an audit.

Klimagassregnskapet skal framstilles på et tosifret nivå i henhold til NS 3451:2022 for de bygningsdelene som inngår i kravet til klimagassregnskap.

Klimagassutslippene skal oppgis uten hensyn til binding av biogent karbon. Dette betyr at klimagasstallene fra norske EPDer skal baseres på GWP-BIOC. For utenlandske EPDer skal klimagasstallene baseres på GWP-total pluss beregnet GWP-BC som beskrevet i avsnitt 5.3.

Tabell 8-1. Mal for dokumentasjon av klimagassregnskap etter TEK17 § 17-1.

Eiendom/byggested		**Titakstype**		
Gnr		Nybygg		
Bnr				Nytt bygg
Kommune		Eksisterende bygg		
Adresse				Hovedombygging
Postnr.				Tilbygg, påbygg, underbygg
Poststed				Annet søknadspliktig tiltak
Areal		**Bruk/formål**		
Totalt bruttoareal (m^2 BTA)				Boligblokk
Totalt bruksareal (m^2 BRA)				Yrkesbygg
Totalt oppvarmet bruksareal (m^2 BRA)				Bygningstypekode

Bygningsdeler	**A1-A3**	**A4**	**A5 (materialer)**	**B2**	**B4**	**Totalt**
	kg CO_2e/ (m^2 BTA,år)	kg CO_2e/ (m^2 BTA,år)	kg CO_2e/ (m^2 BTA,år)	kg CO_2e/ (m^2 BTA,år)	kg CO_2e/ (m^2 BTA,år)	kg CO_2e/ (m^2 BTA,år)
215 Pelefundamentering 216 Direkte fundamentering						
22 Bæresystemer						
23 Yttervegger						
24 Innervegger						
25 Dekker						
26 Yttertak						
Totalt						

Bruttoareal (BTA) er areal begrenset av ytterveggens utside eller midt i delevegg, jf. NS 3940:2012.

Klimagassregnskapet skal ikke sendes til kommunen sammen med rammesøknad, men skal foreligge i tiltaket ved ferdigstillelse sammen med all annen prosjekterings- og utførelsesdokumentasjon. Dokumentasjonen for klimagassregnskapet skal være etterprøvbar og kunne framvises ved f.eks. et tilsyn.

FutureBuilt

To support climate friendly urban development, six municipalities in the Oslo region, Bergen, Trondheim and Stavanger are collaborating on the FutureBuilt programme. Our vision is to show that climate neutral urban areas, based on high quality architecture, are possible.

Our goal is to complete ***100 pilot projects that cut carbon emissions by at least 50%*** compared to current regulations and common practice. This is measured by a ***greenhouse gas accounting tool***, and the reductions must be within the fields of ***transport, energy and materials.***

FutureBuilit Zero - Alternative calculation methodology

Based on NS 3720:2018 but with ***predetermined system boundaries*** (A1-A5, B1-B6, C3, and D).

Can be ***considered as a scenario*** under NS 3720 rules

Utilizes a ***dynamic instead of static*** LCA method

Introduces time factors that **assign less weight to emissions occurring in the future compared to the present**, as supported by two research citations [15-16]

Assumes technology development will reduce emissions over time

It is possible to use already **provided emission factors** for energy use in operation

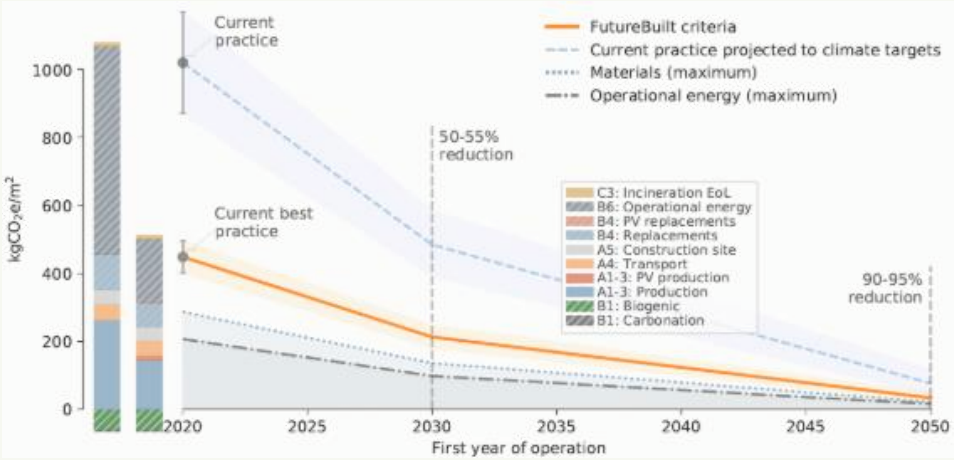


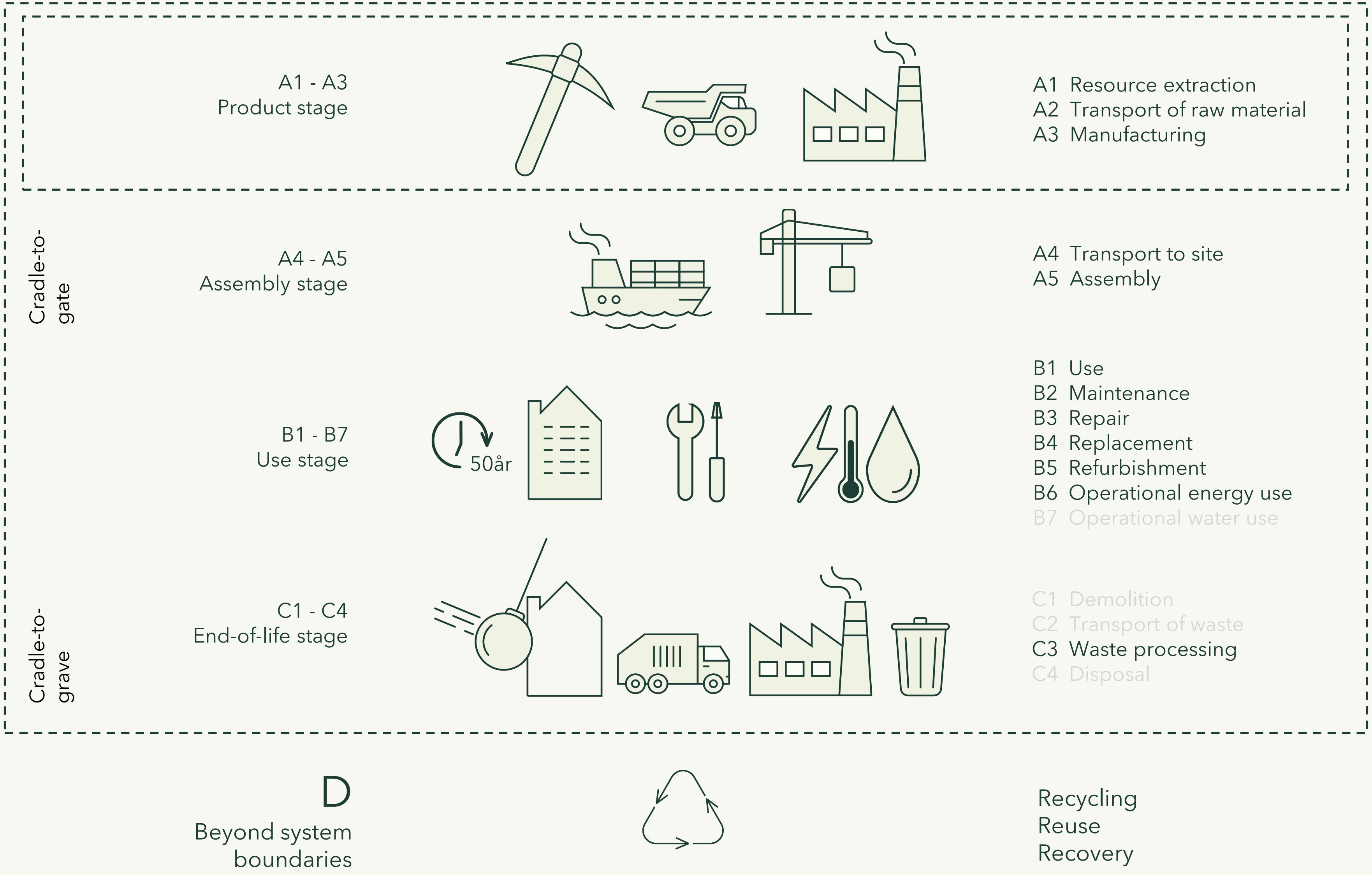
Figure 3 – Carbon emission criteria FutureBuilt [17] .

Table 2. Emission intensities for electricity and district heating.

	Electricity					District heating				
	Emissions [kgCO2e/kWh]	Technology factor	Time factor	Total factor	Weighted emissions [kgCO2e/kWh]	Emissions [kgCO2e/kWh]	Technology factor	Time factor	Total factor	Weighted emissions [kgCO2e/kWh]
2020	0.36	0.3	0.76	0.23	0.084	0.12	0.75	0.76	0.57	0.069
2021	0.35	0.3	0.76	0.23	0.08	0.12	0.75	0.76	0.57	0.068
2022	0.34	0.29	0.76	0.22	0.075	0.12	0.75	0.76	0.57	0.068
2023	0.33	0.29	0.76	0.22	0.071	0.12	0.75	0.76	0.57	0.067
2024	0.32	0.28	0.76	0.21	0.068	0.12	0.75	0.76	0.57	0.066
2025	0.31	0.28	0.76	0.21	0.064	0.12	0.75	0.76	0.57	0.066
2026	0.29	0.27	0.76	0.21	0.061	0.11	0.75	0.76	0.57	0.065
2027	0.28	0.27	0.76	0.2	0.057	0.11	0.75	0.76	0.57	0.065
2028	0.27	0.26	0.76	0.2	0.054	0.11	0.75	0.76	0.57	0.064
2029	0.26	0.26	0.76	0.19	0.051	0.11	0.75	0.76	0.57	0.063
2030	0.25	0.25	0.76	0.19	0.048	0.11	0.75	0.76	0.57	0.063

Figure 4 – Emission intensities for electricity and district heating [15]

Futurebuilt – Scope of Calculation



FutureBuilit Zero - Methodological differences with NS3720:2018

Methodology	Conventional – NS 3720	Dynamic – FutureBuilt ZERO
Future technology	Includes future technology advancement **in power and heat production**.	Includes technology advancement for all emission sources, for **energy and materials**. This puts more weight on emissions that happen today rather than emissions that happen in the future.
Time-weighting	No time-weighting. Uses **static LCA method** (GWP 100) no matter when the emissions happen.	**Emissions are weighted based on when the emissions happen (dynamic LCA).** The emissions contribution to global warming over a 100-year period from construction are included. Global warming impacts further than 100 years in the future are omitted. Emissions that happen in the future contribute less to global warming in the analysis period than emissions that happen today.
Biogenic Carbon	Uptake of biogenic carbon in wood happens before cutting (year 0). Stored biogenic carbon is calculated according to NS-EN 16485, with uptake happening in module A1 and emissions in module C3-C4. **Net impact of uptake and emissions of biogenic carbon is 0**.	Uptake of biogenic carbon happens as a consequence of cutting, during the building's lifetime. Trees and biomass will gradually store carbon, leading to a carbon storage effect. There is a cap to how much of this effect can be written in the account (100 % of combustion emissions and 75 % of production emissions). **Biogenic carbon storage is reported in module B1**.
Module D	Consequences of exported energy, reusability and material and energy recovery are **reported separate** from the main results in module D.	Includes consequences of **exported energy and reusability** in the main results.
Emission factors for materials	Specific data from EPD's and studies of carbon footprint of reused materials.	Same emission factors.
Emission factors for energy use	**Electricity** - European consumption mix (EU28+Norway), assuming a gradual, yearly reduction in fossil fuels towards 2050. Gives an average emission factor of **119 gCO2e/kWh** over 50 years. Also a scenario for the Norwegian mix can be given **(19 gCO2e/kWh)**	Same, but when accounting for time-weighting and future technology factors, the average emission factor over 50 years is **84 gCO2e/kWh**.
	Heat - District heating and cooling is dependent on the energy source of the specific district heating facility. Emissions from heat by waste incineration is treated as «zero emissions». Gives an average emission factor of **11 gCO2e/kWh** over 60 years, based on the mix of energy carriers used to produce district heating in Oslo.	Same, but emissions from heat by waste incineration are allocated 50/50 between waste sector and energy sector. Gives an average emission factor of **82 gCO2e/kWh** over 60 years.

BREEAM-NOR v6.1

- Operated by Norwegian Green Building Council.
- Assess environmental impacts in the design stage or post-construction stage.
- Early phase GHGE assessment is a ***mandatory prerequisite***
- Whole building GWP calculations should at least include (for design and as-built):
  - A1 - A3
  - A4 +A5
  - B2 + B4
- Must include an assessment of ***various alternatives*** for the project
- Building elements to consider are specified in accordance with NS 3451:2022.
- Where no specific provisions are provided, the rules in NS 3720:2018 should be followed.
- Required ***service life is 50 years*** if nothing else is specified by the developer
- Same rules for data quality as stated in NS 3720:2018
- All LCA tools used must meet requirements in the ***Mat 01 calculator***
- LCA tools must include:
  - Climate impacts (CO_2-eq)
  - At least two other environmental impacts
  - Either water or waste treatment.

Using FutureBuilt method in BREEAM-NOR v6.1

Demonstrate compliance with the criteria outlined in the method

Specify what to include in the assessment

Exclude energy use in A5, B6, and D from the assessment

FutureBuilt utilizes a reference value of ***60 years instead of 50 years*** used in BREEAM. Will be updated this year.

Interpretation of results: benchmarking

Reference values are provided to ***benchmark results and reduction potential*** in Norwegian building LCA

The Norwegian Agency for Public and Financial Management (DFØ):

- In 2023 the reference ***study period was changed from 60 to 50 years***. Thus, adjusted references values.
- Reference values in kg CO_2-eq/m^2_{GFA}
- LC-modules: A1-A5, B2, and B4
- A5 = only include emissions related to material losses (TEK17 describes calculation method)
- If the difference in time between the last calculated complete replacement (in B2 and B4) and the end of the calculation period constitutes 25% or less of the component's lifetime being replaced, the number of replacements is rounded down.

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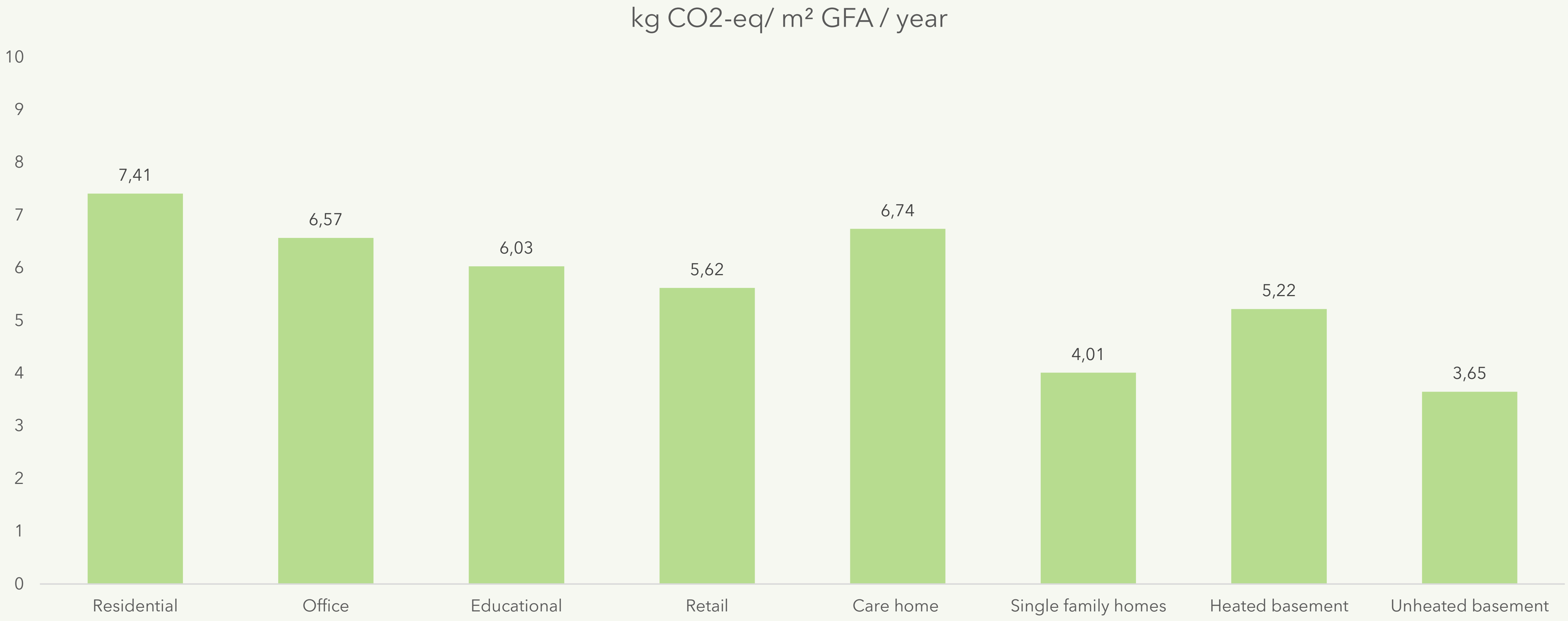
Interpretation of results: benchmarking



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Interpretation of results: benchmarking

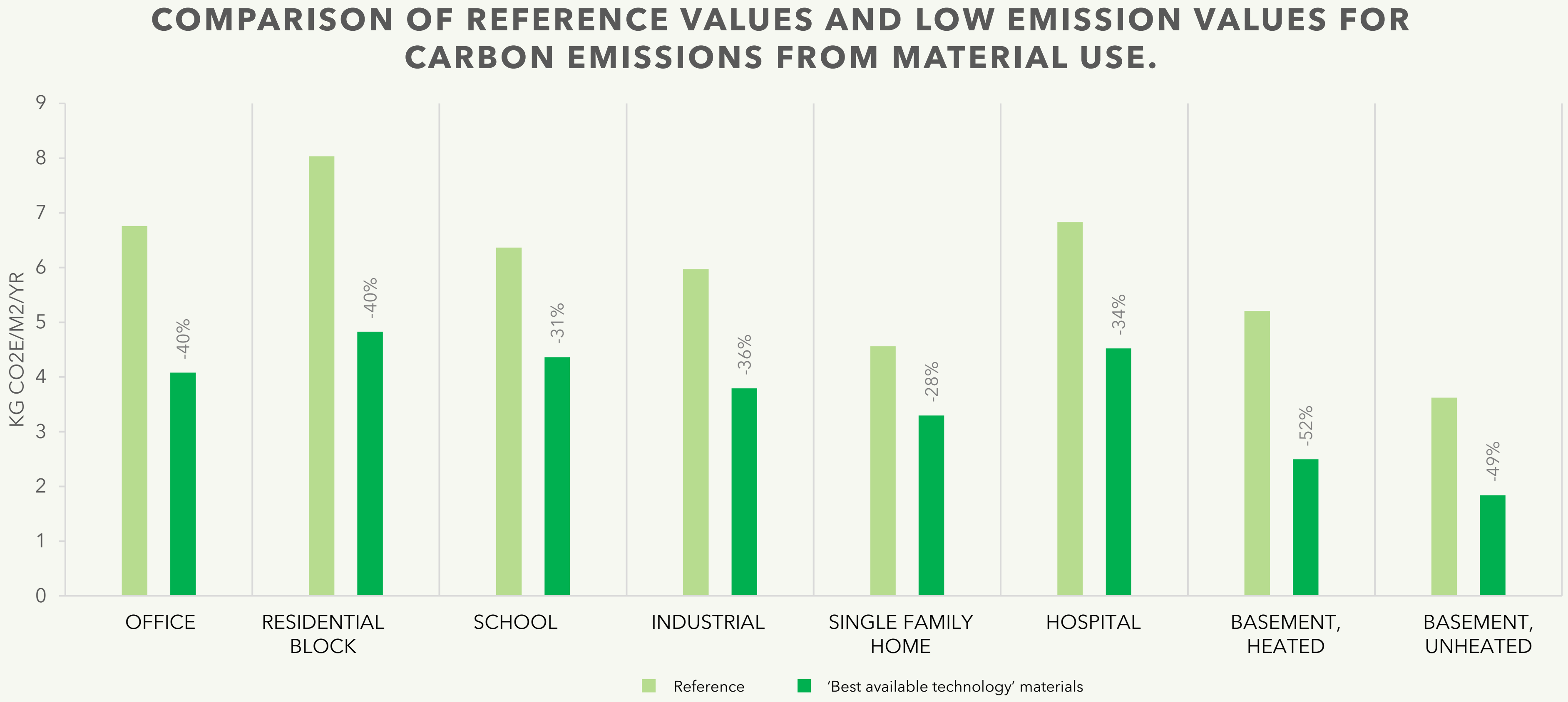
Table 7 - Reference values for GWP for different building typologies normalized to kg CO_2-eq/m²BTAa and kg CO_2-eq/m²BTA. Available in [18].

Building type	kg CO_2-eq/m²BTAa	kg CO_2-eq/m²BTA
Residential	7.4	370
Office	6.6	328
Educational	6.0	302
Retail	5.6	281
Care home	6.7	337
Single family homes	4.0	200
Heated basement	5.2	261
Unheated basement	3.7	183
Industry	Values based on planned height of the buildings	

Table 8 - Reference values for GWP for different building typologies normalized to kg CO_2-eq/m²BTAa from FutureBuilt. Available in [18].

Building type	kg CO_2-eq/m²BTAa
Multi-family homes	7.0
Office	6.0
Educational	5.4
Retail	5.3
Care home	6.2
Heated basement	5.0
Unheated basement	3.4

What do these benchmark values mean?



Calculated reduction potential In the Enova study

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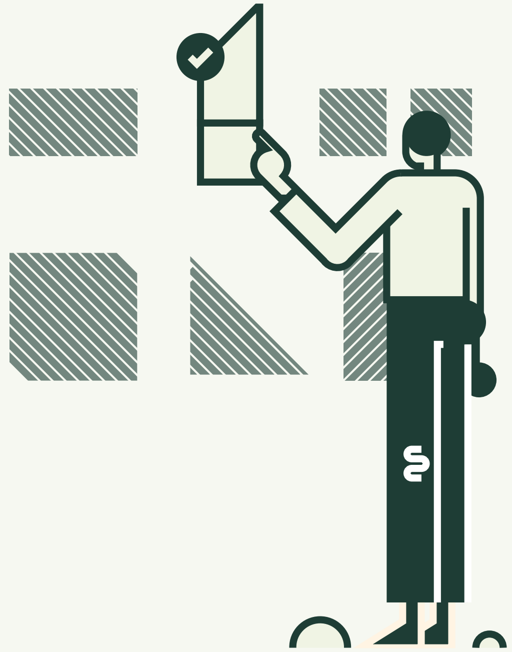
What do these benchmark values mean?

Currently no requirement to document the calculations + establish a database of results

No requirement to achieve results under the limit values but currently under discussion in Norway under TEK17

Limit values requirements for FutureBuilt and BREEAM



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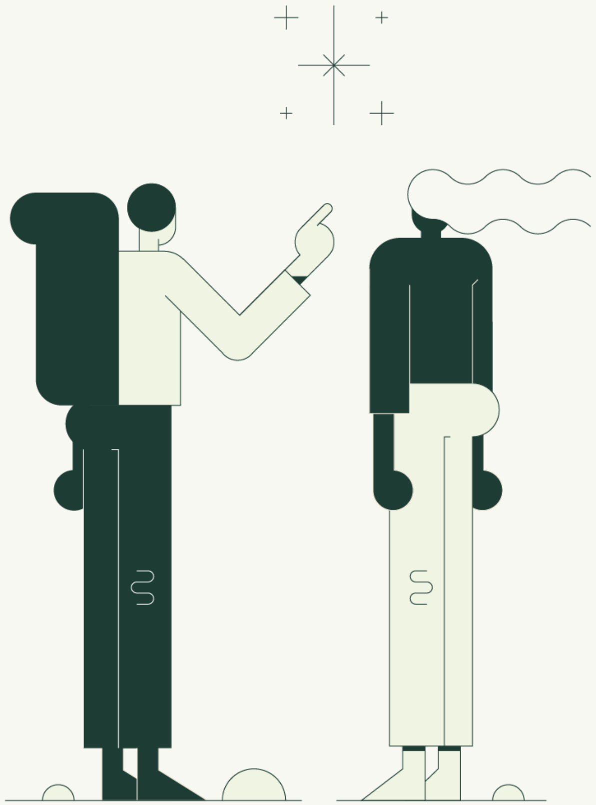
Discussion



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