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Preliminary study on the use of Big Data for environmental benchmarks of residential buildings in Flanders

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Preliminary study on the use of Big Data for environmental benchmarks of residential buildings in Flanders

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Abstract. Building construction and operation both have a high environmental impact. In Flanders (Belgium), public authorities have defined clear targets for improved building energy performance, but a strategy to reduce construction (embodied) impact is still lacking. Environmental benchmarks based on Life Cycle Assessment (LCA) have been identified as a means to limit embodied impacts. Such benchmarks are often derived with a bottom-up approach consisting of a statistical analysis of the building stock, which is usually modelled based on a limited set of representative buildings or archetypes. In this paper, a data-driven approach is applied based on building data from the Flemish Energy Performance of Buildings (EPB) database. In a recent study, the buildings from the EPB database were clustered based on geometric and energy-related parameters, and for each cluster representative buildings were selected. This resulted in 54 buildings representative of newly built residential buildings in Flanders. The building set distinguishes itself from other existing sets because it was automatically generated from a large building database. Up until now, the EPB building set has only been used to evaluate the financial feasibility of energy performance levels in Flanders. In this preliminary study, an LCA is performed to assess the life cycle environmental impacts of five sample cases in view of benchmarking. The sample includes two detached, two semi-detached, and one terraced house, all solid construction and in line with the Flemish EPB requirements of 2014. The results show that the environmental score of the buildings is comparable to benchmark values obtained based on the analysis of Belgian archetypes. Further, the building geometry and compactness are identified as key parameters, whereas the materialisation has a more limited influence on the environmental impact. Next research steps will focus on the modelling of more cases, including different construction types, energy performance levels, and potential impact mitigation strategies. The study concludes that the EPB buildings are promising to define environmental benchmarks for the Flemish dwelling stock.

Keywords: Building database, Life Cycle Assessment, bottom-up benchmarks, data-driven approach

1. Introduction

1.1. Environmental impact of the Flemish dwelling stock

Everyday still new buildings are being constructed to fulfil the needs of our globally increasing population. An important share of those buildings are meant for housing. In Flanders (Belgium), 82% of the building permits for new construction in 2021 were residential projects [1]. The problem is that housing, like buildings in general, have a high impact on the environment. Globally, building construction and operation account for over one third of energy-related carbon dioxide (CO_2) emissions and 50% of resource use [2,3]. In Belgium, heating of dwellings resulted in 1245 kg of greenhouse gas (GHG) emissions per capita in 2019, which was the second highest value in Europe [4]. Furthermore, with an average of 2.1 rooms per person, Belgian houses are believed to be the second largest in Europe [4], which implies a large material footprint.

In the Flemish Climate Strategy 2050, the Flemish Government defined a limit of 2.3 $MtCO_2eq$/year for the building sector by 2050, which is a reduction of 81% compared to its emissions in 2017 [5]. This aim should be achieved by focusing on both improved building energy performance and reduced material (i.e. embodied) impact [5]. Regarding energy performance, clear objectives are defined: e.g. from 2021, every new dwelling needs to fulfil the requirements for a net-zero energy (nZEB) building [5]. Contrarily, for building embodied impacts such explicit ambition is lacking. Nonetheless, the literature reveals that embodied impacts have been increasing due to improved building energy performance [6–10].

Globally, the building sector has started to recognise the increasing importance of embodied impacts and has therefore shifted to evaluating buildings from a life cycle perspective. This has led to an increased integration of Life Cycle Assessment (LCA) in building practice and policy [11]. In Belgium, a national LCA method for buildings (MMG) was developed and translated into an online calculation tool called TOTEM (Tool to Optimize the Total Environmental impact of Materials) [12,13]. The tool enables designers to calculate life cycle environmental impacts of multiple building variants, but does not include any informative, let alone restricting benchmarks to compare the results with. However, such benchmarks are essential for two main purposes: (1) they inform building stakeholders how the environmental performance of their designs compares to current building practice; and (2) they support policy makers in the implementation of compulsory benchmarks in building regulations [11].

1.2. Building environmental benchmarks and representative buildings

Benchmarks can be defined either top-down or bottom-up [14]. Top-down benchmarks are derived by translating global or national environmental goals to target values that buildings should achieve on the long term. Bottom-up benchmarks result from a statistical analysis of the building stock and therefore represent the impact of current building practice. In the latter approach, the building stock is typically represented by a limited set of real reference buildings or generic archetypes [14]. Two challenges of the bottom-up approach are data availability and how to define representative buildings that cover the diverse building stock.

For Belgium, reference buildings for the dwelling stock have been defined in the context of different research projects. In the SuFiQuaD project (Sustainability, Financial and Quality evaluation of Dwelling Types) 16 real cases were selected to represent a wide range of the Belgian dwelling stock [15]. The cases include four common dwelling types (detached, semi-detached, terraced and apartment) from four construction periods (<1945, 1945-1970, 1971-1990, 1991-2001). A recent study on benchmarking assessed the life cycle environmental impact of the four cases from 1991-2001 [16]. A larger set of buildings was defined in the context of the European project TABULA/EPISCOPE [17]. The Belgian set of 35 building typologies includes six construction periods (<1945, 1946-1970, 1971-1990, 1991-2005, 2006-2011, >2012), and six dwelling typologies (ranging from single family houses to apartments). As opposed to SuFiQuaD, these dwellings are fictional: they are based on average values and therefore do not correspond to real cases.

A recent study on cost optimal energy performance levels used Big Data to select buildings that are representative of the Flemish dwelling stock in terms of geometry and energy performance [18]. The buildings were selected from a database that consists of all new residential buildings assessed with the Flemish Energy Performance of Buildings (EPB) calculation tool in the period 2015-2016. The database includes over 5000 records of existing single-family houses (SFH) and apartments. In that study, the buildings were clustered based on geometric and energy-related parameters, and for each cluster representative buildings were selected. This resulted in a set of 54 SFH and apartments representative of new construction in Flanders.

1.3. Study objective

Up until now, the 54 EPB buildings have only been used to evaluate the financial feasibility of energy performance levels in Flanders. However, the buildings show potential to be used for environmental benchmarking of the Flemish dwelling stock. Compared to the other sets of reference buildings, which are based on common Belgian archetypes, the EPB set distinguishes itself because the buildings were selected from a large database based on predefined (i.e. geometric and energy-related) parameters. Further, a statistical analysis was performed to check their representativeness of that database in terms of the predefined parameters. Moreover, no benchmarking studies have been identified that used pre-clustering of a database to select reference buildings. In this preliminary study, an LCA is performed of one building from each cluster to illustrate the potential of the proposed benchmarking approach.

2. Methods

2.1. LCA methodology

As the benchmarks are intended for the Flemish context, the LCA is conducted with the Belgian TOTEM tool. TOTEM is an element-based tool, meaning that designers model buildings as a combination of building elements, which are composed of multiple components. The components in the TOTEM library are modelled based on building material and process records from the generic ecoinvent database (v3.6 at the time of writing) [19]. The LCA scope in the current version of TOTEM is summarised in Table 1.

Table 1. LCA scope in TOTEM.

Functional unit	1 m² gross heated floor area (GHFA) of building
Reference study period	60 years
System boundaries	Life cycle stages according to EN 15978 [20]: A1-3 Product stage; A4-5 Construction process stage; B2 Maintenance; B4 Replacement; B6 Operational energy use; C1-4 End of life stage.
Building elements	According to BB/SfB classification [21]: (13.)+ Floor on grade; (16.2)+ Basement wall (21.)+ External wall; (22.)+ Internal wall; (23.)+ Storey floor; (27.)+ Roof; (31.) External window and door; (32.) Internal door.

The life cycle impact assessment (LCIA) in TOTEM considers the environmental impact indicators recommended by EN 15804+A2 [22]. The indicators are calculated both individually and combined in one aggregated environmental score expressed in millipoints per functional unit (mPt/FU). For the aggregated score, TOTEM applies the weighting approach developed in context of the European Product Environmental Footprint (PEF) [23]. In this study, both the aggregated score and individual indicators are analysed, with a specific focus on the climate change indicator by reason of it being the focus in current policy.

For the calculation of operational energy use TOTEM applies the Equivalent Heating Degree Day (EHDD) method with a default of 1200 EHDD. The calculation considers transmission and ventilation losses, which depend on the building elements' U-values and the building geometry. Currently, the settings for heating and ventilation in TOTEM are fixed. The default heating system is a condensing gas boiler with an efficiency of 102% (lower heating value). For ventilation, a system without heat recovery and a default air infiltration rate of 12 $m^3/h.m^2$ are applied.

2.2. The EPB building database

2.2.1. Representative buildings. The database [18] from which the representative buildings were selected includes 5387 records of existing SFH (4134) and apartments (1244) that were implemented in the EPB tool in 2015-2016. The set of SFH and the set of apartments were subdivided into clusters by a k-means cluster analysis based on geometric and energy parameters. Next, the least squares method was applied to select buildings representative of each of those clusters, resulting in a selection of 26 SFH and 28 apartments. Figure 1 presents the distribution of the 26 selected SFH across the five clusters based on gross heated floor area (GHFA) and compactness. A detailed explanation of the selection procedure as well as the intended use of the representative buildings is given in the report of the study on the financial feasibility of energy performance levels (in Dutch) [18].

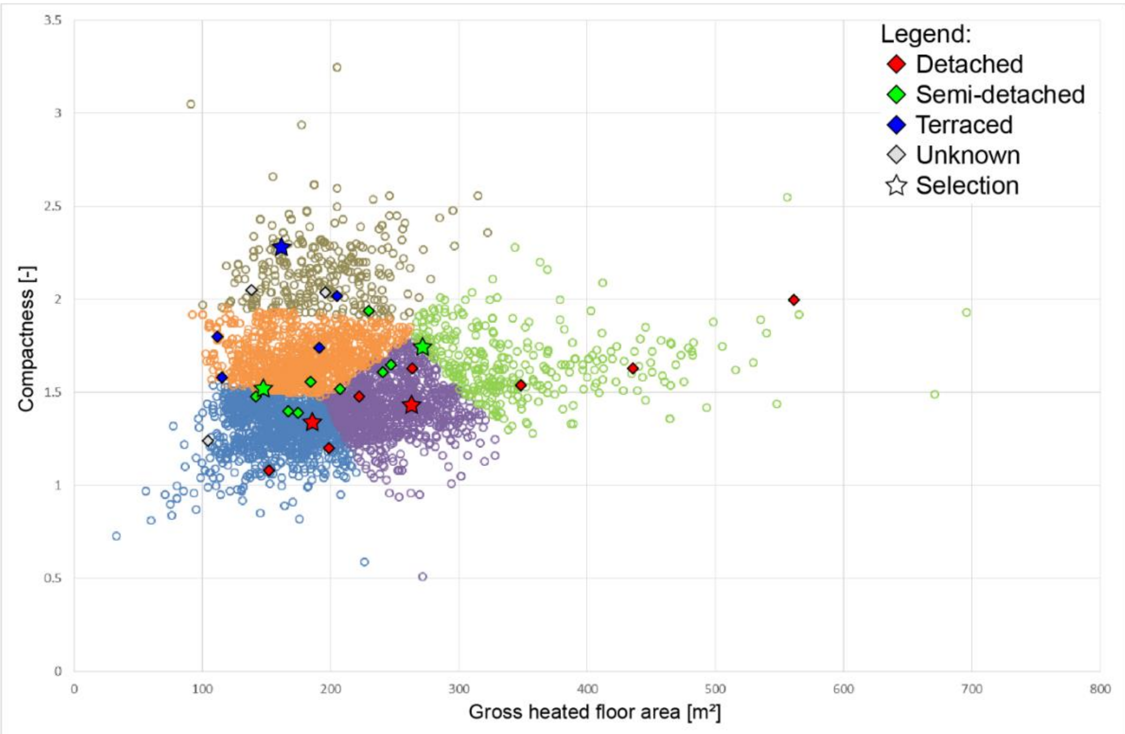

Figure 1. Distribution of all SFH, their representatives and the sample selection across the five clusters based on gross heated floor area and compactness (figure adapted from [18]).

2.2.2. Selection of sample cases. This study analyses a sample selection of the representative SFH. The selection includes one building from each cluster in Figure 1 for which the window-to-GHFA ratio is closest to 15%, a value recommended by the Flemish Company for Social Housing [24]. Table 2 specifies those parameters for the selected cases. The selection includes two detached houses, two semi-detached houses and one terraced house. All five buildings are solid constructions and their energy performance level is in line with the EPB requirements of 2014-2015 [25,26].

Table 2. Building information of the selected cases.

	ID04	ID08	ID10	ID20	ID22
Building type	Detached	Detached	Semi-detached	Semi-detached	Terraced
GHFA [m²]	185	263	147	271	162
Compactness [-]	1.34	1.43	1.52	1.75	2.28
Window-to-GHFA [m²/m²]	16%	16%	17%	17%	13%

2.2.3. From EPB input to TOTEM input. For the LCA, the input data from the EPB files have to be converted to an input for TOTEM. The data required by TOTEM include general building information (e.g. building type, heated volume) and the amount and composition of all the building elements. A drawback of the EPB data is that these only include data on the building elements required for an energy performance calculation, implying two main data gaps: (1) the amount and composition of internal elements, and (2) materialisation of finishing layers and foils that have neglectable influence on the energy calculation. To fill these data gaps as well as to ensure consistency within converting the EPB data to TOTEM input, a detailed workflow was defined and implemented in an excel template.

Firstly, all relevant EPB data of the building and building elements are pasted into the template. For the building elements, all specified components and their thicknesses are inserted as well as the total amount of the building element. For internal walls and floors, the structure and finishing are based on the composition of external walls and roofs, respectively. For the internal doors, a default MDF door from the TOTEM library is selected. The amount of loadbearing and non-loadbearing internal walls and of internal doors is calculated based on average ratios derived from other studies on representative Flemish dwellings [15,27]. The amount of storey floor is derived by subtracting the floor on grade, attic floor (if heated), and floors above unheated space from the GHFA.

Secondly, the building element data are linked to components from the TOTEM library. While the TOTEM library includes specific data from Environmental Product Declarations (EPDs), only generic components are applied in this study. Based on this, the building element compositions are modelled in TOTEM itself. Finally, a macro generates an excel sheet that can be imported into TOTEM to create the full building model, directly linking the amount of building elements to the defined compositions. Table 3 shows the U-values of the modelled building elements and the maximum U-values defined in the EPB regulation of 2014/2015. Table 4 presents for the five buildings the amount of all building elements and their main materialisation as modelled in TOTEM.

Table 3. U-values [W/m²K] of the building elements modelled in TOTEM and their EPB requirement.

	ID04	ID08	ID10	ID20	ID22	EPB2014/2015
(13.)+ Floor on grade	0.24	3.87	0.23	0.26	0.25	0.30
(21.)+ External wall	0.21	0.19	0.15	0.21	0.23	0.24
(22.8)+ Party wall	/	/	0.53	0.50	0.57	1.00 / 0.60
(22.)+ Wall in contact with unheated space	/	1.12	/	/	/	(R=1.40)
(23.)+ Floor above unheated space / outside	/	0.25 / 0.23	/	/	/	0.30
(23.)+ Attic floor	0.22	/	/	/	/	0.24
(27.1)+ Flat roof	/	0.19	/	0.16	0.19	0.24
(27.2)+ Pitched roof	0.21	0.18	0.20	0.19	0.21	0.24
(31.) Windows	1.58	1.57	1.59	1.56	1.56	1.80

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Table 4. Building element amounts and main materials of the five selected buildings.

		ID04	ID08	ID10	ID20	ID22
(13.)+ Floor on grade	[m²]	110	132	90	109	82
	Structure	Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete	Reinforced concrete
	Insulation	PUR foam, EPS board	/	PUR board	PUR foam	PUR foam
(16.2)+ Basement wall	[m²]	/	124	/	/	/
	Structure	/	Reinforced concrete	/	/	/
(21.)+ External wall	[m²]	148	195	82	189	37
	Structure	Hollow fired clay bricks	Hollow fired clay bricks	Reinforced concrete	Hollow fired clay bricks	Hollow sand-lime bricks
	Insulation	PUR board	EPS board / PUR board	PUR board	PUR board	Resol board
	External finishing	Fired clay bricks	Lime plaster / fired clay bricks	Fired clay bricks	Fired clay bricks	Fired clay bricks
(22.1)+ Loadbearing internal wall	[m²]	58	82	53	97	41
(22.3)+ Non-load-bearing internal wall	[m²]	101	144	55	102	60
(22.8)+ Party wall	[m²]	/	/	60	79	240
	Structure	/	/	Cellular concrete	Hollow fired clay bricks	Hollow fired clay bricks
	Insulation	/	/	Glass wool	Glass wool	Glass wool
(22.)+ Wall by unheated space	[m²]	/	12	/	/	/
(23.)+ Storey floor	[m²]	76	104	60	161	80
(23.)+ Floor above unheated space	[m²]	/	132	/	/	/
	Structure	/	Hollow slab	/	/	/
(23.)+ Floor above outside	[m²]	/	22	/	/	/
(23.)+ Attic floor	[m²]	58	/	/	/	/
(27.1)+ Flat roof	[m²]	/	27	/	15	28
	Structure	/	Prestressed hollow slab	/	Prestressed concrete – fired clay blocks	Reinforced concrete slab
	Insulation	/	PUR board	/	PUR board	PUR board
(27.2)+ Pitched roof	[m²]	153	172	120	136	64
	Structure	Timber beams	Timber beams	Timber beams	Timber beams	Timber beams
	Insulation	Glass wool (partly)	Glass wool	Glass wool	Stone wool	Glass wool
	Roof finishing	Fibre cement slating	Unglazed ceramic tiles	Unglazed ceramic tiles	Unglazed ceramic tiles	Unglazed ceramic tiles
(31.) Windows	[m²]	31	47	25	47	21
	Glazing	Double	Double	Double	Double	Double
	Frame	PVC	Aluminium	PVC	Aluminium	Aluminium
(31.) External doors	Pieces	1	1	1	1	2
(31.) Garage doors	Pieces	1	/	/	1	/
(32.) Internal doors	Pieces	12	18	10	18	8

3. Results

3.1. Embodied and operational impact

Figure 2 presents the contribution of the embodied and operational impact to the aggregated environmental score for the five modelled cases. Note that the operational part presents the impact of the energy use as calculated by the simplified EHDD method used in TOTEM, and therefore not based on the detailed results from the EPB software.

Table **5** reveals that the energy use for heating calculated by both methods can highly differ. As the energy calculations in TOTEM will be improved in the near future, this section discusses the operational impact results only briefly. The rest of the paper focusses on the embodied impacts.

The two detached cases ID04 and ID08 have the highest life cycle impact (96 and 105 mPt/m²GHFA, respectively). Semi-detached house ID10 differs only 1 mPt/m²GHFA from detached house ID04, and the impact of semi-detached house ID20 and terraced house ID22 are nearly the same. The lowest life cycle impact is obtained for the terraced house (85 mPt/m²GHFA), which is about 19% lower compared to the highest life cycle impact found for detached house ID08. Similar differences are found for the embodied impacts, which are ranging from 47 mPt/m²GHFA (semi-detached house ID20) up to 60 mPt/m²GHFA (detached house ID08). The embodied impact represents more than half of the environmental score (from 53 to 57%) for all cases.

The difference in life cycle impact between the two detached cases is similar to the impact between the two semi-detached cases. For the detached cases, the operational impact is the same, but the embodied impact of ID08 is 18% higher than that of ID04. This leads to a total score of ID08 which is 9% higher than for ID04. For semi-detached house ID10, both embodied and operational impact are higher than for semi-detached house ID20 (6% and 16%, respectively), resulting in a difference of 10% in total environmental score.

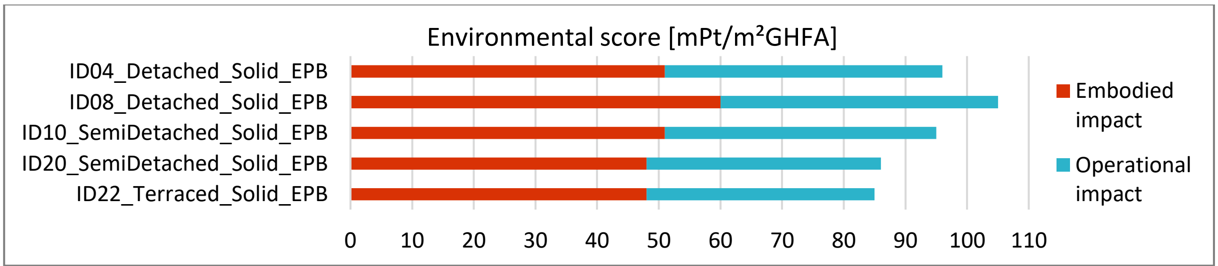

Figure 2. Embodied and operational impact of the five modelled buildings.

Table 5. Final energy use for heating (in MJ/m²GHFA) calculated by the EPB software and TOTEM.

	ID04	ID08	ID10	ID20	ID22
Energy use in EPB [MJ/m²GHFA]	227.75	85.81	296.46	275.69	201.67
Energy use in TOTEM [MJ/m²GHFA]	234.04	234.31	229.69	195.97	190.52

3.2. Environmental impact indicators

Figure 3 shows the embodied share of the aggregated environmental score subdivided in the individual impact indicators. The relative share of the different indicators is very similar across the five cases, with differences of no more than 3%. For all five buildings, the climate change indicator is responsible for the highest impact (26-28%), followed by particulate matter emissions (22-25%), abiotic resource depletion (18-20%) and eco-toxicity, freshwater (9-10%). The other indicators are responsible for less than 6% each.

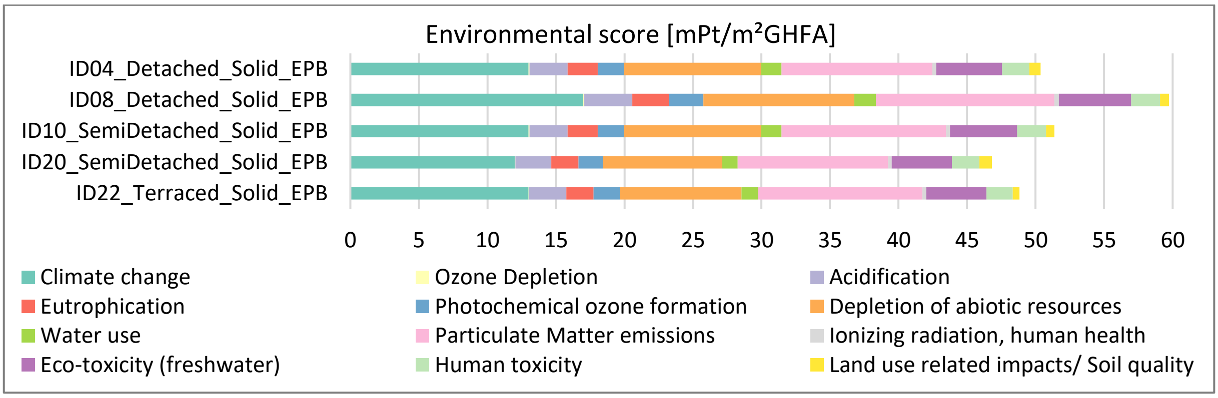

Figure 3. Contribution of the impact indicators to the embodied part of the environmental score.

3.3. *Climate change*

Figure 4 presents the embodied part of the climate change indicator and the contribution of the different life cycle stages. The order from highest to lowest impact is not too different from the embodied environmental score: terraced house ID22 has the lowest embodied climate change impact (497 kgCO_2eq/m²GHFA) and detached house ID08 has the highest impact (658 kgCO_2eq/m²GHFA).

Comparing the two detached houses, it appears that for climate change the difference between these is, relatively speaking, larger than for the embodied environmental score discussed in section 3.1. The impact of ID08 is 30% higher than for ID04, whereas for the environmental score the difference was 18%. Contrarily, the difference between the two semi-detached cases is, in relative terms, the same: ID10's climate change impact is 8% (or 37 kgCO_2eq/m²GHFA) higher than ID20.

The most contributing life cycle stage is 'A1-3 Production', with a share ranging from 51% (ID04 and ID20) to 60% (ID10) of the embodied climate change impact. The second most important life cycle stage is 'B4 Replacement' representing 16-21%, with similar contributions from B4.1 (7-12%) and B4.2 (9-11%). For the remaining stages, it is case-dependent which stages contribute more: for ID04 and ID20 stage 'C4 Disposal' represents a relatively large share of 7-8%; for ID08 and ID22 stages 'A5 Construction' and 'B2 Maintenance' are more important, both representing around 6-8%. Stages C1 to C3 have the lowest impact, accounting for less than 2% each. Note that for the whole life cycle 'B6 Operational energy use' is the largest life cycle stage for climate change.

A similar analysis for the embodied environmental score (in mPt/m²GHFA) shows contributions of 60-65% from 'A1-3 Production' and 15-20% from 'B4 Replacement'. The third and fourth highest contributors are in this case 'B2 Maintenance' (6-7%) and 'A5 Construction' (4-5%) for all five buildings.

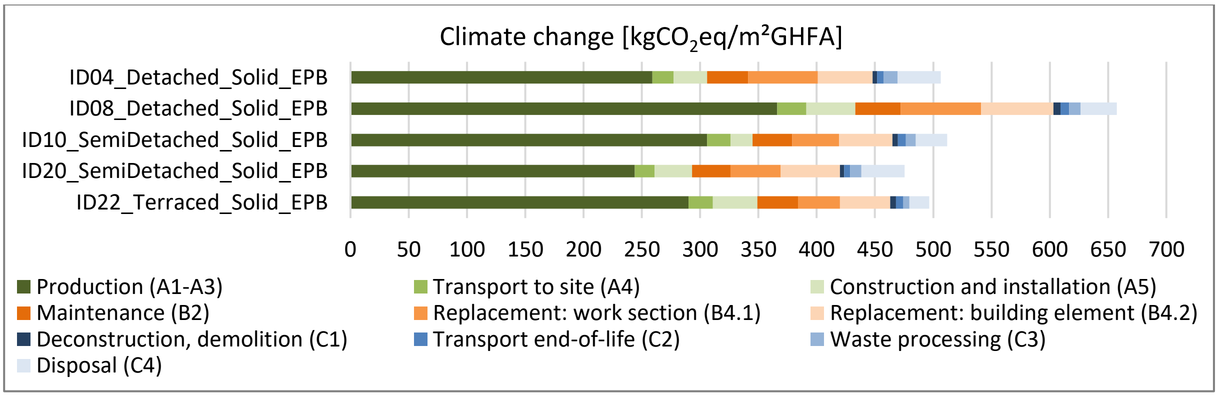

Figure 4. Contribution of the different life cycle stages to the embodied climate change impact.

3.4. Impact of different building elements

Figure 5 shows the contribution of the building elements to the embodied part of the environmental score. Note that the remarkable difference in the share of the floors in ID08 compared to the other buildings is because category '(13.)+ Floor on grade' only includes the basement floor in that case, while category '(23.)+ Storey floor' includes the internal storey floors, the floor in contact with the outside and the floor above the basement.

Reasonably, the contribution of the different wall types differs for the three building typologies. The external walls account for 16% of the embodied impact of the detached houses ID04 and ID08, while they only represent 5% of the impact of terraced house ID22. For the latter case, the party walls contribute 14% to the impact, while for the semi-detached houses ID10 and ID20 these walls account for only 3%, which is a logical consequence of the higher ratios of these walls in terraced houses. Further, the differences in the relative contributions of the internal walls are, although relatively small, largely in line with the default ratios applied for the estimation of the internal wall area for the different building types.

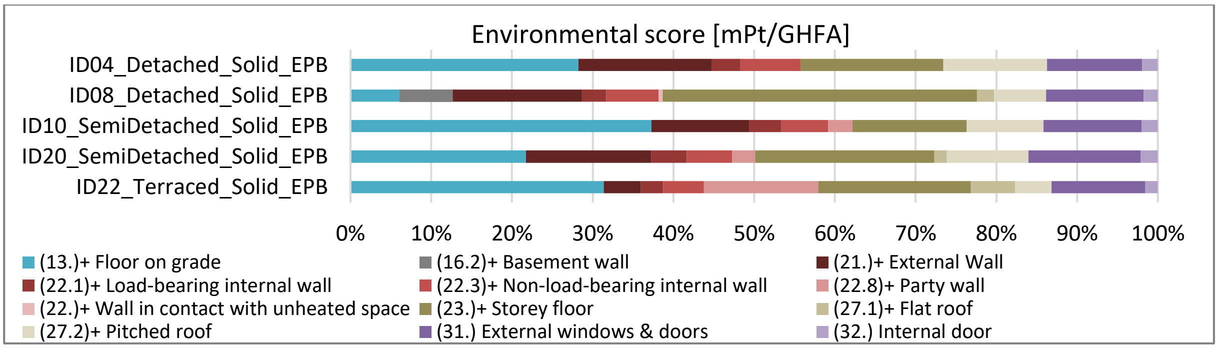

Figure 5. Contribution of the different building elements to the embodied environmental score.

4. Discussion

4.1. Observations from comparing the five cases

In general, the geometry and compactness of the five cases have the most significant influence on the impact results. This is concluded by two observations. Firstly, the impact results reflect the influence of the different dwelling types. For both the embodied and operational environmental score, the worst performing cases are the detached houses and the best performing case is the terraced house. Moreover, the three building types are differentiated by the contributions of the external and internal walls, external walls contributing more in the detached house typology. Further, the influence of the geometry is also illustrated by the high embodied impact of ID08 which is the only case with a basement.

Secondly, the different materialisation of the building elements is not reflected in the results. Even though for some building elements the impact per m² element varies greatly for the different compositions, it is often compensated by differences in ratios. For example, the impact per m² of roof is 60% higher for the roof applied in ID20 than for the one in ID10, but for both buildings their pitched roof contributes around 10% to the total embodied impact. This is explained by the higher pitched roof-to-GHFA ratio of ID10 (0.8) than ID20 (0.5). In fact, for none of the building element types, a relatively high impact per m² of building element results in a visibly higher impact at building scale. However, it should be noted that all five cases are solid construction types and hence variations in materialisation are limited. As shown in the SuFiQuaD-based benchmark study, timber construction enables significant reductions in environmental impact [16].

4.2. Comparison with Belgian archetype buildings

Figure 6 compares the obtained results with the results for solid construction from an earlier study on the SuFiQuaD archetypes [16]. Overall, the impacts are slightly higher for the EPB cases than the SuFiQuad cases: the mean values of both sets differ 2.4 mPt/m²GHFA for the embodied impact (51.4 mPt/m²GHFA for EPB and 49 mPt/m²GHFA for SuFiQuad), 1.9 mPt/m²GHFA for the operational impact (42 mPt/m²GHFA for EPB and 40 mPt/m²GHFA for SuFiQuad), and 4.1 mPt/m²GHFA for the total environmental score (93.1 mPt/m²GHFA for EPB and 89 mPt/m²GHFA for SuFiQuad).

Comparison per building type shows that the difference is highest between the terraced houses and lowest between the semi-detached houses. The semi-detached SuFiQuaD buildings have on average a 0.5 mPt/m²GHFA lower embodied impact, 2.5 mPt/m²GHFA higher operational impact and 2.1 mPt/m²GHFA higher total impact. The impact of the detached cases is on average lower for the EPB cases, i.e. 2.7 mPt/m²GHFA for embodied impact, 3.4 mPt/m²GHFA for operational impact, and 6.1 mPt/m²GHFA for total impact. Note, however, that the impact of ID08 is identical to SuFiQuaD_Detached_Passive. Contrarily, the impact of the terraced EPB case is higher than for SuFiQuaD, i.e. 7 mPt/m²GHFA for both embodied and operational impact, hence 14 mPt/m²GHFA for the total impact.

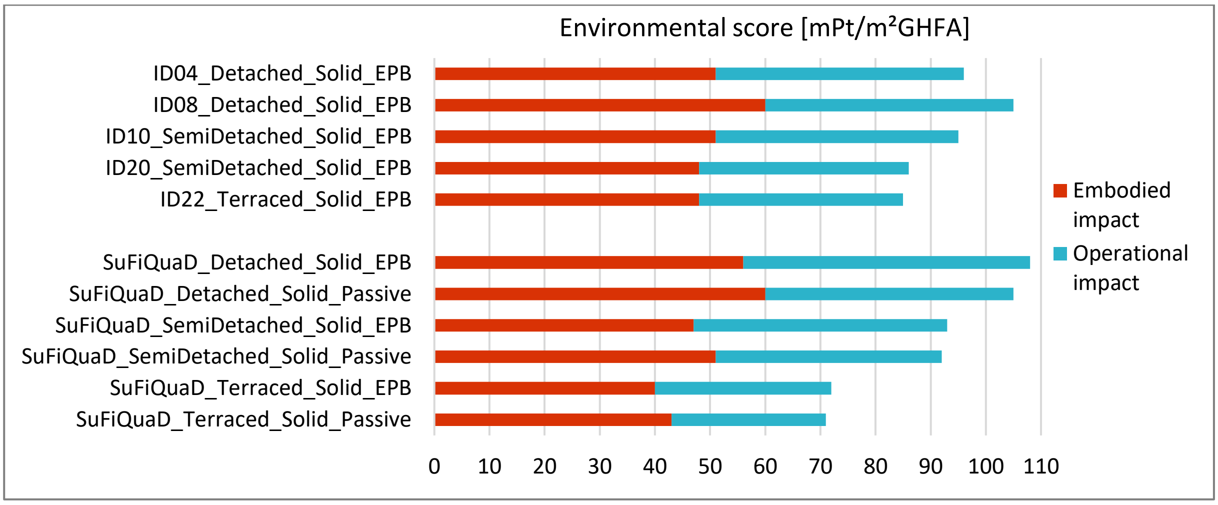

Figure 6. Environmental score of the five cases and of Belgian archetypes from SuFiQuaD [16].

4.3. Limitations

The current study presents some limitations concerning both the modelling in TOTEM and the cases themselves. Regarding the modelling, one important drawback are the fixed default parameters for the operational energy use calculation in TOTEM. For these cases this is particularly an issue for ID08 since (1) it includes a heat pump instead of a gas boiler and (2) its ventilation system includes heat recovery. Another limitation is the impossibility to model technical systems and renewable energy systems in TOTEM. All five cases include either photovoltaic panels or a solar boiler, of which both the embodied impact and reduction in operational impact have been excluded from the assessment.

Regarding the cases, it is important to stress that the buildings were selected for their representativeness in terms of geometry and energy performance, not for their materialisation. The building element compositions are conventional and show little variation among the cases. This implies that their materialisation presumably represents a large share of the Flemish building stock. Further, it should be noted that the representative buildings do not include extreme geometries, but that such buildings are included in the clusters which are represented by a selected representative case. Concerning benchmarking, this implies that the cases are appropriate for defining a reference value, but less suited for defining a limit or best-practice value.

5. Conclusion

This study assessed the life cycle environmental impact of five buildings selected from a set of representative buildings that is planned to be used for benchmarking of Flemish residential buildings. The set of buildings was derived based on their representativeness of the Flemish dwelling stock in terms of geometry and energy performance. The five selected cases include two detached, two semi-detached and one terraced house, all solid constructions in line with the Flemish energy performance of building (EPB) requirements of 2014/2015. A workflow was developed to translate input from the EPB software into input for the TOTEM tool, in which the environmental impacts were calculated.

From these five cases it was concluded that the geometry and building type have a bigger influence on the environmental impact than the materialisation. These preliminary conclusions should however be validated by the assessment of additional cases. Further, a comparison with impacts of Belgian archetype buildings shows that on average the studied buildings have comparable impacts, but a comparison per building type (i.e. detached, semi-detached and terraced) shows slightly larger differences. This indicates the relevance of assessing multiple cases for each building type, instead of assuming one archetype as representative for the respective types.

Next research steps include (1) improve the accuracy of the operational energy use calculations and model the impact of the technical installations; (2) model the whole set of 54 EPB cases, including variations in construction type (both solid and timber construction) and energy performance (from low energy to net zero energy buildings); (3) thereupon, investigate which are potential mitigation strategies; (4) assess life cycle impacts of the cost optimal solutions from the initial feasibility study in order to investigate whether similar conclusions can be drawn from a financial and environmental perspective. These steps will eventually help to define life cycle environmental benchmarks for the Flemish dwelling stock.

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