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MDPI

Supplementary

Section A. The Buildings Elements and the LCA Database Using in this Indicator is According to Life—Cycle Analysis of Buildings [2], in the Annex II (LCA Database). The Building Elements Using in the Francisco de Holando High School Are:

PExt 1: Single wall with support element in masonry of brick (22 cm). The insulation is in molded polystyrene plates with 6 cm thick. The outer shell is in reinforced plaster (2 cm).

PExt 12: Double wall with an exterior cloth in masonry of cast brick (15 cm) and interior cloth in masonry of cast brick of (11 cm). The cloths are separated by a box-of-air with 4 cm thick, filled with insulation of 2cm thick, with Interior and exterior vestments (1.5 cm).

PExt 16: Double wall with an exterior cloth in stone masonry (12 cm) and interior cloth in masonry of brick (11 cm). The cloths are separated by (4 cm). The Interior vestments is coated with traditional plaster (2 cm).

PExt 15 Double wall with an exterior cloth in mass brick (11 cm) and an interior cloth in masonry of bored brick (11 cm). The cloths are separated by a box-of-air (4 cm) filled with insulation in plates, extruded polystyrene (4 cm). The Interior vestments is coated with traditional plaster (2 cm).

Pint 7 Drilled brick masonry single wall (11 cm). The vestments, interior and exterior are coated with traditional plaster (1.5 cm).

Pint 9 Drilled brick masonry single wall (22 cm). The vestments are coated with plaster (1.5 cm).

Cob 1 Traditional flat roof coating in cobble, with 10cm thick and inner coating in traditional plaster of 2cm thick. The support is in solid slab (20 cm), upon which rests: the layer of lightweight concrete form with 10cm thick, upon which rests, the PVC vapour barrier, the thermal insulation in plates of expanded polystyrene (EPS) with 8 cm thick, the layer of waterproofing in PVC membranes, the blanket of geotextile, and the ceramic mosaic.

Cob 12 Sloping roof with wooden structure (ripped with a section (5×3 cm) and sticks (8×12 cm) that serve as support to the outer coating in ceramic tile. Thermal insulation is in extruded expanded polystyrene (8 cm). Under the thermal insulation, there is a vapour barrier in PVC membranes. The interior is in gypsum plasterboard (1.25 cm).

Cob 22 It has a discontinuous structure in wood (5×3 cm) and sticks (8×12 cm) that serve as support to the exterior coating fiber cement sheet. The isolation, in rock wool (10 cm), is laid on the horizontal belt. The belt is composed of support elements in wood (8×12 cm) and the celling is covered with gypsum plasterboards. On the gypsum, plasterboards there is a vapour barrier in PVC membranes.

Pav 7 Pavement composed by alveolar panels (20 cm) containing (4 cm) of concrete layer.

Pav 13 Discontinuous structure pavement, composed by wooden flooring (1.8 cm) wooden beams (25×30 cm) spaced by 65 cm and ceiling coated with plasterboards (1.25 cm).

Env 5 It is composed by PVC window frame system with five chambers, has a sheet with a constructive (depth 7.9 cm) and a ring (7.2 cm). It is equipped with a double-glazing, composed by an outer glass (4mm), an air gap (16mm) and an inner glass (1.6 cm).

Env 8 It is composed by a window frame system with solid or laminated wood profile has a sheet with a constructive (6.8 cm) and a ring (5.8 cm). It is equipped with a double-glazing, composed by an outer glass (4 mm), an air gap (6 mm) and an inner glass (1 cm).

Table S1 shows the description of all solution types used in Francisco de Holanda High School building, their area and quantify the environmental impacts of building life cycle (Barbosa, 2013).

Table S1. Solution types used in FHHS.

Solution Type	Area (m^2)	Quantification of Environmental Impact: m^2 of Each Type of Support Solution.					
		GWP (kg CO_2)	ODP (kg CFC^{-11})	AP (kg SO_2)	POCP (kg C_2H_4)	EP (kg PO_4)	FFDP (MJ)
Solution for Ground and High floor							
1	15,042	58.9694	0.0000049911	0.19	0.01048	0.03928	861.0458
Solution for Exterior walls							
2	13,886.4	82.994	0.0000495	0.16797	0.01756	428.7344	495.78
Solution for Interior walls							
3	18,769	36.7907	0.0000043587	0.1585	0.00341	0.02590	690.6769
Solution for Roofs							
4	7770	20.51	0.000004527	0.22769	0.009365	0.024	411.25825
Solution for Glazed openings							
5	649	68.0023	0.0000004083	0.65498	0.023234	466.0823	1,389.811205
Sum of Impacts 56,116.4		267.2664	0.0000637851	1.39914	0.064049	894.90588	3848.572155
Divide by Lifetime cycle							
Total impacts of life cycle		4.76×10^{-3}	7.28×10^{-12}	2.5×10^{-5}	1.1×10^{-6}	1.59×10^{-2}	6.86×10^{-2}

Section B. Quantification of the Environmental Impacts of the Life Cycle of Reference Solutions (Benchmarks):

For each type of building element, it must be multiplied each environmental impact that corresponds to the reference solution by the total area of that element. In this section, it is presented the calculation procedure needed to help to quantify the categories of environmental impact for life cycle in reference buildings (standard practice and best practice). The quantification of these categories is carried out by completing Table. For the different building components: ground floor, high floors, exterior walls, interior walls, roofs, glazed openings and structure.

B.1.Ground and High Floor

In Table S2 is made a sum of all environmental impacts of ground floor, obtaining an average impact per unit of area.

Table S2. Values corresponding to the standard practice for the ground floor of FHHS.

					Ground and High floor	
	Quantification of environmental impact categories					
	GWP (Kg CO2)	ODP (kg CFC-11)	AP (Kg SO2)	POCP (kg.C2H4)	EP (kg PO4)	FFDP (MJ)
Conventional Solution	$8.02x10^{+01}$	$4.33x10^{-06}$	$2.03x10^{-01}$	$7.53x10^{-03}$	$3.08x10^{-02}$	$5.88x10^{+02}$
			X			
Total area of element (m2)	A1: 15,042					
(P1.2) Impacts from standard practice	1,206,368.80	0.0651318	305,352.60	113.2662	463.2936	8,844.696

B.2. Exterior Walls

In the Table S3 is made a sum of all environmental impacts of exterior walls obtaining an average impact per unit of area.

Table S3. Values corresponding to the standard practice for exterior walls of FHHS.

					Exterior walls	
	Quantification of environmental impact categories					
	GWP (KgCO2)	**ODP (kg CFC-11)**	**AP (Kg SO2)**	**POCP (Kg.C2H4)**	**EP (kg PO4)**	**FFDP (MJ)**
Conventional Solution	$5.89x10^{+01}$	$3.91x10^{-06}$	$1.69x10^{-01}$	$1.72x10^{-02}$	$2.37x10^{-02}$	$6.32x10^{+02}$
			X			
Total surface. l (m2)	A2: 13,886.4					
(P1.2) Impacts from standard practice	817,885.40	0.0542958	2346.8016	238.84608	329.10768	8776204.8

B.3. Interior Walls

In the Table S4 is made a sum of all environmental impacts of interior walls, obtaining an average impact per unit of area.

Table S4. Values corresponding to the standard practice for interior walls of FHHS.

					Interior Walls	
	Quantification of environmental impact categories					
	GWP (KgCO2)	**ODP (Kg CFC11)**	**AP (KgSO2)**	**POCP (kg.C2H4)**	**EP (kg PO4)**	**FFDP (MJ)**
Conventional Solution	$3.14x10^{+01}$	$2,17x10^{-06}$	$8.22x10^{-02}$	$4.54x10^{-03}$	$1.35x10^{-02}$	$2.82x10^{+02}$
			X			
Total area of the element (m^2)	A3: 18,769					
(P1.3) Impacts from standard practice	589,346.60	0.0407287	1,542.81	85.21126	253.3815	5292858

B.4. Roof

In the Table S5 is made a sum of all environmental impacts of roof, obtaining an average impact per unit of area.

Table S5. Values corresponding to the standard practice for roofs of Francisco de Holanda High School (FHHS).

					Roofs	
	Quantification of environmental impact categories					
	GWP (KgCO2)	**ODP (kg CFC-11)**	**AP (KgSO2)**	**POCP (kg.C2H4)**	**EP (kg PO4)**	**FFDP (MJ)**
Conventional Solution	88	$4.75x10^{-06}$	$1.84x10^{-01}$	$9.66x10^{-03}$	$2.94x10^{-02}$	$6.15x10^{+02}$
			X			
Total Surface (m2)	A4: 7,770					
(P1.4) Impacts from standard practices	683,760	0.0369075	1429.68	75.0582	228.438	4,778,550

B.5. Glazed Openings

In the Table S6: is made a sum of all environmental impacts of glazed openings, obtaining an average impact per unit of area.

Table S6. Values corresponding to the standard practice for windows and glazed openings of FHHS.

					Glazed openings	
	Quantification of environmental impact categories					
	GWP (KgCO2)	**ODP (kg CFC-11)**	**AP (KgSO2)**	**POCP (kg.C2H4)**	**EP (kg PO4)**	**FFDP (MJ)**
Conventional Solution l	8.31	$1{,}17x10^{-06}$	0.116	-2.9×10^{-5}	8.18×10^{-3}	1.04×10^{3}
			X			
Total surface (m2)	**A6**					
(P1.7) Impacts from standard practices	5276.37	0.0007593	75.284	−0.18821	5.3088	0.67496

B.6. Benchmarks Associated to the Building's Life Cycle

The Table S7 and Table S8 present the auxiliary calculation process required to quantify the life cycle environmental impact categories in reference buildings (standard and best practice).

Table S7. Impacts of life cycle corresponding to the standard practice of FHHS.

					Standard Practice	
	Quantification of environmental impact categories					
	GWP (KgCO2)	**ODP (kgCFC-11)**	**AP (KgSO2)**	**POCP (kg.C2H4)**	**EP (kg PO4)**	**FFDP (MJ)**
Total impacts incorporated (P1.2+P1.3+P1.4+P1.5 +P1.6 +P1.7 + P1.8)	3,302,637.17	0.19782	310747.17	512.19353	1279.529	18,856,458.2
			÷			
Duration of cycle life of reference (years)	50 years					
(P1.9) Impacts of the life cycle of standard practices	58.8533	3.52×10^{-6}	5.5375464	0.0091273	0.0228013	336.024018

Table S8. Impacts of life cycle corresponding to the best practice of FHHS.

					Best practice	
	Quantification of environmental impact categories					
	GWP (KgCO2)	**ODP (kgCFC-11)**	**AP (KgSO2)**	**POCP (kg.C2H4)**	**EP (kg PO4)**	**FFDP (MJ)**
Total Impacts Incorporated $\frac{SP\ \%}{4}$	825,659.29	0.09891	77,686.79	128.04838	319.8822	84.006
			÷			
Duration of the life cycle of reference (years)	50 years					
(P1.10) Best practice life cycle impacts	14.713325	8.8×10^{-7}	1.3843866	0.0002282	0.0057	4714114.6

Section C. Normalization and Aggregation of the Environmental Impact Categories

By the filling of Table S9, it is possible to determine the normalized value of each one of the environmental impact categories.

The normalization is made through the following equation:

$$\overline{P_i} = \frac{P_i - P_{i*}}{P_i^* - P_{i*}} \quad (1)$$

GWP (Kg CO_2):

$$\overline{P_i} = \frac{0.00476 - 58.8}{0.147 - 58.8} = 1.0023 \quad (2)$$

ODP (kg CFC-11):

$$\overline{P_i} = \frac{0.00000000000728 - 0.00000352}{0.00000088 - 0.00000352} = 1.33 \quad (3)$$

AP ($KgSO_2$):

$$\overline{P_i} = \frac{0.000025 - 5.54}{1.38 - 5.54} = 1.33 \quad (4)$$

POCP ($kg.C_2H_4$):

$$\overline{P_i} = \frac{0.0000011 - 0.00913}{0.000228 - 0.00913} = 0.3516 \quad (5)$$

EP (kg PO_4):

$$\overline{P_i} = \frac{0.0159 - 0.0228}{0.0057 - 0.0228} = 0.403508 \quad (6)$$

FFDP (MJ):

$$\overline{P_i} = \frac{0.0686 - 336}{4710 - 336} = 0.076 \quad (7)$$

Table S9. Standardization and assessment of the global environmental performance of the solution assessed of FHHS.

Environmental Impact Categories	Life Cycle Impacts (per m² of Useful Area of Pavement, Year)				Weight of the Environmental Impact Category [B]	Weighted Value [A]×[B]
	Best Practice [Pi*] = (P1.7)	Standard Practice [Pi*] = (P1.6)	Solution Assessed [Pi] = (P1.1)	Standardisation Value (1) [A]		
GWP (Kg CO_2)	0.147	58.8	4.76×10^{-3}	1.0023	40.7%	0.4
ODP (kg CFC-11)	0.88×10^{-6}	3.52×10^{-6}	7.28×10^{-12}	1.33	8.4%	0.11
AP (Kg SO_2)	1.38	5.54	0.25×10^{-4}	1.33	13.6%	0.18
POCP ($kg.C_2H_4$)	2.28×10^{-4}	9.13×10^{-3}	1.1×10^{-6}	0.35	10.15%	0.036
EP (kg PO_4)	5.7×10^{-3}	2.28×10^{-2}	1.59×10^{-2}	0.40	13.6%	0.054
FFDP (MJ)	471	336	6.86×10^{-2}	0.076	13.6%	0.012
			(PLCA) (P1.24) Σ = Environmental performance of the solution			0.792

Based on this calculus, the value given to this indicator is 0.79—A.