

Evaluating Deep Renovation vs. Reconstruction: A BIM-LCA and AHP Decision-Making Framework Balancing Environmental Performance and Safety

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Supplementary Materials

Table S1. GHG emissions of construction phase processes as resulted from LCA for Experts software modelling

Construction phase hotspot analysis			
SCENARIO 1 – RENOVATION		GHG per FU [kg CO ₂ eq. per sqm/year]	% contribution
Construction Materials	Partial demolition for renovation	0.043	1.2%
	Concrete	0.135	3.9%
	Steel	0.205	5.9%
	Aluminium	2.37	66.9%
	Insulation	0.153	4.2%
	Wood	0.069	1.9%
	Plaster	0.006	0.2%
	Other materials	0.485	13.7%
	Transport	0.005	0.1%
	Electricity used on site	0.074	2.1%
	TOTAL	3.546	100%
SCENARIO 2 – RECONSTRUCTION			
Construction Materials	Total demolition prior to reconstruction	0.39	4.0%
	Plaster	0.17	1.7%
	Concrete	1.36	14.3%
	Steel	0.64	6.5%
	Aluminium	2.37	24.4%
	Bricks	1.65	17.3%
	Insulation	0.19	1.9%
	Wood	0.08	0.8%
	Other materials	2.5	25.5%
	Transport	0.05	0.5%
	Electricity used on site	0.3	3.1%
	TOTAL	9.70	100%

Table S2. GHG emissions of construction phase processes as resulted from OneClick LCA, LCA software modelling

Construction phase hotspot analysis			
SCENARIO 1 – RENOVATION		GHG per FU [kg CO₂eq. per sqm/year]	% contribution
Construction Materials	Partial demolition for renovation	0.024	1.0%
	Concrete	0.072	2.9%
	Steel	0.199	8.0%
	Aluminium	1.568	63.8%
	Insulation	0.155	6.4%
	Wood	0.052	2.10%
	Plaster	0.004	0.20%
	Other materials	0.304	12.1%
	Transport	0.014	0.60%
	Electricity used on site	0.079	3.1%
TOTAL		2.471	100%
SCENARIO 2 – RECONSTRUCTION			
Construction Materials	Total demolition prior to reconstruction	0.22	3.10%
	Concrete	0.8	11.4%
	Steel	0.67	9.5%
	Aluminium	1.568	22.8%
	Bricks	1.16	16.70%
	Insulation	0.19	2.7%
	Wood	0.05	0.70%
	Plaster	0.11	1.6%
	Other materials	1.67	24.20%
	Transport	0.19	2.70%
	Electricity used on site	0.32	4.6%
TOTAL		6.948	100%

Table S3. Climate change impact results for construction-phase in the renovation scenario. Both LCA for Experts and OneClick LCA, LCA results are shown.

Software	Partial demolition for renovation	Construction Materials	Transport	Electricity Used on site
OneClick LCA	0.024	2.4	0.014	0.079
LCA for Experts	0.043	3.5	0.005	0.074

Table S4. Climate change impact results for construction-phase in the reconstruction scenario. Both LCA for Experts and OneClick LCA, LCA results are shown.

Software	Total demolition prior to reconstruction	Construction Materials	Transport	Electricity Used on site
LCA for Experts	0.39	9.1	0.05	0.3
OneClick LCA	0.22	6.3	0.19	0.32

Table S5. Climate change impact results by material type for the construction phase in the renovation scenario. Both LCA for Experts and OneClick LCA, LCA results are shown.

Software	Concrete	Steel	Aluminum	Insulation	Wood	Plaster	Other Materials
LCA for Experts	0.14	0.21	2.4	0.15	0.069	0.006	0.49
OneClick LCA	0.072	0.2	1.6	0.16	0.052	0.004	0.3

Table S6. Climate change impact results by material type for the construction phase in the reconstruction scenario. Both LCA for Experts and OneClick LCA, LCA results are shown.

Software	Concrete	Steel	Aluminum	Insulation	Wood	Plaster	Bricks	Other Materials
LCA for Experts	1.4	0.64	2.4	0.19	0.08	0.17	1.7	2.5
OneClick LCA	0.8	0.67	1.6	0.19	0.05	0.11	1.17	1.7

Table S7. Main background datasets used in the LCA for Experts model. Dataset names and geographical identifiers reproduce the information available in the archived models; additional metadata were retrieved from the corresponding database documentation where available.

Model section/process	Dataset name	Data provider/database	Geography	Technology represented	Reference year/period	Scenario 1	Scenario 2
Demolition	GLO: Excavator, 100 kW, construction	Sphera MLC	GLO	Construction excavator operation, 100 kW	2019	✓	✓
Transport	GLO: Truck, Euro 4, 26–28 t gross weight / 18.4 t payload capacity	Sphera MLC	GLO	Heavy-duty freight transport by Euro 4 truck	n.a.	✓	✓
Fuel supply	RER: Diesel mix at filling station (100% fossil)	Sphera MLC	RER	Fossil diesel supply at filling station	2020	✓	✓
Fuel supply	RER: Diesel mix at filling station	Sphera MLC	RER	Diesel supply at filling station	2021+	✓	✓
Temporary/formwork structures	RER: Plywood board (EN15804 A1-A3)	Sphera MLC	RER	Plywood board production	2022	✓	✓
Structural materials	EU: Steel rebar (2019)	worldsteel	EU	Reinforcing steel	2016	✓	✓
Structural materials	RER: Concrete C25/30 (Ready-mix concrete) (EN15804 A1-A3)	Sphera MLC	RER	Ready-mix concrete C25/30	2021+	✓	✓
Structural materials	RER: Concrete C8/10 (Ready-mix concrete) (EN15804 A1-A3)	Sphera MLC	RER	Ready-mix concrete C8/10	n.a.	—	✓
Strengthening	GLO: carbon fibre reinforced plastic, injection moulded	ecoinvent 3.9.1	GLO	Injection-moulded carbon-fibre-reinforced plastic	2022+	✓	—
Vertical structures	RER: Stone wool	Sphera MLC	RER	Stone-wool insulation	n.a.	✓	✓
Vertical structures	RER: Gypsum plasterboard	ELCD/EUROGYPSUM	RER	Gypsum plasterboard	2013	—	✓
Vertical structures	RER: Aluminium profile (EN15804 A1-A3)	Sphera MLC	RER	Extruded aluminium profile; average mill-finished aluminium profile for construction applications, including façades and windows	2019	✓	✓

Model section/process	Dataset name	Data provider/database	Geography	Technology represented	Reference year/period	Scenario 1	Scenario 2
Masonry	RER: Bricks vertically perforated (EN15804 A1-A3)	Sphera MLC	RER	Vertically perforated bricks	n.a.	—	✓
Horizontal/vertical structures	RER: Expanded Polystyrene (EPS) Foam (25 kg/m ³ , EN15804 A1-A3)	Sphera MLC	RER	EPS insulation, 25 kg/m ³	2022+	✓	✓
Horizontal structures	RER: Bitumen sheet v 60 (EN15804 A1-A3)	Sphera MLC	RER	Bituminous sheet production	2018+	✓	✓
Horizontal structures	RER: Expanded Polystyrene (EPS) Foam (30 kg/m ³ , EN15804 A1-A3)	Sphera MLC	RER	EPS insulation, 30 kg/m ³	2022+	✓	✓
Horizontal structures	RER: Laminated woodboard softwood (EN15804 A1-A3)	Sphera MLC	RER	Laminated softwood board	2022+	✓	✓
Horizontal structures	RER: Stainless steel sheet (EN15804 A1-A3)	Sphera MLC	RER	Stainless-steel sheet production	2022+	✓	✓
Horizontal structures	RER: Glass ceramic production	Sphera MLC	RER	Glass-ceramic production	n.a.	—	✓
Windows/fixtures	RER: Polyvinyl chloride sheet (PVC)	PlasticsEurope	RER	PVC sheet production	2004	✓	✓
Windows/fixtures	RER: Window glass simple (EN15804 A1-A3)	Sphera MLC	RER	Window glass production	2017+	✓	✓
Finishing	CN: Gypsum plaster (CaSO ₄ beta hemihydrate)	Sphera MLC	CN	Gypsum plaster production	n.a.	✓	✓
Finishing	CN: Stoneware tiles unglazed	Sphera MLC	CN	Unglazed stoneware-tile production	2019	✓	✓
Building operation	IT: Electricity grid mix	Sphera MLC	IT	Italian electricity grid mix	2021	✓	✓

Model section/process	Dataset name	Data provider/database	Geography	Technology represented	Reference year/period	Scenario 1	Scenario 2
Building operation	IT: Tap water from groundwater	Sphera MLC	IT	Tap-water production from groundwater	2020†	✓	✓
Building operation	RER: Municipal waste water treatment (mix)	Sphera MLC	RER	Municipal wastewater treatment	2022	✓	✓
End-of-life	RER: Municipal waste landfill (EN15804 C4)	Sphera MLC	RER	Municipal-waste landfill treatment, module C4	2020†	✓	✓

† For some Sphera datasets, the reference year was retrieved from publicly available documentation for the corresponding dataset with the same technological coverage but a different geographical variant (e.g., DE or EU-28 instead of RER, IT or CN). Where sufficiently corresponding public metadata could not be retrieved, the reference year is reported as “n.a.”