BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF CIVIL ENGINEERING

FAKULTA STAVEBNÍ

INSTITUTE OF BUILDING STRUCTURES

ÚSTAV POZEMNÍHO STAVITELSTVÍ

EARTHEN STRUCTURES FROM THE PERSPECTIVE OF LCA (LIFE CYCLE ASSESSMENT)

KONSTRUKCE Z NEPÁLENÉ HLÍNY Z POHLEDU LCA ANALÝZY

APPENDIX F – LIST OF FIGURES AND TABLES

MASTER'S THESIS

DIPLOMOVÁ PRÁCE

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BRNO 2026

Adobe brick building				
EXTERNAL WALL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Clay plaster (0,02m)	0,02	0,87	0,02
2	Adobe bricks(0,25m)	0,25	0,69	0,36
3	Straw bale (0,25m)	0,25	0,052	4,81
4	Clay plaster (0,02m)	0,02	0,87	0,02
			Σ R	5,22
			R_{si}	0,13
			R_{se}	0,04
			R_T	5,39
			U	0,19

Table 3.1 – U-value of the external wall of the adobe brick building

SLAB IN CONTACT WITH SOIL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Wooden floor (10mm)	0,01	0,18	0,06
2	Polyethylene fleece (0,002m)	0,00	0,33	0,01
3	Cement screed (0,06m)	0,06	1,50	0,04
4	SBS modified asphalt strip 2x (0,004m)	0,01	0,17	0,05
5	XPS (0,14m)	0,14	0,03	4,38
6	Concrete (0,2m)	0,20	1,70	0,12
7	Compacted gravel (0.15m)	0,15	1,50	0,10
			Σ R	4,74
			R_{si}	0,13
			R_{se}	0,04
			R_T	4,91
			U	0,20

Table 3.4 – U-value of the slab in contact wih soil of the adobe brick building

WARM ROOF				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Spanish clay tiles (0.008m)	0,01	0,57	0,01
2	Timber roofing lath 40×60 mm (0.04m)	0,04	0,12	0,33
3	Air space (min. 0.04m)	0,04	0,00	0,18
4	Ventia Titanium Plus 190G (Sd≈0.02 m) (0.001m)	0,00	0,22	0,00
5	PIR boards (Thermano Roof AL) (0.12m)	0,12	0,02	5,22
6	Bitumen felt (0.004m)	0,00	0,19	0,02
7	OSB board 2x (0.025m)	0,03	0,13	0,19
8	Air space	0,00	0,00	0,18
9	Timber rafter 200×240 mm(0.2m)	0,20	0,12	1,67
10	Plasterboard (0.0125m)	0,01	0,25	0,05
			Σ R	7,86
			R_{si}	0,13
			R_{se}	0,04
			R_T	8,03
			U	0,12

Table 3.7 – U-value of the warm roof of the adobe brick building

INTERIOR WALL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Lime-cement (0,01m)	0,01	0,48	0,02
2	Lime-sand bricks (0,115m)	0,12	0,38	0,30
3	Lime-cement (0,01m)	0,01	0,48	0,02
			Σ R	0,34
			R_{si}	0,13
			R_{se}	0,04
			R_T	0,51
			U	1,94

Table 3.10 – U-value of the interior wall of the adobe brick building

Rammed earth building				
EXTERNAL WALL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Clay plaster (0.02 m)	0,025	0,87	0,03
2	Rammed earth (0.25 m)	0,25	0,7	0,36
3	Straw bale (0,25m)	0,25	0,052	4,81
4	Air space (0,03m)	0,03	0	0,00
5	Cembrit board (0.012 m)	0,012	0,3	0,04
			Σ R	5,23
			R_{si}	0,13
			R_{se}	0,04
			R_T	5,40
			U	0,19

Table 3.2 – U-value of the external wall of the rammed earth building

SLAB IN CONTACT WITH SOIL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Wooden floor (10mm)	0,01	0,18	0,06
2	Polyethylene fleece (0,002m)	0,00	0,33	0,01
3	Cement screed (0,06m)	0,06	1,50	0,04
4	SBS modified asphalt strip 2x (0,004m)	0,01	0,17	0,05
5	XPS (0,14m)	0,14	0,03	4,38
6	Concrete (0,2m)	0,20	1,70	0,12
7	Compacted gravel (0.15m)	0,15	1,50	0,10
			Σ R	4,74
			R_{si}	0,13
			R_{se}	0,04
			R_T	4,91
			U	0,20

Table 3.5 – U-value of the slab in contact wih soil of the rammed earth building

WARM ROOF				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Spanish clay tiles (0.008m)	0,01	0,57	0,01
2	Timber roofing lath 40×60 mm (0.04m)	0,04	0,12	0,33
3	Air space (min. 0.04m)	0,04	0,00	0,18
4	Ventia Titanium Plus 190G (Sd≈0.02 m) (0.001m)	0,00	0,22	0,00
5	PIR boards (Thermano Roof AL) (0.12m)	0,12	0,02	5,22
6	Bitumen felt (0.004m)	0,00	0,19	0,02
7	OSB board 2x (0.025m)	0,03	0,13	0,19
8	Air space	0,00	0,00	0,18
9	Timber rafter 200×240 mm(0.2m)	0,20	0,12	1,67
10	Plasterboard (0.0125m)	0,01	0,25	0,05
			Σ R	7,86
			R_{si}	0,13
			R_{se}	0,04
			R_T	8,03
			U	0,12

Table 3.8 – U-value of the warm roof of the rammed earth building

INTERIOR WALL

Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Lime-cement (0,01m)	0,01	0,48	0,02
2	Lime-sand bricks (0,115m)	0,12	0,38	0,30
3	Lime-cement (0,01m)	0,01	0,48	0,02
			Σ R	0,34
			R_{si}	0,13
			R_{se}	0,04
			R_T	0,51
			U	1,94

Table 3.11 – U-value of the interior wall of the rammed earth building

Traditional building

EXTERNAL WALL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Lime-cement (0,01m)	0,01	0,48	0,02
2	Lime-sand bricks (0,24m)	0,24	0,38	0,63
3	Cement based adhesive (0,005m)	0,005	0,54	0,01
4	Mineral wool (0,16m)	0,16	0,036	4,44
5	Cement mortar (0,002 m)	0,002	0,054	0,04
6	Fiberglass (0,001m)	0,001	0,054	0,02
7	Cement mortar (0,002 m)	0,002	0,054	0,04
8	Silicate primer (0.001m)	0,001	0,8	0,00
9	Silicon plaster (0,008 m)	0,008	0,66	0,01
			Σ R	5,21
			R_{si}	0,13
			R_{se}	0,04
			R_T	5,38
			U	0,19

Table 3.3 – U-value of the external wall of the traditional building

SLAB IN CONTACT WITH SOIL				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Wooden floor (10mm)	0,01	0,18	0,06
2	Polyethylene fleece (0,002m)	0,00	0,33	0,01
3	Cement screed (0,06m)	0,06	1,50	0,04
4	SBS modified asphalt strip 2x (0,004m)	0,01	0,17	0,05
5	XPS (0,14m)	0,14	0,03	4,38
6	Concrete (0,2m)	0,20	1,70	0,12
7	Compacted gravel (0.15m)	0,15	1,50	0,10
			Σ R	4,74
			R_{si}	0,13
			R_{se}	0,04
			R_T	4,91
			U	0,20

Table 3.6 – U-value of the slab in contact wih soil of the traditional building

TRADITIONAL FLAT ROOF				
Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Soil (0,06m)	0,06	0,70	0,09
2	Polyethylene fleece (0,003m)	0,003	0,33	0,01
3	HDPE drainage board (0,025m)	0,025	0,04	0,63
4	Polyethylene fleece (0,0036m)	0,0036	0,33	0,01
5	SBS modified asphalt strip 2x (0,008m)	0,008	0,19	0,04
6	EPS (0,2m)	0,2	0,04	5,56
7	EPS sloping (0,04m)	0,04	0,04	1,11
8	Bitumen felt (0,004m)	0,004	0,02	0,21
9	Reinforced concrete (0,20m)	0,2	2,00	0,10
10	Lime-cement (0,01m)	0,01	0,75	0,01
			Σ R	7,76
			R_{si}	0,13
			R_{se}	0,04
			R_T	7,93
			U	0,13

Table 3.9 – U-value of the flat roof of the traditional building

INTERIOR WALL

Layer	Material	d [m]	λ [W/m.K]	R [m2.K/W]
1	Lime-cement (0,01m)	0,01	0,48	0,02
2	Lime-sand bricks (0,115m)	0,12	0,38	0,30
3	Lime-cement (0,01m)	0,01	0,48	0,02
			Σ R	0,34
			R_{si}	0,13
			R_{se}	0,04
			R_T	0,51
			U	1,94

Table 3.12 – U-value of the interior wall of the traditional building

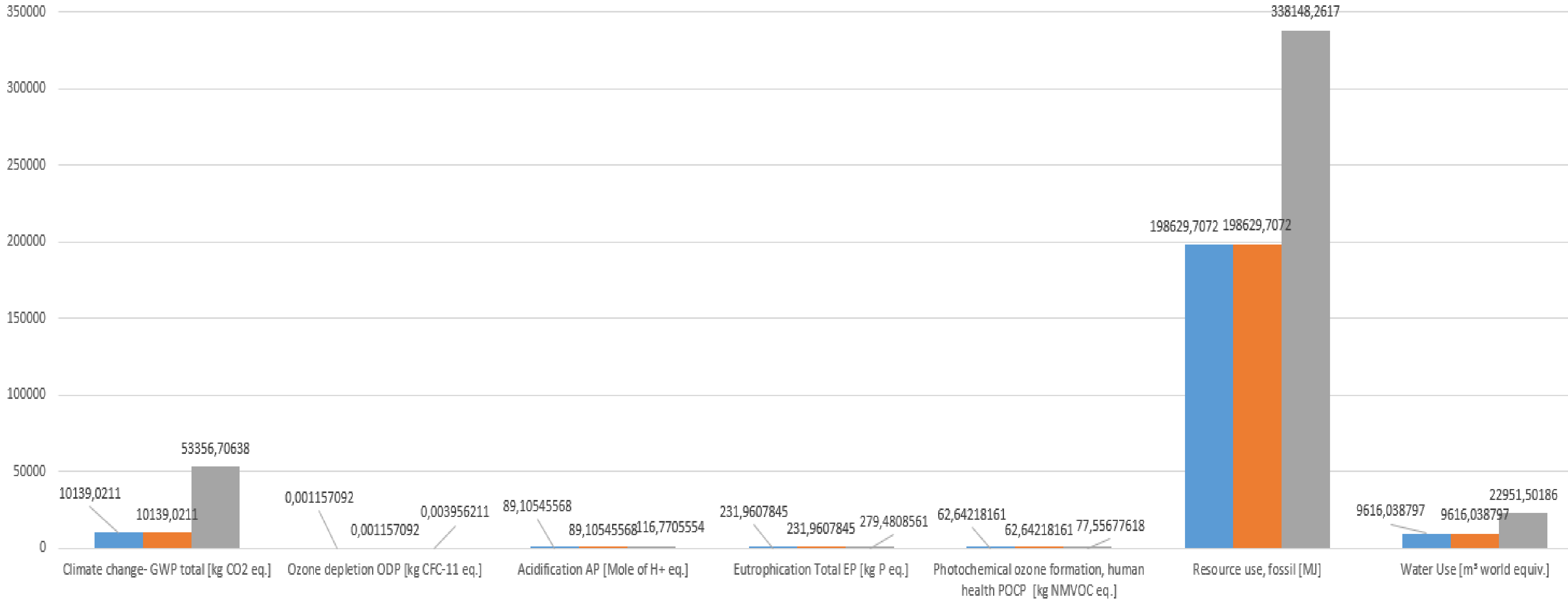


Table 4.1 – A1–A3 Environmental Impact Results of Adobe, Rammed Earth, and Traditional Buildings

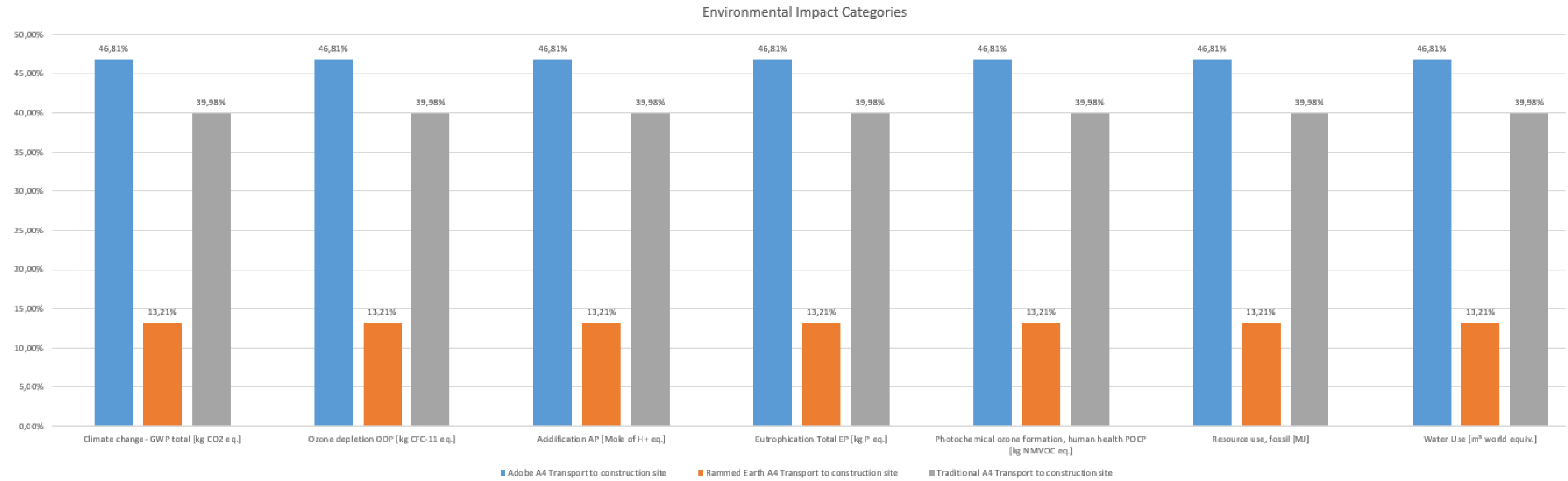
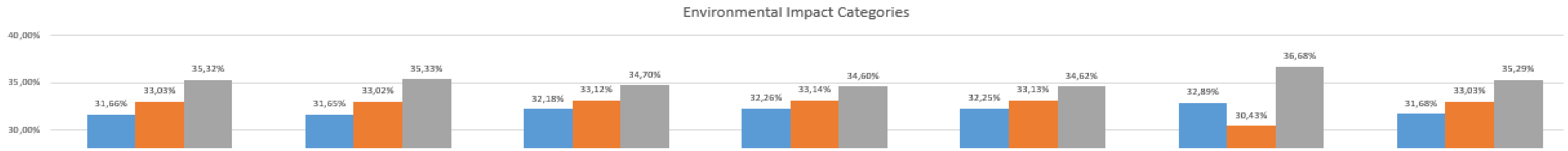


Figure 4.1 – Relative comparison of environmental impacts for the A4 transport stage across Adobe, Rammed Earth, and Traditional construction systems.



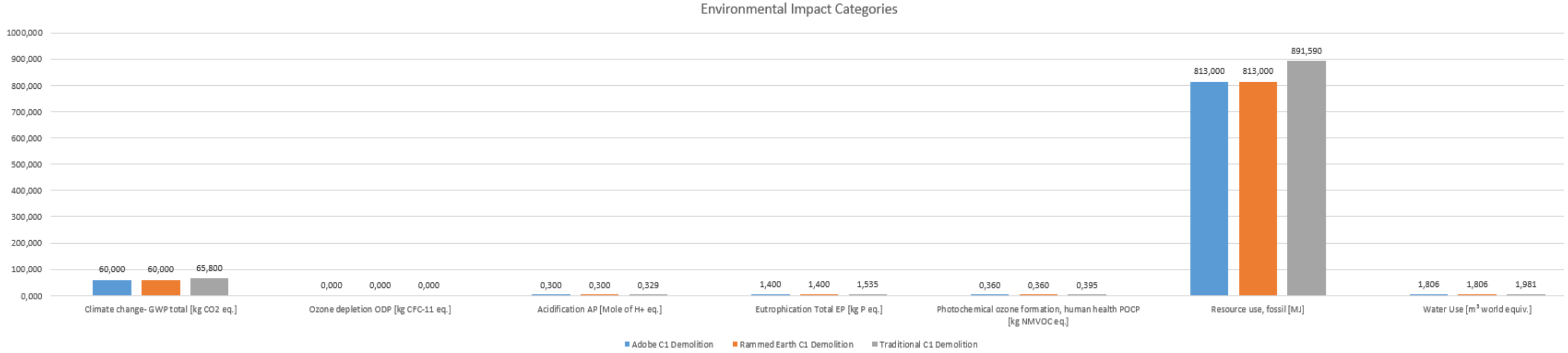


Figure 4.3 C1 Demolition - Environmental impacts of the C1 demolition stage for Adobe, Rammed Earth, and Traditional construction systems. In the C1 demolition stage, the environmental impacts are mainly related to machinery use and energy consumption during dismantling activities. The results indicate only minor differences between the three construction systems, as similar demolition assumptions and equipment are applied. However, the traditional construction system shows slightly higher impacts due to the greater mass and mechanical resistance of concrete-based elements. This stage includes demolition activities, transport of waste materials, and waste processing or recycling.

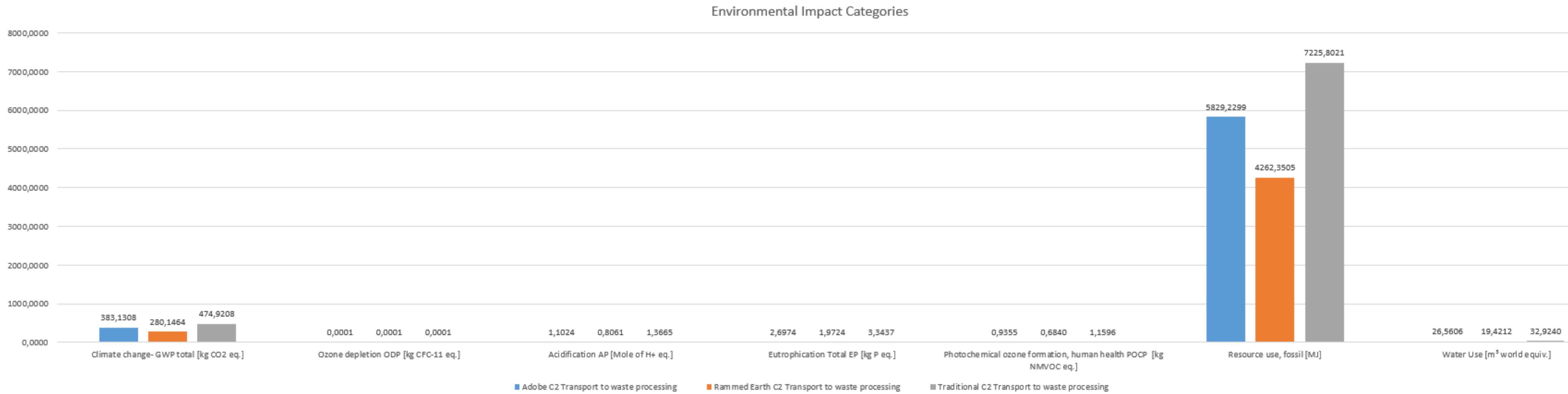


Figure 4.4 C2 Transport to waste processing - Environmental impacts of the C2 transport to waste processing stage for Adobe, Rammed Earth, and Traditional construction systems. For the C2 transport stage, differences between the construction systems become more visible. The traditional variant exhibits higher impacts, which can be attributed to larger quantities of demolition waste and longer transport requirements for mixed mineral materials. In contrast, adobe and rammed earth systems benefit from lower material mass and simpler waste streams, resulting in reduced transport-related environmental burdens.

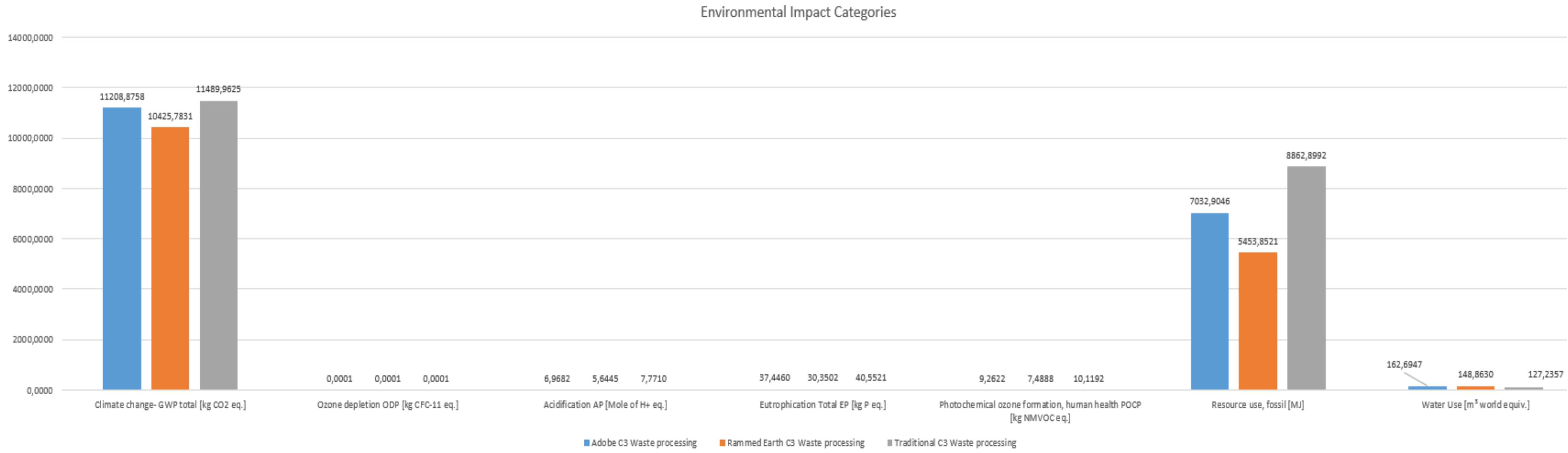


Figure 4.5 C3 Waste processing - Environmental impacts of the C3 waste processing stage for Adobe, Rammed Earth, and Traditional construction systems. The C3 waste processing stage shows the clearest distinction between earthen and traditional construction systems. Earthen materials demonstrate lower environmental impacts due to their ability to be reused, recycled as mineral material, or returned to the natural environment with minimal processing. Traditional construction systems, on the other hand, require more energy-intensive waste treatment processes, particularly for concrete and fired brick materials.

Stages	Climate change- GWP total [kg CO2 eq.]	Ozone depletion ODP [kg CFC-11 eq.]	Acidification AP [Mole of H+ eq.]	Eutrophication Total EP [kg P eq.]	Photochemical ozone formation, human health POCP [kg NMVOC eq.]	Resource use, fossil [MJ]	Water Use [m³ world equiv.]
A1-A3 Product stage	10139,0211	0,001157092	89,10545568	231,9607845	62,64218161	198629,7072	9616,038797
A4 Transport to construction site	897,0383668	0,000102315	1,289940883	3,156367072	1,094661986	6821,009358	31,07959909
A5 Construction / installation	3059,137918	0,000325699	11,14333863	56,02277186	14,23301103	18490,70722	46,91292272
B4 Replacement	248,1744958	7,94816E-05	4,400091848	12,35309142	3,775277043	10916,88367	364,9398395
B6-B7 Operational energy and water use	758849,4178	0,003391356	852,882024	2006,74834	476,498412	5576301,6	21050,4396
C1 Demolition	119,72154	0,00001281	0,3	1,399833	0,36	813	1,806
C2 Transport to waste processing	560,5463593	6,39353E-05	0,806065484	1,972368336	0,684038513	4262,350535	19,42119397
C3 Waste processing	20851,57308	8,42378E-05	5,644465683	30,35019689	7,488828636	5453,852138	148,8630382
Overall	794724,6307	0,005216927	965,5713822	2343,963753	566,7764108	5821689,11	31279,50099

Table 5.1 – Life-cycle environmental impact results for the representative rammed earth residential building. The results indicate that the operational stage (B6–B7) represents the dominant contribution to total impacts, while the product stage (A1–A3) remains the main source of embodied environmental burdens.

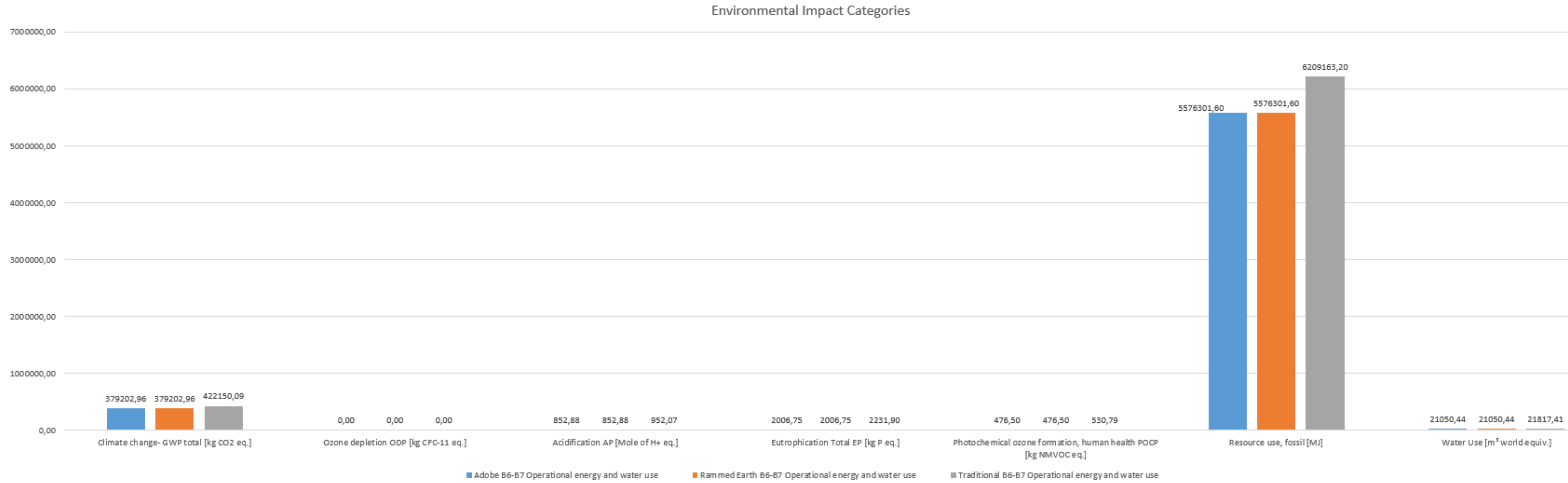


Figure 5.8 – Comparison of operational environmental impacts (B6–B7) for Adobe, Rammed Earth, and Traditional residential buildings across selected impact categories.