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RESEARCH ARTICLE

APPLYING THE LIFE CYCLE ANALYSIS IN THE CONSTRUCTION OF SOCIAL HOUSING IN CAMEROON: THE CASE OF SINGLE-STOREY HOUSES AT THE SIC RESIDENTIAL AREA IN OLEMBE (YAOUNDÉ)

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ABSTRACT

This study proposes an analysis approach of the life-cycle of two types of social housing of « T4 single-storey houses ». This is to determine which phase of the life-cycle calls for special attention in the process of reducing the impact of this sector on the environment. In order to successfully carry out this task, we first carried out a general review of the LCA as a decision-making guiding tool. Then, we alluded to social housing projects in Cameroon as the implementation framework of our guiding tool. Finally, after updating the database of some components of the building sector, we proceeded to the implementation on our two samples. Results obtained highlight the importance of the exploitation phase. More interestingly, considering all the twelve environmental impact indicators taken into account, the utilization phase that involves exploitation and maintenance is more predominant, causing 82 to 86% of the total impact, followed by the construction phase with 13 to 18%, and then by the demolition phase with 0.01 to 1%. As concerns the economic aspect, the utilization phase remains the most preoccupying. It represents at least 65% of the overall cost of the life cycle, also followed by the construction phase and then the demolition phase.

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INTRODUCTION

The housing crisis that has been plaguing Cameroon for close to twenty years has prompted the State to launch social housing projects in various cities of the country. That is why a pilot programme for the construction of 10.000 low-cost houses was initiated in the two major cities of Cameroon, that is Yaoundé, the political capital at the Olembé neighborhood (at the northern entrance of the city) and in Douala, the economic capital, in the Mbanga – Bakoko area. However, it is well-known that the civil engineering works in general, and construction of houses in particular, transform and severely damage the environment. As a matter of fact, the construction activity requires the massive use of natural renewable or non-renewable raw materials. This also implies the production of important quantities of inert wastes and the emission of pollutants such as carbon dioxide, fine particles, and volatile organic compounds. That is why it is imperative to integrate the environmental preservation aspect in the management of projects of such magnitude, because for too many years, the emphasis was mainly laid on the cost of activities, leaving aside the analysis of impacts made on the environment. Thus, in order to render buildings more ecological, it is important to know the various phases of their life cycle. We should also be able to determine the most important phase in terms of environmental impacts and avoid shifting pollution from one phase to the other. In order to fill this need and have an integral view of the issue, the Life Cycle Analysis appears to be the appropriate tool. It is in this light that this paper was drafted with the objective of applying the life cycle analysis to a « T4 one-storey » low-cost house in the urban area of the center Region. We shall present the LCA tool, the various phases of the life cycle of a building and determine the most toxic phase in terms of environmental impacts. A better knowledge of the impacts associated to products helps to set an order of priorities for improving and informing organizational and technical options.

Life cycle analysis

The Life Cycle Analysis (LCA), that was developed in the sixties, is used to quantify the impacts of a « product » (good, service or process), from the collection of its constitutive raw materials up to their destruction, through their distribution and use

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(« from the cradle to the grave » analysis). The flow of raw materials and energies involved and produced at each step of the life cycle are listed, and an exhaustive account is made of the consumption of energy, natural resources and polluting emissions in the environment (air, water and soils). The ISO14040 standard describes the essential characteristics of an LCA and good practices in conducting such a study (methodological framework, transparency requirements, measures applicable in case of transmission to third persons, etc.)

The four main steps of a life cycle analysis are as follows:

- The definition of the objective and scope of the study: ISO14041
- The inventory of resource consumption and of emissions: ISO14041
- The impact assessment of the life cycle : ISO14042
- The interpretation of the life cycle's results: ISO14043

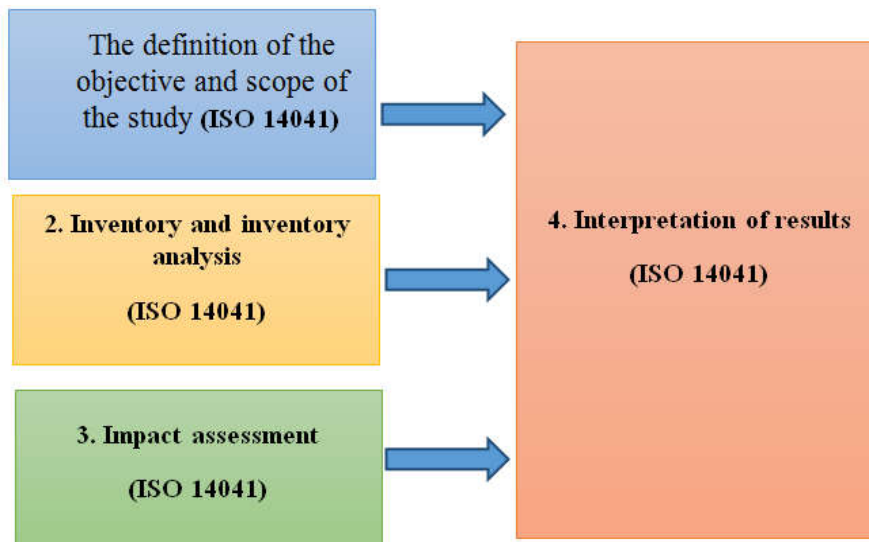


Figure 1. Interactions between the life cycle analysis steps (ADEME, 2005)

Defining the objective and the scope of the study

Defining the objective

The aim of our study is to apply the LCA to the low-cost house in urban areas in order to measure the environmental impacts during the life cycle of our building. This will be done on the basis of the LCA methodology that thoroughly assesses the impacts of a building using twelve environmental indicators:

i. Indicators on the consumption of:

- Energy;
- Water;
- Resources.

ii. The indicators of emissions into nature such as:

- Inert waste;
- Radioactive waste ;
- GWP100;
- Acidification;
- Eutrophization;
- Ecotoxicity;
- Human toxicity;
- O₃-smog;
- Odours.

Defining the scope

The scope within which we shall carry out our study features the following items:

i. Function and related functional units

Functional units adopted to determine the value of the various indicators during the three phases of the building’s lifespan:

- Internal usable surface: 93.7 m² ;
- Internal usable volume of the building:225m³ ;
- Occupation: 6 persons ;
- In-house services provided by household appliances and usual entertainment products such as the gas cooker, the refrigerator, the air-conditioner, the computer, the TV set and the radio ;
- Water supply by CDE;
- Electricity: voltage provided 220 volts.

Lifespan

It is supposed that construction works of our building start in July 2016 and end in December 2016. Thus, our house is ready on 1st January 2017; the lifespan of our house is estimated at 50 years.

Limits of the system

The limits define the scope within which the system is studied. All what fall without this framework is not taken into consideration. The system studied covers the construction, utilization maintenance and demolition of the building period and designed following a good number of well-established hypotheses. Figure 2 presents a sketchy view as well as the scope within which all the flows of materials and energy are listed for the life cycle of the building. This sketchy model of the life cycle is designed to include the astuteness of giving more importance to the nearest material supply points.

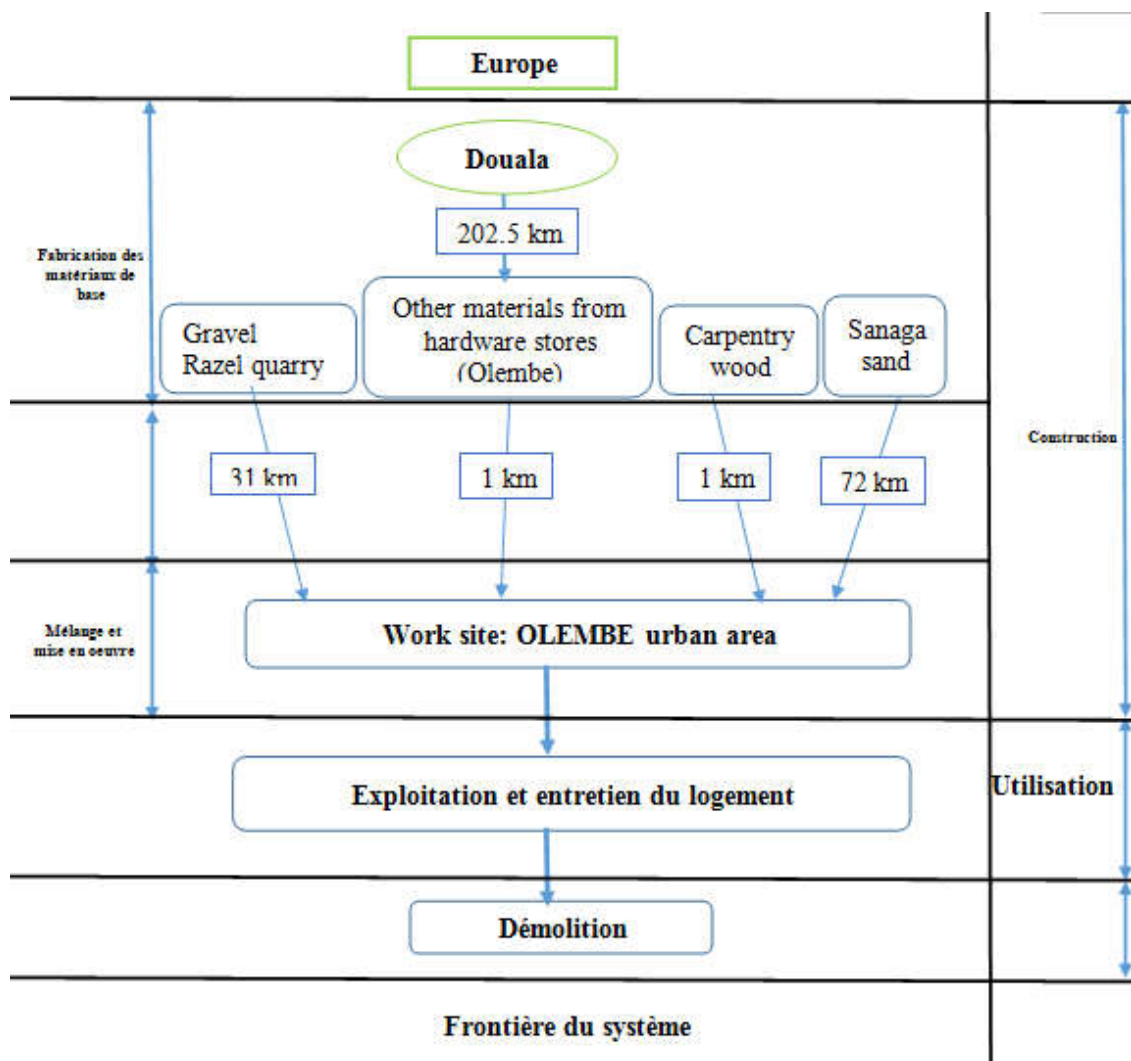


Figure 2. Sketch of the building’s life cycle

Flow inventory

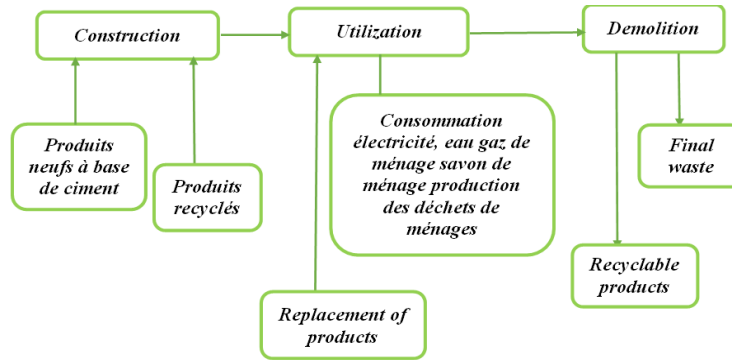


Figure 3. Principle for the calculation of the inventory

Presentation and justifications of the building

This is a single-storey low-cost house located in the Olembé neighborhood at a latitude of 3.9500° and a longitude of 11.533° in Yaoundé, whose characteristics are given in the tables below, as well as the Distribution plan. An estimate of the building is also attached.

Table 1. Civil engineering features of the low-cost building

Various parts of the building	Projet surface area	120 m ²		
	Surface area used	94 m ²		
	Internal volume	225 m ³		
	Type of materials	Materials made with cement		
	Structure of the building (inner net dimensions of these elements (1 to 7) represent the living area of the building)	1 living room	19 à 30 m ² (27.76)	Paillasse de (2.50x0.60) m ² et 0.90m de hauteur
		Three bedrooms	10 à 13 m ²	
		1 kitchen	7 m ²	
		1 bathroom	3.5 m ²	
		1 toilet		
			1 m ²	
passageway		At most 12% of the living area		
1 drier / launderette				
Dimension of doors and windows	Entry doors of the house	1.10mx 2.17m		
	French windows	1.04mx2.17m- 1.04mx 2.40m		
		1.20mx 2.17m- 1.20mx 2.40m		
		1.40mx 2.17m- 1.40mx 2.40m		
	Windows	0.80mx 0.63m-1.20mx 1.60 m		
		0.90mx 1.40m-0.90mx 1.50 m		
		1.20mx 1.20m-1.20mx 1.40 m		
Inner doors	0.85mx 2.10- 0.95mx 2.10m			
	0.70 mx2.1m			

Table 2. Electrical features of the low-cost house

Various parts of the building	1 parlour	1 or 2 lighting spots (1DA+ 1SA) or 1DA 2 or 3 sockets with ground connection (P+T) 1 collective TV antenna
	Bedrooms	1 lighting spot SA. 1 socket 1 collective antenna socket in the 2 nd bedroom (for parents)
	1 kitchen	1 SA lighting spot on the ceiling 1 0.60 light tube with T-positive socket above the kitchen garden 2 sockets with ground connection (P+T) at 1.60m above ground level.
	Toilet	1 SA lighting spot

Table 3. Carpentry equipment, technical and sewage disposal ducts of the house

Equipment	Description
Carpentry	Carpentry works must be done with good quality materials according to the rule book; measures for perfect adjustments and setting up must be respected to the letter. In any case, the choice of the type of materials must be justified technically (resistance, behaviour, durability, water-proofness, thermal and acoustic performances) and financially. Entry doors of the houses must also obey to safety and anti-intrusion requirements by the type of materials used, the sealing method and the shutting system. In short, carpentry works must be carried out according to international rules and norms relating to the type of the proposed carpentry works.
Technical ducts	Four technical ducts must be provided for and put in place according to norms in force ; they will host electrical installations for power, telephone and TV supply
Sewage disposal system	Separate plumbing piping must be provided for waste sewage, sewage water and rainwater. They could end into a single main sewer, especially in the case of a combined system. Rainwater will be drained through appropriate piping; we should avoid direct draining over front walls or other method that could contribute to their rapid degradation.

a) Estimates

Table 4. Estimates

WORKS DESCRIPTION	UNIT	QUANTITY
Work site installation		
Work site installation and clearing	FF	
Subtotal 1.00		
Draining and disposal of rainwater		
Putting in place of reinforced or prefabricated manholes	u	1
Subtotal 2.00		
Sanitation EU-EV		
Construction of manholes EU-EV	u	3
125 PVC piping network	ml	1.5
Construction of water treatment and sanitation systems EU-EV (fosse septique et puisard)	Ens	1
Subtotal 3.00		
Establishment – Foundations		
Pit excavations	m ³	11.38
Trench excavations	m ³	29.5
Paved compacted backfills	m ³	25.16
Excavation backfills	m ³	4.84
Oversite concrete at a dosage of 150kg/m ³	m ³	2.7
Concrete for pillar and long beam shoes at a dosage of 300kg/m ³	m ³	3.5
Concrete blocks for basement wall	m ²	30
RC foundation wall tie at a dosage of 350kg/m ³	m ³	3
Subtotal 4.00		
Bricklaying		
Hollow concrete blocks of 15x20x40	m ²	203
Reinforced concrete for pillars, lintels and upper wall ties	m ³	11.5
Cement mortar coating	m ²	405
Bushhammered cement topping	m ²	110
Flagstone paving at a dosage of 300kg/m ³ over a sandy bed	m ²	94
Subtotal 5.00		
FRAMEWORK – ROOFING		
Wooden trusses 3*15	m ³	2
Wooden purlins (4*8)	m ³	1.5
Roofing aluminum sheets 6/10	m ²	99.69
Fascia boards protected with sheets of 7/10	m ³	120
PVC rainwater gutters, including hooks and others accessories	ml	19.81
Downspouts, including holders	ml	29.38
Dropped ceiling, including joisting	m ²	110
Subtotal 6.00		
Carpentry - Wood		
Supply and installation of complete solid doors of de 0.85 x 2.10	U	7
Supply and installation of complete thermal-reakdoor of of 0.65x2.10	U	2
of 0.02x0.6x2.10	U	1
Supply and installation of glass sash window frames	U	7
Supply and installation of complete cupboards, including all room implements (240x220)	U	4.69
Supply and installation under-counter cupboards	U	1
Subtotal 7.00		
Metal joinery NACO & glazing		
10 mm-Wrought iron security grids	U	7
Pairs of 8-balde NACO sashes	U	8
Of 5 blades	U	3
1.2m clear NACO blade	U	66
Of 0.6m	U	19.06
Subtotal 8.00		
Electricity		
Straps	U	1
Distribution box	U	1
S.A. Switch	U	7

Three-way switches	U	7
Double S.A switches	U	7
Double three-way switches	U	7
Push buttons	U	7
Light tubes	U	15
Bulbs	U	6
Simple windows	U	3
Installation	FF	
Subtotal 9.00		
Plumbing		
Cold water PVC pressure supply pipe 20/27	ml	16.88
Cold water PVC pressure supply pipe 15/27	ml	26.25
Hot water copper supply pipe	ml	18.13
PVC Æ 63 waste pipe	ml	27.19
PVC Æ 100 waste pipe	ml	11.25
Supply and installation of a complete washstand, including valves and fittings et vidage	U	2.81
Supply and installation of a WC low-end flushing tank accessoires compris	U	2.81
Supply and installation of a complete Bidet, including fittings and waste outlet	U	
Supply and installation of a ground bathroom floor drain compris	U	2.44
Supply and installation of a stainless two-compartment sink including fittings and waste outlet	U	1
Supply and installation of a complete shower stack, including fittings and waste outlet	U	2.44
Supply and installation of a bathroom shelf	U	2.81
Supply and installation of a soap holder	U	2.81
Supply and installation of a toilet paper dispenser	U	2.81
Supply and installation of a 60x40 bathroom mirror	U	2.81
Supply and installation of a two-layer towel bar	U	2.44
Supply and installation of a ground floor drain	U	2.44
Supply and installation of a single compartment laundry tub	U	1
Supply and installation of a faucet	U	1
Subtotal 10.00		
Wall facing and flooring		
Stoneware tiles for living room and dining room	m ²	25
2X2 Stoneware tiles in toilet floorings and W.C	m ²	9,38
Éaïence tiles of 15X15 on toilet and W.C walls and at 0.45 cm above the sink of the kitchen's work top	m ²	11.25
Subtotal 11.00		
Paintings		
Vinyl paint on outer walls, including all main spaces	m ²	187,5
Vinyl paint on inner walls, ceilings and subfloors, including main spaces	m ²	490,63
Glycerophthalic paint on woodworks, metallic joinery, kitchen and wash-up rooms and adjoining areas	m ²	35,94
Cellulosic lacquer on all woodworks and adjoining areas comprises	m ²	4,53
Subtotal 12.00		

Hypotheses and elements of the study

In order to apply the LCA on social lodging, we need to set down some hypotheses and we must have some elements.

Hypotheses

H1: General environmental impacts indicators obtained at the end of the building's life cycle are assessed following the steps described below.

Data presented, taking into consideration the extraction of the raw materials and the production of materials that are manufactured or not; then impacts resulting from the following processes are added:

- Transportation of manufactured parts to the building site;
- Energy and carbon dioxide produced during the manual phase of the use of the building's components ;
- Impact indicators throughout the use of the building (lighting, specific electricity);
- Environmental impact of maintenance and improvement materials;
- Environmental impacts of the destruction of the house ;
- However, it should be noted that the value of environmental impacts during the production of building materials (trucks, wheelbarrows, scoops, vibrators, etc.) were not taken into account.

H2: It is considered that environmental impacts of the building's components are constant over the time.

H3: Processes and factor excluded. In a deconcentrated effort of architectural systems that directly impact the use of energy and the overall heating potential of the low-cost house, some components of a low-cost house and some external factors were not listed. Below is a list of some questions that were not included in the study:

- The location, since it deals with impacts on local ecosystems, personal questions on transportation, and urban issues on planning (including sewage and road infrastructures) ;
- The house surroundings (for instance footpath concrete, developments, draining)
- Furniture (kitchen and bathroom boxes, etc.);
- TV and telephone connections (external and internal systems, including wiring and fire alarm) ;
- Behavioral models of inhabitants ; this involves food consumption, leisure equipment, clothing, furniture, the supply of pet animals, cleaning products or other articles that require no energy for the operation;
- Other environmental impacts happening in the whole life cycle;
- Environmental and social impacts related to the origin of building materials;
- Upcoming technological developments that significantly reduce energy consumption and the cost of household appliances;

H4: Materials supply sites remain the same throughout the life cycle.

H5: For an overall appraisal of our building, it is supposed that the price of materials would slightly increase in the long run.

Elements of the study

We have established a correlation between the HNPS and the EQUER software in order to fill the indicator deficit of the HNPS. Of course, we carried out a compatibility operation on our various indicators so that our study should not be distorted.

Transportation of materials

- Supply of materials manufactured in Douala ;
- Gravel supply site: Razel quarry situated at Nkometou.

Table 5. Transportation of materials (ELIME, 2012)

Materials	Equipment	Energy consumed (MJ/t.km)	Distance (km)
Sand	20t truck	1.1	72
Gravel	20t truck	1.1	31
Hardware store materials (cement, steel...)	16t truck	1.1	203.5

The power of the 16t truck remains equal to that of the 20t truck to take the vehicle's energy consumption in Cameroon into account, due to their age.

Table 6. Unit power consumption for the production of basic constituents and basic tasks needed for the building (ELIME *et al.*, 2009)

Designation	Unit power consumption
Steel	26355.00MJ/t
PVC	9 240.00MJ/t
Cement	5 473.6MJ/t
Lime	10164.00MJ/t
Asphalt	5 390.00MJ/t
Geotextile	96.56MJ/m ²
Asphalt emulsion 60%	3 839.00MJ/t
Crushed aggregates	44.00MJ/t
Rolled aggregates	33.00MJ/t
Fuel	36.00MJ/t
Deforestation. cleaning and clearing off of the land acquired	18.56KMJ/m ²
Clearing of light materials	13.80MJ/m ³
Clearing of rock materials	38.4MJ/m ³
Storage of cleared materials	6.72MJ/m ³
Compacting the backfill	6.04MJ/m ³
Transportation with trucks	luluMJ/txkm
Transportation by sea	300.00MJ/tour
Hot coating production station	302.50MJ/t
Lukeworm coating production station	25 7.40MJ/t
Cold production station (concrete)	15.40MJ/t
Water station	10 00MJ/t
Clearing of shoulders	1.6MJ/T
Platform reshaping over 10cm	6.72MJ/m ³
Reshaping with mixing	33.67MJ/m ³
Reinforced concrete lining by m ³ of concrete	6.13MJ/m ³
Reinforcement	3.25MJ/T
Steel tube guard rails	253.5MJ/ml
Geotextile works	3.12MJ/m ²
Construction of guard rails	6.05MJ/Mml

Power sources used utilisées

Table 7. Power source

Indicator	Unit	Electricity hydro per MJ of production	Cooking gas	Fuel per T produced
Energy (MJ)	MJ	1.299	1.558	36
Water	kg	0.02481	0.1036	6.032052117
Resources	10 ⁻⁰⁹	7.7E-18	4.389E-16	8.94723E-15
Waste	Teq	0.0058	0.006819	0.105302932
Radioactive waste	dm ³	0.000000034	0.00000052	0.000140717
GWP100	kgC02	0.00117	0.08395	2.352312704
Acidification	kgS02	0.000006	0.000099	0.005159609
Eutrophization	kgPO ₄ ³⁻	0.00000058	0.000011	0.000328339
Ecotoxicity	m ³	0.04933	0.3737	67.89576547
Human toxicity	kg	7.686	0.00013	0.007035831
03-smog	kg	0.0000036	0.000084	0.004221498
Odours	m ³	7.686	159.3	463.8957655

Constituants de bases

Table 8. Indicateurs des constituants de base et transport

Indicators	Unit	Reinforcement steel (T)	Galvanized steel sheets (T)	PVC (T)	Cement (T)	Lime (T)	Sand (T)	Crushed aggregates (T)	Rolled aggregate s (T)	Transportation per ton per km (T)	Water station (T)	Wood for development (T)	Iron door (T)	Tilings (T)	Paint (T)
Energy(MJ)	MJ	26355.000	70380.000	9240.0	5473.600	10164.00	33.000	44.000	33.000	1.100	10.000	6545.000	1.7E+05	8110.000	24089.400
Water	kg	15537.600	3.4E+05	6584.2	3263.180	7463.220	18.453	91.845	23.690	0.487	389.575	664.950	1.0E+05	3100.000	20746.800
Resources	10 ⁻⁰⁹	3.69E-12	4.26E-10	0.0	9.30E-13	3.22E-12	5.00E+00	2.56E-14	9.38E-15	4.33E-16	6.72E-15	2.18E-13	2.41E-13	2.24E-12	3.07E-10
Waste	Teq	0.972	1.301	0.0	2.544	0.000	1392.830	0.192	0.000	0.034	0.003	29.150	2979.900	190.000	110.700
Radioactive waste	dm ³	0.030	0.041	0.0	0.008	0.0E+00	0.064	0.001	0.0E+00	4.1E-06	3.2E-05	0.007	0.126	0.047	0.046
GWP100	kgC02	1277.370	3880.000	273.6	955.506	1216.979	1.857	8.086	1.788	0.067	0.003	-455.217	8421.233	360.000	675.000
Acidification	kgS02	3.242	20.890	2.0	2.361	3.141	0.006	0.028	0.021	0.001	0.000	0.079	21.047	1.000	4.320
Eutrophization	kgPO ₄ ³⁻	0.341	1.359	0.1	0.279	0.362	0.001	0.005	0.003	0.000	0.000	0.013	2.233	0.140	0.221
Ecotoxicity	m ³	0.166	3.3E+05	14895.3	0.014	17859.96	0.000	0.000	54.417	2.191	0.675	0.001	1.078	0.003	19134.900
Human toxicity	kg	46.232	53.200	3.1	6.385	4.059	0.014	0.063	0.026	0.001	0.045	0.770	191.730	2.100	17.820
03-smog	kg	0.419	8.258	0.8	0.102	2.632	0.002	0.009	0.021	0.001	0.000	0.018	2.823	0.071	1.512
Odours	m ³	0.000	6.6E+07	3.9E+05	0.000	1.7E+06	0.000	0.000	3128.850	77082.000	28.996	0.00E+00	7.70E-04	0.00E+00	1.8E+06

Table 9. Récapitulatifs des indicateurs de fabrication des mélanges pour 1 m³

	Unit	Mortar for coating (dosage at 300kg/m ³)	Mortar for briquettes (dosage at 300kg/m ³)	Concrete at a dosage of 300 for pavement base	Reinforced concrete at a dosage of 350 for longitudinal beam pillars	Oversite concrete at a dosage of 150kg/m ³
Indicators		Density 2395 (kg/ m ³)	Density 2245 (kg/m ³)	Density 2580 (kg/ m ³)	Density 2720.2 (kg/ m ³)	Density 2505 (kg/ m ³)
		Indicators related to production	Indicators related to production	Indicators related to production	Indicators related to production	Indicators related to production
Energy	MJ	1744.073	1735.388	1768.127	3105.06208	950.337
Water	Kg	1082.559041	1070.513065	1170.982885	1972.623717	664.292142
Resources	10 ⁻⁰⁹	9.607245283	8.981773585	4.128113206	4.003018868	4.553433962
Waste	Teq	2674.997715	2500.893867	1150.1001014	1115.455297	4.553433962
Radioactive waste	dm ³	0.12554079	0.117521114	0.055979418	0.056016007	0.060273789
GWP100	kgCO ₂	292.8515671	292.4544076	301.6139902	401.2517281	158.767475
Acidification	kgSO ₂	0.720745445	0.719942734	0.749917848	0.99953794	0.397631405
Eutrophization	kgPO ₄ ³⁻	0.086000569	0.085859004	0.090972114	0.118866464	0.049391979
Ecotoxicity	m ³	0.122308268	0.105426045	0.10239312	0.126577522	0.059756299
Human toxicity	m ³	1.950416141	1.947527583	2.016359405	4.198039263	1.06033054
O3 – smog	kg	0.034615889	0.034356165	0.043757584	0.066092981	0.029054502
Odours	m ³	5.07431939	4.34941664	4.204436107	4.929343145	2.464669438

Data on the building site's processes**Table 10. Building processes given by the 2008 HNSP**

Work site process	Unit	Energy
Loose materials	MJ/m ³	13.8
Cold production site (concrete)	MJ/t	15.4
Reinforced concrete formwork by m ³ of concrete	MJ/m ³	6.13
Reinforcement	MJ/t	3.25

Table 11. Energetical formulas

Symbol	Name	Formulas
Ea	Energy spent for physical activity per hour	$E_T = E_a * GWP_0 * T * N$
EO	Energy during inactive period and per hour	
GWP100	CO2 releases by an individual per hour and in terms of physical activity	$E_T = E_a * GWP_0 * T * N / E_0$
GWP ₀	CO2 released by an idle person and per hour	
T	temps de travail en heure	
N	Number of persons carrying out a given task	

Table 12. Energy and GWP100 indicators for some work site processes

Work site process	Unit	Energy per person (kcal)	Number of persons	Working time (H)	Energy in MJ	CO2 released in kg
Trenching of soft soil laid at 20m	m ³	400	2	4.1	13.8	0.83350588
Cold production station (concrete)	t	400	2	4.6	15.4	0.93515294
Reinforced concrete lining per m ³ of concrete	m ³	275	2	2.67	6.13	0.37037647
Reinforcement and Long beam pillars ...	t	200	1	3.88	3.25	0.19719529

Table 43. Energy for the manual use of project's materials

Implementation energy within the project's context						
Unité	Number of persons	Time in Hours	Energy (Kcal) per person and per hour	Energy (MJ/ m ²)	Thickness (mm)	Overall energy (MJ)
Mortar for coating	m ³	1	24	120		12.0384
Chipboards	T	1	5	140		2.926
Wood and framework	m ³	2	16	140		18.7264
Energy for the use of some building materials within the framework of the project						
Unit	Number of persons	Time in Hours	Energy (Kcal) per person and per hour	Energy (MJ/ m ²)	Thickness (mm)	Overall energy (MJ)
Roofing	m ²	2	0.2	150	0.2508	836
Paint	m ²	1	0.15	130	0.08151	271.7
Doors	m ²	1	0.1	135	0.05643	1.881
WC/toilet tiles	m ²	1	0.6	100	0.2508	62.7

Table 54. Complementary data per kg of constitutive material

Indicator	Unit	Adobe	Raw compressed earth blocks	Cinderblock (dosage 300kg/m ³)
AR	MJ	0.002745	0.002521	0.76506
Water	kg	0.00015	5.89E-05	0.46544
Resources	10 ⁻⁰⁹	0	0	0.00391
Waste	Teq	0	0	1.08735
Radioactive waste	dm ³	0	0	0.00005
GWP100	kgCO ₂	0.04565	0.042	0.12764
Acidification	kgSO ₂	0	0	0.00031
Eutrophization	kgPO ₄ ³⁻	0	0	0.00004
Ecotoxicity	m ³	0	0	0.00005
Human toxicity	kg	0	0	0.00085
O3-smog	kg	0	0	0.00001
Odours	m ³	0	0	0.00189

Table 75. Some features of the two buildings

Designation	Urban area
Water supply	CDE
Lighting and household equipment power supply	Electricity
Plumbing equipment	Complete
Equipment network for power use	Finished electrical
waste liquid solid	Septic tanks HYSACAM company

RESULTS

Given:

E: raw materials extraction indicator; *F*: indicator for the production of materials; *T*: transportation indicator; and finally, *M*: indicator for the putting in place of the building site; *I*: being the environmental impact indicator. We have therefore:

$$I = E + F + M + T$$

Tableau 6. Environmental impact indicators during construction phase

Indicator	Unit	Béton de propreté	Mortar	Concrete blocks	Concrete	Reinforced concrete	Framework	Alu iron sheets	Woodend door and window frames	Iron door	Tiles	Paint	TOTAL
Energy	MJ	5126.612	10173.0195	13883.1784	18505.4889	19866.4081	60192.6236	49.1610806	115.502852	2415.105	21.9779478	4840.251	135189.328
Water	kg	3103.001	6071.18166	8841.67966	11864.8294	12356.1092	6106.79624	21.94172	11.7392042	1418.004	8.62985595	4168.60435	53972.5163
Resources	10 ⁻⁰⁹	9.4337E-13	1.9354E-12	2.7991E-12	3.6787E-12	3.5474E-12	2.001E-12	1.9295E-14	3.8935E-15	3.3558E-15	7.68E-15	6.1683E-11	7.6622E-11
Waste	Teq	7220445.677007	13772341.6	8043643.98	10916365.1	6685626.38	267.738675	1.56159122	0.51650882	41.4477	0.56790116	22.242902	46638756.8
Radioactiv	dm ³	0.34047644	0.65070569	0.39726874	0.5380221	0.34046447	0.06566129	0.00021607	0.00012603	0.0017493	7.3134E-05	0.0092226	2.34398586
GWP100	kgCO ₂	814.925	1575.39481	2198.37311	2964.9696	2477.6091	-4179.53126	2.95768187	-7.96608246	117.1317	1.18603122	135.626498	6100.67545
Acidification	kgSO ₂	2.217	4.45659223	6.21599842	8.23451138	6.77730458	0.72584867	0.03142082	0.00150981	0.29274	0.01278235	0.86801181	29.8335023
Eutrophization	kgPO ₄ ³⁻	0.27552467	0.56206344	0.79145656	1.04188178	0.83801109	0.12152245	0.00501987	0.00025185	0.031059	0.00204443	0.04448619	3.71332133
Ecotoxicity	m ³	818.054337	2249.78451	2919.76822	3354.05343	2356.59181	6.09237596	94.4126156	0.38724589	0.014994	38.4893754	3844.74218	15682.3911
Human	kg	5.60187785	10.9681371	15.313067	20.5321762	26.155531	7.07249902	0.03933776	0.0136536	2.66679	0.01588238	3.58053311	91.9594849
O3-smog	kg	0.38589404	0.98260527	1.35020245	1.61481222	1.23904098	0.16714323	0.03378227	0.00045336	0.03927	0.01376708	0.30380808	6.13077897
Odours	m ³	28801.9215	79208.2915	102795.524	118086.169	82967.3557	214.270567	3323.82423	13.6326997	0.00001071	1355.02993	366950.281	783716.299

Table 17. Environmental impact indicators during the exploitation phase

Indicator	unit	Electricity		Water			Cooking gas			Wooden equipment, furniture.			Exploitation overall indicator			
		indicator per TD of production	Overall consumption in TD	Overall indicator	indicator by T of production	Consumption during the life cycle	Overall indicator	Transport par bouteille	Indicator in number of 13 kg bottles	Number of bottles during life cycle	Overall indicator	Transportation		indicator in TD of production	Overall quantity	Overall indicator
Energy	MJ	1.299	279936	363636.9	10	4320	43200	0.0143	1003.97	600	602393.7	0.605	357	2.9988	1072.3859	1010302.95
Water	kg	0.02481		6945.212	389.5749		1682963.6	0.006301	66.75984		40059.685	0.266583	36.27		109.56591	1730078.031
Resources	10 ⁻⁰⁹	7.7E-18		2.16E-12	6.72E-15		2.902E-11	5.62E-18	2.83E-13		1.697E-10	2.38E-16	1.19E-14		3.634E-14	2E-10
Waste	T eq	0.0058		1623.629	0.002973		12.84323	0.000415	4.394164		2636.7472	0.017559	1.59		4.820749	4278.039963
Radioactive waste	dm ³	3.4E-08		0.009518	3.24E-05		0.1397744	5.28E-08	0.000335		0.2010845	2.23E-06	0.00039		0.0011762	0.351552929
GWP100	kgCO2	0.0011		327.52	0.003359		14.511182	0.000868	54.097		32458.949	0.036715	-24.83		-74.3501	32726.634
Acidification	kgSO2	6E-06		1.679616	3.29E-05		0.1422763	9.43E-06	0.063796		38.28302	0.000399	0.0043		0.0140916	40.11900353
Eutrophization	kgPO ₄ ³⁻	5.8E-08		0.016236	2.19E-06		0.009474	1.51E-06	0.007088		4.2539455	6.39E-05	0.00072		0.0023506	4.282006412
Ecotoxicity	m ³	0.04933		13809.24	0.675289		2917.248	0.028487	240.8123		144504.46	1.205211	0.000036		3.6142949	161234.5653
Human toxicity	kg	7.686		2151588	0.044788		193.48243	1.17E-05	0.083772		50.270218	0.000495	0.042		0.1274336	2151831.976
O3-smog	kg	3.6E-06		1.00777	1.16E-05		0.0502054	1.02E-05	0.05413		32.483872	0.000431	0.00098		0.0042313	33.54607867
Odours	m ³	7.686		2151588	28.9961		125263	1.00288	102652		61592354	42.42982	0		127.2385	63869332

Table 18. Indicateurs d'impacts sur l'environnement en phase d'entretien

Indicator	Unit	Wall (bricklaying and coating)	Paint	Sheets for roofing	Wooden door	Iron door	Floor covering	Toilet and WC equipment	Total
Power	MJ	2672.91088	43562.259	49.1610806	269.506654	1610.07	4675.07088	73.7726449	52912.7511
Water	kg	1656.98459	37517.4391	21.94172	27.3914764	945.336	2997.43059	27.3278772	43193.8514
Resources	10 ⁻⁰	5.2606E-13	5.5514E-10	1.9295E-14	9.0848E-15	2.2372E-15	9.2936E-13	2.432E-14	5.5665E-10
Waste	T eq	2423998.4	200.186118	1.56159122	1.20518726	27.6318	2757818.55	1.79835366	5182049.33
Radioactive waste	dm ³	0.1164416	0.08300338	0.00021607	0.00029406	0.0011662	0.13592137	0.00023159	0.33727429
GWP100	kgC	419.307547	1220.63848	2.95768187	-18.5875257	78.0878	749.044952	3.75576552	2455.2047
Acidification	kgS	1.18584341	7.81210627	0.03142082	0.0035229	0.19516	2.08029761	0.04047743	11.3488284
Eutrophization	kgP	0.15039111	0.40037574	0.00501987	0.00058765	0.020706	0.26321224	0.00647401	0.84676662
Ecotoxicity	m ³	574.394748	34602.6796	94.4126156	0.90357374	0.009996	847.339813	121.883022	36241.6234
Human toxicity	kg	2.92013378	32.224798	0.03933776	0.03185839	1.77786	5.18707609	0.05029419	42.2313582
O3-smog	kg	0.25920086	2.73427273	0.03378227	0.00105783	0.02618	0.40795256	0.04359574	3.50604198
Odours	m ³	20222.6461	3302552.53	3323.82423	31.8096325	0.00000714	29832.2952	4290.92811	3360254.03

Table 19. Impact indicators during the destruction phase

Indicator	Unit	Excavator for destruction		Truck for transportation			Overall destruction Indicator
		Indicator by tons of aggregates	Transportation in tons per km	Quantity of aggregates to transport in tons	Distance (km)		
Power	MJ	16	1.1	97	5	2085.5	
Water	kg	7.050131926	0.48469657			683.8628	
Resources	10 ⁻⁰⁹	6.29024E-15	4.32454E-16			6.102E-13	
Waste	T eq	0.464379947	0.031926121			45.044855	
Radioactive waste	dm ³	5.910E-05	4.062E-06			0.00573	
GWP100	kgCO2	0.970976	0.0667517			94.1846	
Acidification	kgSO2	0.01055	0.0007255			1.0237	
Eutrophization	kgPO ₄ ³⁻	0.001688	0.000116			0.16379	
Ecotoxicity	m ³	31.87335	2.191292			3091.715	
Human toxicity	kg	0.0130870	0.000899			1.2694	
O3-smog	kg	0.011398	0.0007836			1.10564	
Odours	m ³	1122.1108	77.1451			108844.7	

Table 20. Summary of environmental impacts of the various phases of the life cycle of the urban L.C. H.

	Unit	Construction	Exploitation	Maintenance	Destruction	Total
Water	kg	53972.5163	1730078.03	43193.8514	918.940633	1828163.34
Resources	10 ⁻⁰⁹	7.6622E-11	2.0091E-10	5.5665E-10	8.1989E-13	8.3501E-10
Waste	Teq	46638756.8	4278.03996	5182049.33	60.5290237	51825144.7
Radioactive waste	dm ³	2.34398586	0.35155293	0.33727429	0.00770369	3.04051677
GWP100	kgCO2	6100.67545	32726.6349	2455.2047	126.560686	41409.0757
Acidification	kgSO2	29.8335023	40.1190035	11.3488284	1.37565963	82.6769939
Eutrophization	kgPO ₄ ³⁻	3.71332133	4.28200641	0.84676662	0.22010554	9.0621999
Ecotoxicity	m ³	15682.3911	161234.565	36241.6234	4154.49208	217313.072
Human toxicity	kg	91.9594849	2151831.98	42.2313582	1.70581794	2151967.87
O ₃ -smog	kg	6.13077897	33.5460787	3.50604198	1.4857124	44.668612
Odours	m ³	783716.299	63869332.3	3360254.03	146260.132	68159562.7

The diagram above shows that the exploitation phase is the most important for all indicators, except for two indicators: waste and radioactive waste. This situation is due to the fact that liquid and solid wastes produced by users are not taken into account. Thus, these two indicators are two outlier points of the study.

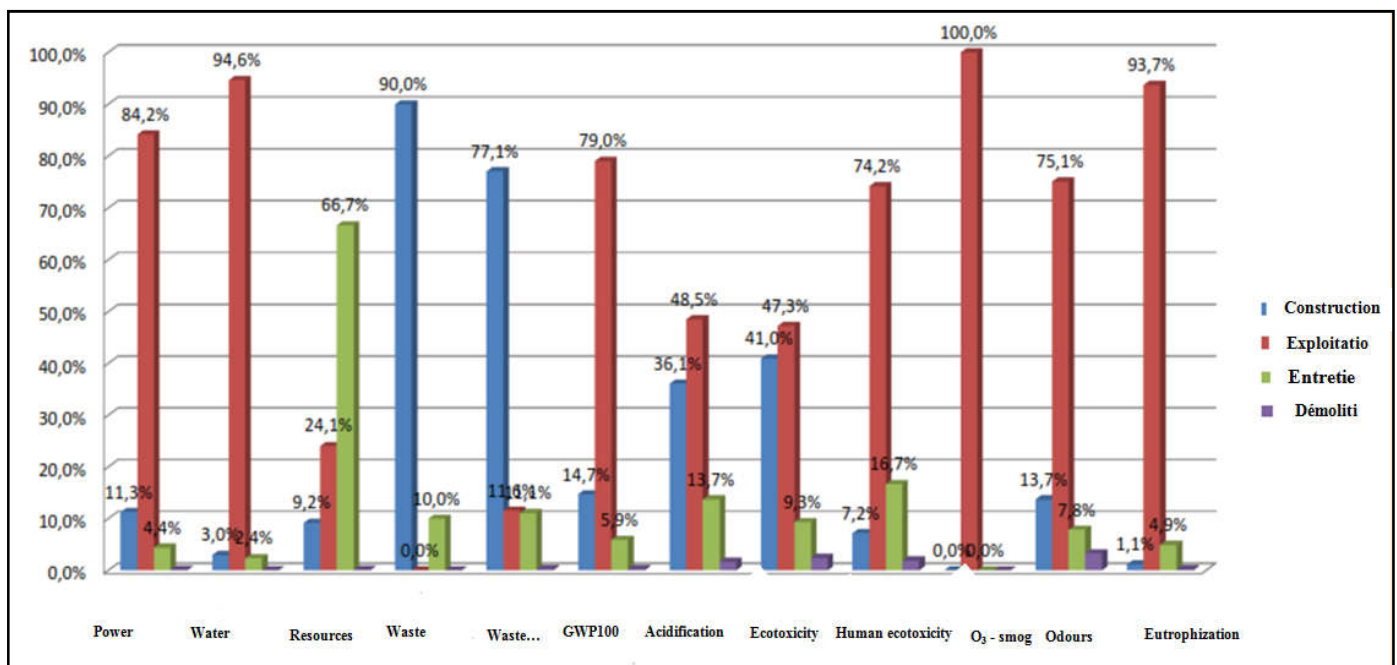


Figure 4. Impact indicators of urban low-cost housing

Of the twelve indicators under study, two have the most exploited results of the study within the framework of LCA applied to the building. These are power and overall heating potential (**GWP₁₀₀**). The power indicator mainly deals with:

- Any power taken from nature to produce building materials;
- The production of power such as electricity. household gas (grey power);
- Exploitation power (electricity AES-SONEL);
- Production power and power used to pump water into houses.

Flow assessment

Water and electricity consumption

Table 21.. Water and electricity consumption

	Unit	Number of persons	Daily consumption per inhabitant	Monthly consumption of the household	Maintenance
Electricity	KWH	6	0.5944	107	0
Water	m ³	6	0.06	10.8	780

Gas and soap consumption

Table 22. Consommation du gaz domestique et du savon de ménage

	Unit	Number of persons	Monthly consumption of the household
Domestic gas	L	6	26.5
Household soap	300g cube	6	12

Use of the urban house

Table 23. Use of the urban house

State employee	Number	Number of years	Frequency of replacements during the life cycle
Electrical bulb	8	1.16	43.10344
Electric installation repairs électrique	1	20	1.5
Wooden furniture	1	25	2
Wooden bed for bedroom	3	15	3.34
Conboard repairs	4	15	2.34

Maintenance of the urban house

Table 24. Maintenance of the social house

State employee	Number or quantity	Usage duration	Frequency of replacement
Walls		45	0.11
Inner paintings		5	9
Outer paintings		5	9
toiture		25	1
Emntving the sentic tank		7	6.15
Plumbing rehabilitation		5	9
Equipping of toilets		10	4
Floor covering		25	1
Windows repairs	7	35	0.42
Wooden doors	5	25	1
Iron outer door	2	35	0.42

RESULTS ANALYSIS

Impact study

Here is the list of the twelve environmental impact indicators of the two houses according their various life cycle phases.

		Construction	Exploitation	Maintenance	Destruction
	Unit	Urban low-cost house en ville	Urban low-cost house	Urban low-cost house	Urban low-cost house
Energy	GJ	135.19	1010.30	52.91	2.09
Water	kg	53972.52	1730078.03	43193.85	918.94
Resources	10 ⁻⁰⁹	7.66E-11	2.01E-10	5.57E-10	8.20E-13
Water	Tea	46638756.81	4278.04	5182049.33	60.53
Radioactive waste	dm ³	2.34	0.35	0.34	0.01
GWP100	kgCO ₂	6100.68	32726.63	2455.20	126.56
Acidification	kgSO ₂	29.83	40.12	11.35	1.38
Eutrophization	kgPO ₄ ³⁻	3.71	4.28	0.85	0.22
Ecotoxicity	m ³	15682.39	161234.57	36241.62	4154.49
Human toxicity	kg	91.96	2151.98	42.23	1.71
O3-smog	kg	6.13	33.55	3.51	1.49
Odours	m ³	783716.30	63869332.26	3360254.03	146260.13

Of the twelve environmental impact indicators examined, it appears that:

- The destruction phase is the one that has the smallest number of environmental impacts while the exploitation phase has the higher number (9/12) and the most important ones. This could be explained by the high speed and the precision with which destruction is generally carried out; conversely, exploitation takes more time.
- For the water consumption indicator, the urban house has a high consumption rate. This is due to the fact that water supply in town (CDE) is done with many losses.
- For consumption indicators of: *Waste, Radioactive waste and odours*, the construction phase features the highest number of indicators.

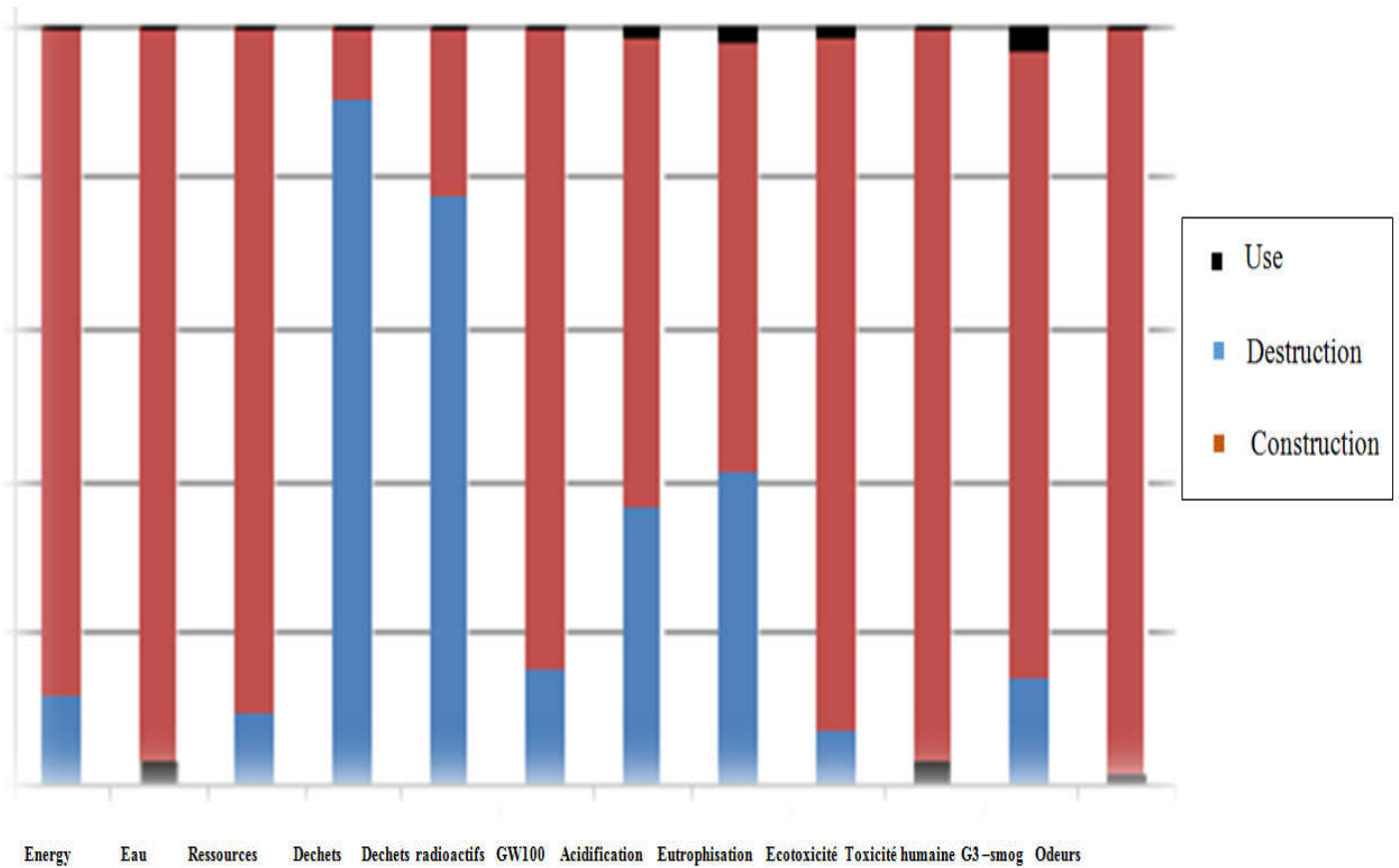


Figure 5. Share of impacts for various phases of urban low-cost housing

Balance sheet and Interpretation of the life cycle of LCH

The results of the LCA of the building constructed up till now apply to all environmental aspects: raw materials and power consumption; waste; greenhouse-effect gas; acidification; eutrophization; Ecotoxicity; human ecotoxicity and odours; power consumption; impact on the climatic change called GWP100 are impacts that could be well directly appraised by users of the buildings.

Of the twelve indicators, except the two on waste (because waste produced by users of the building were not taken into account) ; the contribution of the use phase (exploitation and maintenance) of the building is very preoccupying as illustrated by the following table.

Table 25. Percentage of environmental impacts of various phases of the buildings' life cycle

	Utilization	Construction	Destruction
Urban house	86%	13%	1%

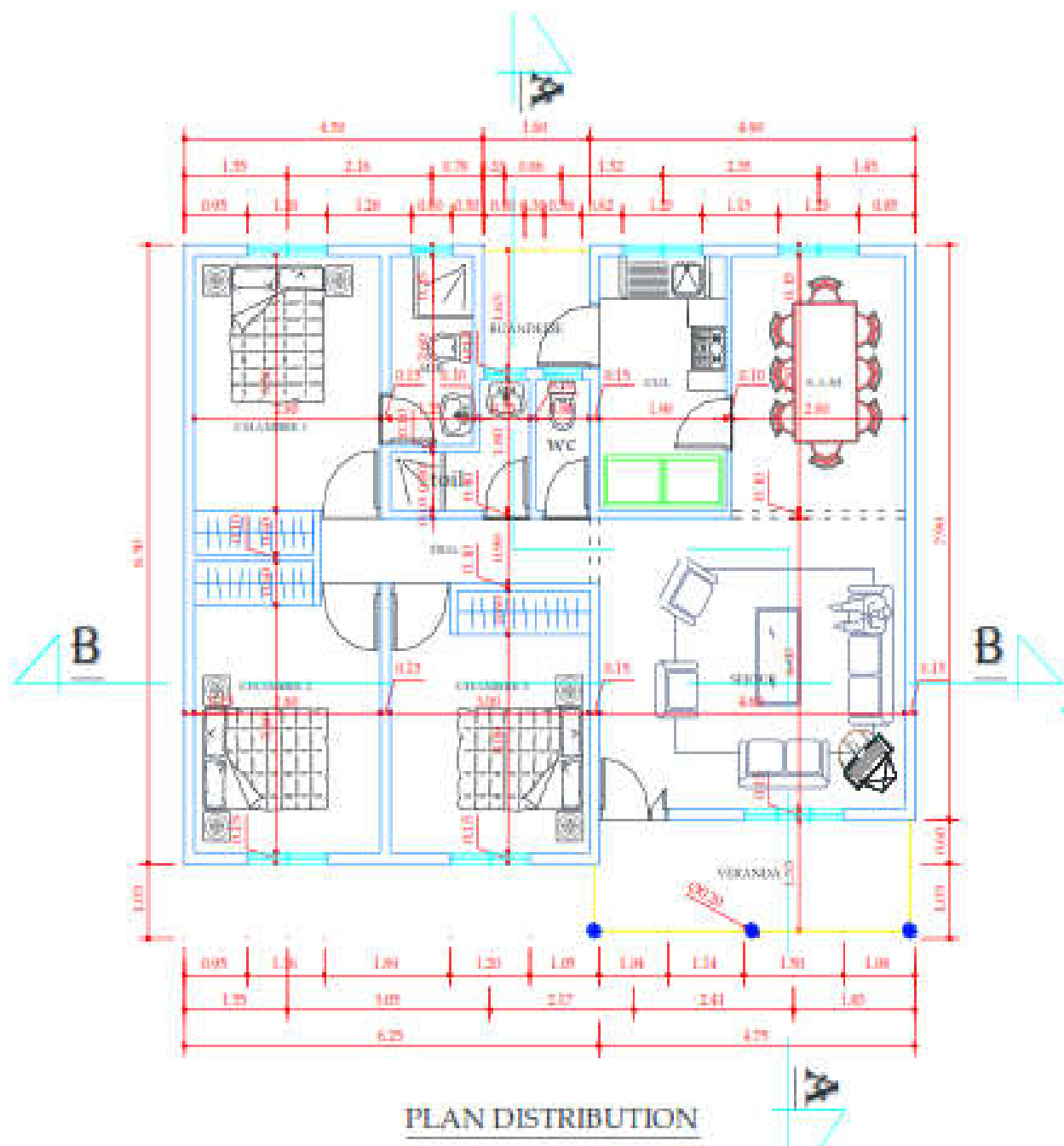
As concerns the twelve indicators, except the two waste indicators. the percentage of the utilization phase is overwhelming for the two houses.

Conclusion

At the end of our study, the issue was applying life cycle analysis (LCA) to a « T4 single-storey » urban low-cost house. To that end, we had a database set up by the HNPS in 2008; using the database from Switzerland. We completed the data missing in the 2008 HNPS database. On the basis of these data, we applied the LCA to a low-cost house and to that effect. We used the twelve impact indicators for a complete implementation of the LCA.

The methodology used for the LCA of our building involved quantifying materials and components, and then the substances taken and released from and into the environment, taking into consideration inventories mainly provided by the 2008 HNPS database, the ECOINVENT database from the EQUER software and field analyses. Results provided by our sample low-cost house reveal that the basis of utilization (exploitation and maintenance) is the most preoccupying at the level of environmental impacts, which reach their highest point during this phase and represent 86% of the life cycle's overall impacts.

Annexes



Annex 1. Architectural Aspect: the model chosen is of type T4

REFERENCES

- ABDO JOSEPH, 2011. *Analyse du cycle de vie des structures routières. 69P. cycle de vie pour l'efficacité énergétique des bâtiments/*
- ADEME, 2005. *Introduction à l'analyse de cycle de vie. 14P.*
- ADEME, 2009. *Étude d'une méthode simplifiée pour la réalisation des ACV des bioproduits. France. 32P.*
- CITEPA, 2009. *Inventaire des émissions des polluants atmosphériques en France séries sectorielles et analyse étendues SECTEN rapport d'inventaire national. 306P.*
- COIMBA 2011. *Développement des outils d'évaluation de la qualité environnementale des bâtiments par l'analyse du cycle de vie. 244P.*
- CSTB, 2011. *Évaluation de la performance environnementale des bâtiments. Définition d'ordre de grandeur. traitement statistique. Université de paris est. 166P.*
- ELIME BOUBOAMA, MAMBA MPELE, TAMO TATIETSE, 2009. *L'ACV appliquée à l'évaluation énergétique d'une route: outil d'aide à la décision. Ecole nationale supérieur polytechnique. Cameroun. 429-467P.*
- ELIME BOUBOAMA A, 2012. *Élaboration d'un indicateur d'analyse du cycle de vie : application à la consommation*

- d'énergie*. thèse de doctorat. Ecole nationale supérieur polytechnique. Cameroun. 153P.
- LASVAUX SEBASTIEN, 2010. *Étude d'un modèle simplifié pour l'analyse de cycle de vie des bâtiments*. Thèse de doctorat. Ecole nationale supérieur des mines de paris. 434P.
- MBESSA MICHEL, 2005. *Traité de génie civil : matériaux* vol1. 172P.
- MESSI ALFRED, 2011. *Cours de béton armé*. Ecole nationale supérieure polytechnique. Cameroun.
- NGNIKAM E, 2006. *énergie et écodéveloppement en Cameroun*. 42P
- PEUपोर्टIER B. 2012. *EQUER : développement du noyau de calcul des Indicateurs d'impacts environnementaux* version 3.2.3.582
- PEUपोर्टIER B. 2012. *analyse du cycle de vie dans la construction*. Ecole des Mines de Paris. 10P.
- PEUपोर्टIER B. 2004. *La simulation et les nouvelles attentes liées à concept de développement durable*. Ecole des Mines de Paris. 19P.
- SALMAN ABDEL AZIZ, 2010. *Mise au point d'une base de données des rendements prévisionnels dans les travaux des bâtiments* Mémoire d'ingénieur de conception de génie civil. ENSP. 96 p.
- TROCME M., PEUपोर्टIER B, 2007. *Analyse de cycle de vie d'un bâtiment*. Ecole des Mines de Paris. centre énergie et procédé. 10P.
- WILLIAM WAMBA, 2011. *Analyse du cycle de vie d'un logement social* Mémoire d'ingénieur de conception de génie civil. ENSP. 103 P.
- ENCYCLOCOLO, 2013. *Épuisement des ressources naturelles*. http://www.encyclo-ecolo.com/Epuisement_des_ressources. (Consulté le 28 mars 2013)
- INVESTIR AU CAMEROUN, 2013. *10000 localités des zones rurales camerounaise sans électricité*. <http://www.investiraucameroun.com/energie/> (consultation le 31 juin 2013)
- MINH DU, 2013. *Programme de construction de 10.000 logements et 50.000 parcelles* <http://www.minhdu.gov.cm> (consulté le 01 juillet 2013)
- NYA JEAN *épuration des eaux usées : les leçons de l'expérience*. <http://www.cipcre.org/ecovox/eco27/actual15.htm> (consulté le 01 septembre 2013)
