Original Paper

Applying the Life Cycle Analysis in the Construction of Social Housing in Cameroon: The Case of Single-Store Houses at the Sic Residential Area in Olembe (Yaounde)

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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 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, followed by the construction phase and demolition phase.

Keywords
life cycle analysis, social housing, sustainable development, environmental impact
1. 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 program 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 Olombéneighborhood (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 matter off act, 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 analys is 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 Analys is appears to be the appropriate tool. It is in this light that this paper was drafted with the objective of applying the life cycle analys is 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 as sociated to products helps to seta order of priorities for improving and informing organizational and technical options.

1.1 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 (“from the cradle to the grave” analysis). The flow of raw materials and energies involved and produced teach step of the life cycle relisted, 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 conducing 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 areas 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.
2. Method

2.1 Defining the Objective and the Scope of the Study

2.1.1 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 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;
   - Cidification;
   - Eutrophization;
   - Co toxicity;
   - Humantoxicity;
   - O3-smog;
   - Odours.
2.1.2 Defining the Scope

The scope with 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 life span:

- Internal usable surface: 93.7m²;
- 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.

**ii. Life span**

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

**iii. 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](image-url)
vi. Flow inventory

![Figure 3. Principle for the Calculation of the Inventory](image)

2.2 Presentation and Justifications of the Building

This is a single-storey low-cost house located in the Olembén neighbor hood at an altitude of 3.9500° and 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 |
|-------------------------------------------------------------|
| Projet surface area 120m²                                    |
| Surface area used 94 m²                                     |
| Internal volume 225 m³                                      |
| Type of materials Materials made with cement               |
| Various parts of the building                               |
| 1 living room 19 à30m² (27.76) Paillasse 0.60               |
| 3 bedrooms 10 à13m²                                         |
| 1 kitchen 7m²                                               |
| 1 bathroom 3.5m²                                            |
| 1 toilet                                                   |
| 1 drier/laundrette                                         |
| Passage way Atmost 12% of the living area                   |
| 1 entry doors of the house 1.10m x 2.17m                    |
| French windows 1.04m x 2.17m-1.04m x 2.40m                   |
| Dimension of doors and                                       |
| 1.20m x 2.17m-1.20m x 2.40m                                 |
| 1.40m x 2.17m-1.40m x 2.40m                                 |
Table 2. Electrical Features of the Low-Cost House

| Various parts of the building | Description                                                                 |
|------------------------------|-----------------------------------------------------------------------------|
| 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 2nd bedroom (for parents)               |
|                              | 1 SA lighting spot on the ceiling                                           |
| 1 kitchen                    | 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                       | 1SA lighting spot                                                           |

Table 3. Carpentry Equipment, Technical And Sewage Disposal

| 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, behavior, durableness, water-proofness, the rmalandacoustical 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. Inshort, carpentry works must be carried out according to international rules and norms relating to the type of the proposed carpentry works. Four technical ducts must be provided for and put in place according to norms inforce; they will host electrical installations for power, telephone and TV supply. Separate plumbing piping must be provided for wastes ewage, sewage water and rain water. They could end into a single main sewer, especially in the case of a combined system. Rain water will be drained through appropriate piping; we should avoid direct draining over front walls or other method that could contribute to their rapid corrosion.                                                                                                                                                                                                 |

degradation.

Table 4. Estimates

| WORKS DESCRIPTION                                      | UNIT | QUANTITY |
|--------------------------------------------------------|------|----------|
| **Work site installation**                             |      |          |
| Work site installation and clearing                    | FF   |          |
| **Subtotal 1.00**                                      |      |          |
| **Draining and disposal of rain water**                |      |          |
| Putting in place of reinforced or prefabricated manholes| u    | 1        |
| **Subtotal 2.00**                                      |      |          |
| **Sanitation EU-EV**                                   |      |          |
| Construction of man holes EU-EV                        | u    | 3        |
| 125PVC piping network                                  | ml   | 1.5      |
| Construction of water treatment and sanitation systems EU-EV (skeptical pits and sumps) | Ens  | 1        |
| **Subtotal 3.00**                                      |      |          |
| **Establishment-Foundations**                          |      |          |
| Pit excavations                                        | m³   | 11.38    |
| Trench excavations                                     | m³   | 29.5     |
| Paved compacted back fills                             | m³   | 25.16    |
| Excavation back fills                                  | m³   | 4.84     |
| Oversite concrete at a dosage of 150kg/m³              | m³   | 2.7      |
| Concrete for pillar and long beams hoesata dosage of 300kg/m³ | m³   | 3.5      |
| Concrete blocks for basement wall                      | m²   | 30       |
| RC foundation wall tie at a dosage of 350kg/m³         | m³   | 3        |
| **Subtotal 4.00**                                      |      |          |
| **Bricklaying**                                        |      |          |
| Hollow concrete blocks of 15x20x40                      | m²   | 203      |
| Reinforced concrete for pillars, lintels and upper wall ties | m³   | 11.5     |
| Cement mortar coating                                  | m²   | 405      |
| Bush hammered cement topping                           | m²   | 110      |
| Flags tone paving at a dosage of 300kg/m3 over a sandy bed | m²   | 94       |
| **Subtotal 5.00**                                      |      |          |
| **FRAMEWORK– ROOFING**                                 |      |          |
| Wooden trusses 3*15                                     | m³   | 2        |
| Wooden purlins (4*8)                                   | m³   | 1.5      |
| Item                                                                 | Quantity | Price  |
|---------------------------------------------------------------------|----------|--------|
| Roofing aluminum sheets 6/10                                        | m²       | 99.69  |
| Fascia boards protected with sheets of 7/10                        | m³       | 120    |
| PVC rain water gutters, including hooks and other accessories       | ml       | 19.81  |
| Downspouts, including holders                                       | ml       | 29.38  |
| Dropped ceiling, including joisting                                 | m²       | 110    |
| **Subtotal 6.00**                                                   |          |        |
| **Carpentry-Wood**                                                  |          |        |
| Supply and installation of complete solid doors of 0.85 x 2.10      | U        | 7      |
| Supply and installation of complete thermal-reak door of 0.65 x 2.10| U        | 2      |
| Supply and installation of glass sash window frames                 | U        | 7      |
| Supply and installation of complete cupboards, including all room implements (240 x 220) | U        | 4.69   |
| Supply and installation under-counter cup boards                    | U        | 1      |
| **Subtotal 7.00**                                                   |          |        |
| **Metal joinery, NACO & glazing**                                   |          |        |
| 10 mm Wrought ironsecurity grids                                   | U        | 7      |
| Pairs of 8-balde NACO sashes                                        | U        | 8      |
| Of 5 blades                                                        | U        | 3      |
| 1.2 clear NACO blade                                                | U        | 66     |
| Of 0.6m                                                            | U        | 19.06  |
| **Subtotal 8.00**                                                   |          |        |
| **Electricity**                                                    |          |        |
| Straps                                                             | U        | 1      |
| Distribution box                                                   | U        | 1      |
| S.A.S witch                                                        | 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**

Coldwater PVC pressure supply pipe 20/27 ml 16.88  
Coldwater PVC pressure supply pipe 15/27 ml 26.25  
Hotwater copper supply pipe ml 18.13  
PVCÆ63 waste pipe ml 27.19  
PVCÆ100 waste pipe ml 11.25  
Supply and installation of a complete wash stand, including valves and fittings and emptying U 2.81  
Supply and installation of a WC low-end flushing tank accessories included 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 included 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 towelbar 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**

Stone ware tiles for living room and dining room m² 25  
2X2 Stone ware tiles in toilet floorings and W.C m² 9.38  
Faience tiles of 15X15 on toilet and W.C walls, and at 0.45cm above the sink of the kitchen’s work top  

**Subtotal 11.00**

**Paintings**

Vinyl pain to nouter walls, including all main spaces m² 187.5  
Vinyl paint on inner walls, ceilings and subfloors, including main spaces m² 490.63  
Glycerophtalic paint on wood works, metallicjoinery, kitchen and wash-uprooms and adjoining areas m² 35.94  
Cellulosiclacquer on all wood works and adjoining areas comprises m² 4.53  

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2.3 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.

2.3.1 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 through hout 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, Wheel barrows, 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. Inade concentratedeff or to farchitectural systems that directly impact the use of energy and the overall heating potential of the low-cos 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 foot path 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 house hold appliances;

**H4**: Materials supply sites remain the same through hout the life cycle.
**H5**: For an overall lappraisal of our building, it is supposed that the price of materials would slightly increase in the long run.

**2.3 Hypotheses and Elements of the Study**

**2.3.1 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.

1) 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                       | 20 truck  | 1.1                       | 72            |
| Gravel                     | 20 truck  | 1.1                       | 31            |
| Hardware store materials   | 16 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                                          | 473.6MJ/t Lime         |
| 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 | 18.56MJ/m2            |
| Clearing of light materials                      | 13.80MJ/m3             |
| Clearing of rock materials                       | 38.40MJ/m3             |
Storageofclearedmaterials  6.72MJ/m³
Compactingthebackfill  6.04MJ/m³
Transportationwithtrucks luMJ/tkmTransportation bysea  300.00MJ/tour Hotcoatingproductionstation 302.50MJ/t
Lukeworn coatingproductionstation .40MJ/t Coldproductionstation(concrete)  15.40MJ/t Water station 10.00MJ/t
Clearing of shoulders  1.6MJ/T
Platform reshaping over10cm  6.72MJ/m³
Reshaping withmixing  33.67MJ/m³
Reinforcedconcrete liningby m³ofconcrete  6.13MJ/m³
Reinforcement  3.25MJ/T Steeltube guardrails  253.5MJ/ml Geotextileworks  3.12MJ/m²
Constructionofguardrails  6.05MJ/Mml

| Table 7. Powersource |
|----------------------|
| **MJ of production** |
| Energy(MJ) | MJ |
| 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 |
| Radioactivewaste dm³ | 0.000000034 | 0.000000052 | 0.000140717 |
| GWP100 kgCO₂ | 0.00117 | 0.08395 | 2.352312704 |
| Acidification kgSO₂ | 0.000006 | 0.000099 | 0.005159609 |
| Eutrophization kgPO₄³⁻ | 0.000000058 | 0.000011 | 0.000328339 |
| Ecotoxicity m³ | 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 m³ | 7.686 | 159.3 | 463.8957655 |

| Table 8. Basics Constituent’s Indicators |
|-----------------------------------------|
| Indicators | Unit | Reinforcementsteel(T) | Galvanized steelsheet(T) | PVC(T) | Cement(T) | Lime(T) | Sand(T) | Crushed (%) | Replaced (%) | Transportation km | Water station (T) | Woodlist (T) | Irondoor (T) | Tiling(T) | Paint(T) |
| Energy(MJ) | MJ | 26355.000 | 70380.000 | 9240.0 | 547.0 | 10164.0 | 5.000 | 44.0 | 33.000 | 33.000 | 1.100 | 10.000 | 564.5 | 1.7E+05 | 8110.0 | 24089.4 |
| Water kg | 15337.600 | 3.4E+05 | 6584.2 | 526.1 | 146.0 | 18.453 | 91.845 | 23.690 | 0.487 | 302.575 | 664.950 | 1.0E+05 | 3100.0 | 20746.8 |
| Resources 10⁷⁷ | 5.0E-12 | 4.2E-10 | 0.0 | 9.3E-13 | 3.2E-12 | 5.0E-10 | 2.5E-14 | 9.3E-15 | 4.3E-16 | 6.7E-15 | 2.1E-15 | 2.4E-12 | 3.0E-10 |
| Waste Teq | 0.972 | 1.301 | 0.0 | 2.544 | 0.000 | 1392.830 | 0.192 | 0.000 | 0.054 | 0.003 | 29.150 | 2979.800 | 190.0 | 110.700 |

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Table 9. Summary of Building Indicators of Mixing for 1m³

| Indicator             | Production | Production | Production | Production | Production |
|-----------------------|------------|------------|------------|------------|------------|
| DV                    | MJ         | Water      | 1744.073   | 1735.388   | 1768.127   | 3105.06208 | 950.337    |
| DV                    | MJ         | Resources  | 1082.559041| 1070.513065| 1170.982885| 1972.623717| 664.292142 |
| DV                    | MJ         | Waste      | 9.607245283| 8.981773585| 4.128113206| 4.003018686| 4.553433962|
| DV                    | MJ         | Radioactive| 2674.997715| 2500.893867| 1150.1001014| 1115.455297| 4.553433962|
| DV                    | MJ         | GWP100     | 0.12554079 | 0.105426045| 0.10239312  | 0.05979418  | 0.060273789|
| DV                    | MJ         | Acidification| 0.9270745445 | 0.719942734 | 0.749917848 | 0.99953794  | 0.397631405|
| DV                    | MJ         | Eutrophization| 0.086000569 | 0.08589004  | 0.090972114  | 0.11886464  | 0.049391979|
| DV                    | MJ         | Ecotoxicity | 0.122308268 | 0.105426045| 0.10239312  | 0.126577522 | 0.059756299|
| DV                    | MJ         | Human toxicity| 1.950416141 | 1.947527583 | 2.016359405 | 4.198039263 | 1.06033054|
| DV                    | MJ         | O3-smog    | 0.034615889 | 0.034356165 | 0.043757584 | 0.066092981 | 0.029054502|
| DV                    | MJ         | Odors      | 5.07431939 | 4.349416646 | 4.204436107 | 4.929343145 | 2.464669438|

Table 10. Building Processes Given by the 2008 HNSP

| Work site/process      | Unit | Energy |
|------------------------|------|--------|
| Loosematerials         | MJ/3 | 13.8   |
| Cold production site (concrete) | MJ/t | 15.4   |
| 3                      | 3    | 6.13   |
| Reinforced concrete formwork by mof concrete | MJ/m |
| Reinforcement          | MJ/t | 3.25   |
| Symbol   | Name                                                      | Formulas                                                                 |
|---------|-----------------------------------------------------------|--------------------------------------------------------------------------|
| Ea      | Energy spent for physical activity per hour               | Energy during in active period and per hour                               |
| ET      | *GW * T*NEO                                               |                                                                          |
| GWP100  | CO2 releases by an individual per hour and in terms of physical activity |                                                                          |
| GWP0    | CO2 released by an idle person and per hour               |                                                                          |
| T       | working time in hours                                    |                                                                          |
| N       | Number of persons carrying out a given task               |                                                                          |

### Table 12. Energy and GWP100 Indicators for Some Work Site Processes

| Worksite process                     | Unit          | Number of persons | Working time | Energy per Person (kcal) | CO2 released in (kg) |
|--------------------------------------|---------------|--------------------|--------------|--------------------------|----------------------|
| Trenching of soft soil laid at 20m   | Person (kcal) | persons (H)        | 3 m          | 400                      | 2                    |
|                                      |               |                    | 2            | 4.1                      | 13.8                 |
|                                      |               |                    | 6            | 0.83350588               |                      |
| Cold production station (concrete)   | Person (kcal) | persons (H)        | 400          | 2                        | 4.6                  |
|                                      |               |                    | 2            | 15.4                     | 0.93515294           |
| Reinforced concrete lining per m³ of concrete | Person (kcal) | persons (H)        | 275          | 2                        | 2.67                 |
|                                      |               |                    | 2            | 6.13                     | 0.37037647           |

### Table 13. Energy for the Manual Use of Project’s Materials

| Material                        | Unit          | Number of persons | Time in Hours | Energy (Kcal) per Person and per hour | Overall energy (MJ) |
|---------------------------------|---------------|--------------------|---------------|--------------------------------------|---------------------|
| Mortar for coating              | M³            | 1                  | 24            | 120                                  | 12.0384             |
| Chipboards                      | T             | 1                  | 5             | 140                                  | 2.926               |
| Wood and framework              | m³            | 2                  | 16            | 140                                  | 18.7264             |

### Table 14. Complementary Data Per kg of Constitutive Material

| Material                        | Thickness (mm) | Overall energy (MJ/m²) |
|---------------------------------|----------------|------------------------|
| Roofing                        | 0.2            | 0.2508                 |
| Paint                          | 0.15           | 0.08151                |
| Doors                          | 0.1            | 0.05643                |
| WC/toilet tiles                | 0.6            | 0.2508                 |

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Table 15. Some Features of the Two Buildings

| Designation                          | Urbanarea                        |
|--------------------------------------|----------------------------------|
| Water supply                         | CDE                              |
| Lighting and household equipment     | Electricity                      |
| power supply                         |                                  |
| Plumbing equipment                   | Complete                         |
| Equipment network for power use      | Finished electrical              |
| waste liquid soliquid solid          | Septic tanks                     |
|                                      | HYSACAMcompan                    |

3. Result

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: being the environnemental impact indicator. We have therefore: \( I = E + F + M + T \)

Table 16. Environmental Impact Indicators during Construction Phase

| Indicator                  | Unit | Adobe | Raw (compressed earth dosage 300kg/m³) | Cinderblock |
|----------------------------|------|-------|---------------------------------------|-------------|
| AR                         | MJ   | 0.002745 | 0.002521 | 0.76506   |
| Water                     | kg   | 0.00015 | 5.89E-05 | 0.46544   |
| Resources                 | 10⁻⁹ | 0      | 0        | 0.00391   |
| Waste                     | Teq  | 0      | 0        | 1.08735   |
| Radioactivewaste          | dm³  | 0      | 0        | 0.00005   |
| GWP100                    | Kg C02 | 0.04565 | 0.042 | 0.12764   |
| Acidification             | Kg S02 | 0      | 0        | 0.00031   |
| Eutrophization            | Kg   | 0      | 0        | 0.00004   |
| Ecotoxicity               | m³   | 0      | 0        | 0.00005   |
| Human toxicity            | kg   | 0      | 0        | 0.00085   |
| O3-smog                   | kg   | 0      | 0        | 0.00001   |
| Odours                    | m³   | 0      | 0        | 0.00189   |
| Indicator                   | Unit                            | Cleaning concrete |
|---------------------------|---------------------------------|-------------------|
| Mortar                    | Concrete blocks                 |                   |
| Concrete                  | Reinforced concrete             |                   |
| Framework                 | Alu ironsheets                  |                   |
| Irondoor                  | Tiles                           | Paint OTAL        |
| Energy MJ                 | 5126.612                        | 10173.0195        |
| Water kg                  | 3103.001                        | 6071.1816         |
| Resources 10^-9           | 9.4337E-13                      |                   |
| Waste Teq                | 7220445.67700                   |                  |
| Radioactive waste dm³     | 0.34047644                      |                  |
| GWP100 kg CO2             | 814.925                         |                  |
| Acidification kg SO2      | 2.217                           |                  |
| Eutrophization kg PO₄⁻³  | 818.054337                      |                  |
| Human kg                  | 5.60187785                      |                  |
| O3-smog kg                | 0.38589404                      |                  |
| Odours m³                 | 28801.9215                      |                  |
| Table 17. Environmental Impact Indicators during the Exploitation Phase |

| Indicator   | Unit | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-------------|------|---|---|---|---|---|---|---|---|---|----|
| Energy MJ   |      | 1.299 | 2799156 | 363636.9 | 10 | 4320 | 43200 | 0.0143 | 1003.97 | 600 | 402391.7 | 0.605 | 357 | 2.9988 | 1072.389 | 1010302.95 |
| Water kg    |      | 0.02481 | 6945.212 | 389.5749 | 1682965.6 | 0.006301 | 66.75984 | 40059.685 | 0.266983 | 56.27 | 109.5691 | 1730078.011 |
| Resources 10^-9 |      | 7.7E-14 | 2.1E-12 | 6.72E-15 | 2.98E-11 | 5.62E-8 | 2.83E-15 | 1.697E-10 | 2.58E-16 | 1.98E-14 | 3.64E-14 | 2E-10 |
| Waste Teq   |      | 0.0058 | 1623.629 | 0.002973 | 12.84321 | 0.000415 | 4.394164 | 2636.7472 | 0.017559 | 1.59 | 4.820749 | 4278.03963 |
| Radioactive waste dm³ |      | 3.4E-08 | 0.009118 | 3.24E-05 | 0.1397744 | 5.28E-08 | 0.000335 |

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Table 18. Environmental Impact Indicators during the Maintenance Phase

| Indicator | Unit | Material/Activity | Indicator | Unit | Material/Activity | Indicator | Unit | Material/Activity | Indicator | Unit | Material/Activity | Indicator | Unit | Material/Activity | Indicator | Unit | Material/Activity |
|-----------|------|------------------|-----------|------|------------------|-----------|------|------------------|-----------|------|------------------|-----------|------|------------------|-----------|------|------------------|
| Power     | MJ   | 2672.91088       | 43562.259 | 49.1610806 | 269.506654 | 1610.07 | 4675.07088 | 73.7726449 | 52912.751 |
| Water     | kg   | 1656.98459       | 37517.439 | 21.94172    | 27.3914764 | 945.36   | 2997.43059 | 27.3278772 | 43193.8514 |
| Resources | 10⁻⁹ | 5.2606E-13       | 5.5514E-10 | 1.9295E-14 | 9.0848E-15 | 2.2372E-15 | 9.3936E-13 | 2.432E-14  | 5.5665E-10 |
| Waste     | Teq  | 2423998.4        | 200.186118 | 1.56159122 | 1.20518726 | 27.6318  | 2757818.55 | 1.79134566 | 518049.33 |
| Radioactive waste | dmv | 0.1164416 | 0.08300338 | 0.00021607 | 0.00029406 | 0.0011662 | 0.13592137 | 0.00023159 | 0.33727429 |
| GWP100    | kgC  | 419.307547       | 1220.63848 | 2.95768178 | -18.5875257 | 78.0878  | 749.043952 | 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 | 0.00051987 | 0.00058765 | 0.020706 | 0.26321224 | 0.00647401 | 0.84676662 |
| Ecotoxicity | m³  | 574.394784       | 34602.6796 | 94.4126156 | 0.90357374 | 0.0009996 | 847.333813 | 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    | m³   | 20222.6461       | 330255.53  | 3323.82423 | 31.8096325 | 0.0000714 | 29832.2952 | 4290.92811 | 3360254.03 |

Table 19. Impact Indicators during the Destruction Phase

| Indicator | Unit | Indicator | Track for transportation | Overall destruction Indicator |
|-----------|------|-----------|--------------------------|-------------------------------|
| Power     | MJ   | 16        | 1.1                      | 97                            | 5                            | 2085.5          |
| Water     | kg   | 7.050131926 | 0.48469657               | 683.8628                      |
| Resources | 10⁻⁹ | 6.29024E-15 | 4.32454E-16              | 6.102E-13                     |
| Waste     | Teq  | 0.464379947 | 0.031926121              | 45.044855                     |
| Radioactive waste | dmv | 5.910E-05 | 4.062E-06               | 0.00573                       |
| GWP100    | kgC  | 0.970976   | 0.066751                | 94.1846                       |
| Acidification | kgS | 0.01055   | 0.0007255               | 1.0237                        |
| Eutrophization | KgP | 0.001688 | 0.000116               | 0.16379                       |

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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  | 1828163.34 |
| Resources | 10^-9°      | 7.6622E-11   | 2.0091E-10  | 5.5665E-10  | 8.1989E-13 |
| Waste | g            | 46638756.8   | 4278.03996  | 5182049.33  | 51825144.7 |
| Radioactive waste | Teq        | 2.34398586   | 0.35155293  | 0.33727429  | 0.00770369  |
| GWP100 | kgCO2       | 6100.67545   | 32726.6349  | 2455.2047   | 41409.0757 |
| Acidification | kgSO2    | 29.8335023   | 40.1190035  | 11.3488284  | 1.37565963 |
| Eutrophization | kgPO₄³⁻ | 3.71332133   | 4.28200641  | 0.84676662  | 0.22010554 |
| Ecotoxicity | m³         | 15682.3911   | 161234.565  | 36241.6234  | 4154.49208 |
| Humantoxicity | kg         | 91.9594849   | 2151831.98  | 42.2313582  | 1.70581794 |
| O3-smog | kg          | 6.13077897   | 33.5460787  | 3.50604198  | 4.4468612 |
| Odors | m³          | 783716.299   | 63869332.3  | 3360254.03  | 146260.132 |

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, the set 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 with in the frame work 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. House holdgas (grey power);
• Exploitation power (electricity AES-SONEL);
• Production power and power used to pump water into houses.

3.1 Flow Assessment

Table 21. Water and Electricity Consumption

| Unit        | Number of persons | Daily consumption per inhabitant | Monthly consumption of the household |
|-------------|-------------------|----------------------------------|--------------------------------------|
| Electricity KW | 6                 | 0.5944                           | 107                                  |
| H           |                   |                                  | 0                                    |
| Water m³   | 6                 | 0.06                             | 10.8                                 |

Table 22. Cooking Gas and Soap Consumption

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

Table 23. Use of the Urban House

| Item                              | Number or quantity | Usage duration | Frequency of replacement |
|-----------------------------------|--------------------|----------------|--------------------------|
| Electrical bulb                   | 8                  | 1.16           | 43.10344                 |
| Electric installation repairs     | 20                 | 1.5            |                          |
| Wooden furniture                  | 1                  | 25             | 2                        |
| Wooden bed for bedroom            | 3                  | 15             | 3.34                     |
| Cop board repairs                 | 4                  | 15             | 2.34                     |

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 Roos 25    | 1                        |
| Emptying the septic 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                        |
4. Result Analysis

4.1 Impact Study

Here is the list of the twelve environmental impact indicators of the two houses according to their various life cycle phases. 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.
- intown(CDE) is done with many losses.
- For consumption indicators of: Waste. Radio active 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](image)

4.2 Balance Sheet and Interpretation of the Life Cycle of LCH

The results of the LCA of the building constructed until now apply to all environmental aspects: raw materials and power consumption; waste; green house-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 pre occupying 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%          |

5. 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 data base setup by the HNPS in 2008; using the data base 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 invent ories mainly provided by the 2008 HNPS database, the ECOINVENT data base 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.

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Appendix

Architectural Aspect: the model chosen is of type T4
