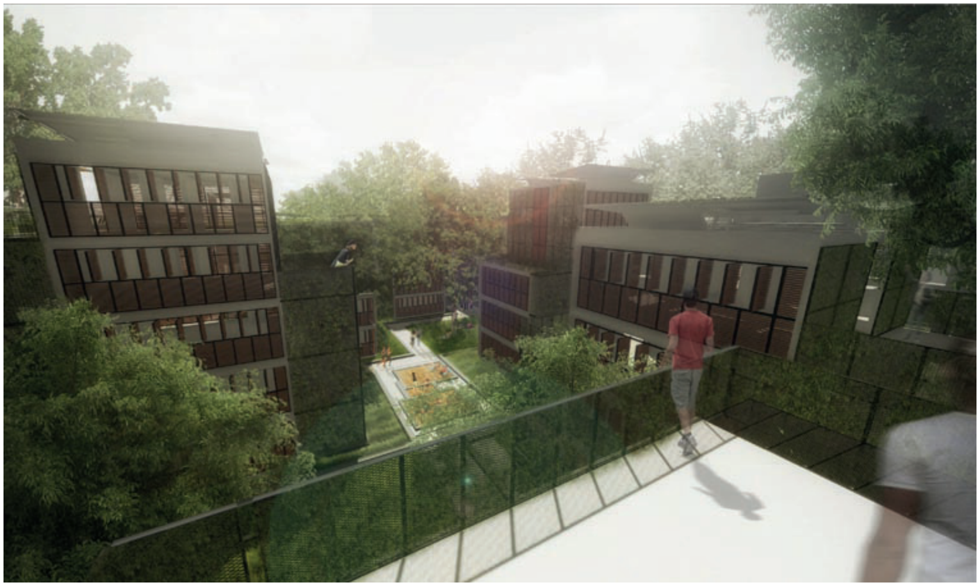
Chapter 5

Sustainability



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Introduction

The construction sector is probably one of the human activities with the highest demand for natural resources and energy (Bakens, 2003; cited by Rodríguez & Fernández, 2010).This sector employs approximately half of the resources that the humankind consumes from nature and it is considered that 25% of waste materials come from construction and demolition (Alarcón, 2005; cited by Rodríguez & Fernández, 2010) and more than 70% of worldwide energy moves around this sector (Oteiza & Tenorio, 2007; cited by Rodríguez & Fernández, 2010). Considering that sustainable development and climate change have become two new challenges for the humankind. Having synergies and mutual interdependences, measures focused on the construction sector drive to sustainability positively and affect the mitigation and adaptation to this climate change (Rodríguez & Fernández, 2010).

Mihouse is a dynamic and sustainable solution for real neighborhood conditions in Cali, Colombia, with possibilities to be adapted anywhere. The team's main goal is to offer an innovative neighborhood with high affordability conditions through a high density of 128 living units that can expand soon for productive purposes. Its design includes a generous green environment offering a comfortable living unit, flexible, progressive and productive along the time. Considering sustainable principles, an integrated water management plan has been designed, in which rainwater harvesting allows us to consume less potable water and reusing it for cleaning bathrooms among others. For the integrated solid waste management, the creation of a small company to manage the community's residues is proposed. Furthermore, Mihouse takes advantage of the Sun as a free energy source using a solar photovoltaic grid-connected system with storage capacity, that will produce and use its own electrical energy as well as being able to sell the excess of captured energy to the grid, making the system sustainable during the time.

This project is focused on achieving a balance between the three pillars of sustainable development (economic, social and environmental benefits). The environmental component is present in all these activities, plans and processes carried out in the Mihouse urbanization. Regarding the social and economic aspects, the Mihouse project is oriented towards guaranteeing food security and to generate job opportunities through the production, management and marketing of crops cultivated in the garden areas. Moreover, the transformation of organic solid wastes into compost considered in the urbanization, which can be marketed in the area and used as fertilizer in gardens, allows us to have other job opportunities for the inhabitants in this urbanization. The use of solar panels, the reuse of greywater and the exploitation of rainwater, allow us to have huge savings in economic terms, because we use solar energy as alternative source of energy instead of the grid and we use treated greywater and rainwater instead of using drinking water for flushing the toilets or watering the green areas and gardens. With the examples mentioned before, it is evident that Mihouse aims to make a positive and lasting impact on a city which needs to consider a different paradigm regarding sustainable construction of social housing. This approach allows us the preservation of natural resources in compliance with the three pillars of sustainable development mentioned before. Moreover, the Mihouse project considers key aspects stated in the new legislation in Colombia for sustainable construction and for saving water and energy in buildings, the Resolución 0549 de 2015. Thus, Mihouse will be the first step to achieve sustainable construction in social housing projects in Colombia.

Mihouse proposal looks highly attractive for the industrial sector, responding to specific problems of the social and economic context and especially to tropical environments and climatic conditions.

Water Strategies

General context: the hydraulic system is an integrated system that has been designed keeping in mind the effective use of available space and the reduction of the length of pipes. Additionally, in order to prevent heat loss when water passes through the pipes, the location of the solar water heater is as close as possible to the utilities. Also, the location of the tanks considers that it is more feasible to locate them under ground because they do not have any visual and spatial hindrance.

Solar context: considering that the house in the urban context is the transposition of the prototype into the structure of a building, some aspects will be similar to the mentioned before, such as the length of the pipes and the solar water heater location as close as possible to profits. It is known that at the urban level there are two types of buildings, the first one where the top floor varies the type of apartment, and the second one is a building where the apartment is like the prototype, which has 3 roofs and another building with a smaller apartment. So far it has been planned to have a total of 128 apartments, for a total of 30 buildings, 22 of which have 4 stories and 8 have 5 stories, where systems for the reuse of greywater and rainwater are set, this is described in section Plumbing System.

Strategies for Reducing Water Consumption

One goal of the project Mihouse is to propose a sustainable water management. In order to ensure a reduction of water consumption. The following strategies for the prototype and urban areas were set:

Recycling, reuse. It is very important that the design of the apartments and residential buildings integrate significant savings in the consumption of drinking water, a resource that is indispensable although its availability is depleted over time. This is the reason why the project Mihouse seeks alternatives to allow the recycling and reuse of water, in order to avoid excessive consumption of this resource. Considering this approach, we can generate economic savings.

Reuse of rainwater. The efficient use of rainwater as an alternative for ornamental purposes, and maintenance of green areas, represents in terms of the sustainability of resources, significant savings related to the cost of water service, and environmental protection. The rainwater is collected through pipes on each building, making their own use and storage in elevated tanks located on the top floors of the buildings, in order to re-use this resource for irrigation of green areas.

In general terms, the rainwater system consists of a rainwater collection and conveyance system composed of channels that transport water to the elevated storage tanks located on the roof, where it is taken to use it to irrigate green areas, washing floors, and so on.

Greywater reuse system. Urban Context: In this project you can see a greywater treatment system for the entire residential condo that allows us the reuse of greywater from showers, laundry (washing machine and laundry) and sink for toilets flushing in each apartment. The greywater system is based on the accumulation of water from the second cycle of the washing machine. We do not propose to use the water from the first cycle of the washing machine because it has a higher level of dirt.

For the greywater management, we propose to have two collection tanks located underground at the green areas. For the greywater treatment, a train based on grease trap, followed by a tank where the coagulation and flocculation is performed, is pro- posed; then, the water distribution is performed by pumps, in this way the treated water is transported to each apartment.

Wastewater management. Urban Context: In order to evacuate the wastewater that has been used for working tasks, personal care and hygiene, the Mihouse project proposes a separation of the wastewater and the greywater for each apartment on the entire housing complex. The discharges of wastewater coming from the toilets and dishwasher are interconnected in a horizontal pipe which distributes them to an outer inspection box to be finally delivered to the municipal public sewer.

Cali has a domestic Wastewater Treatment Plant (WWTP) called Cañaveralejo, which is administered by the Emcali company. This WWTP is located at the east side of the city, it has an advanced primary treatment and it is in the process of optimizing the system by achieving secondary treatment. Due to the existence of WWTP Cañaveralejo Cali, we do not consider any kind of treatment for the wastewater in this project. The system only provides the connection to the municipal sewer network.

Incentive for the Use of Water Saving Accessories and Equipment

The following types of water saving devices or accessories that should be implemented on the project Mihouse at the urban level and at the prototype has been identified in the market: Lavatory faucets or valves, shower valves, water-flush toilets with double discharge, among others, that help to reduce water consumption. By installing such devices, the water consumption is reduced, saving this resource.

Water Cycle

Catchment

Drinking Water: Initially, the Cauca’s river water is collected and treated in Puerto Mallarino’s Drinking Water plant. Then this water is distributed to different areas of Santiago de Cali, including the area where the Mihouse project is planned.

Rainwater: Santiago de Cali has abundant rainfall through the year. This water availability is exploited by the effective areas of the roofs in the buildings, which allow us to capture this valuable resource.

Distribution and use

Drinking water: Once the water is supplied to the residential complex, through the connections with the main network of the aqueduct, it is distributed to each of the apartments through a pumping system.

Rainwater: The rainwater collected by the roofs in each block is transported through gutters and downspouts, which finally is conducted into two storage tanks. The rainwater stored will be used to irrigate the green areas.

Reuse

Water from sinks, washing machines and showers (greywater) is reused. These waters will be collected in a storage tank for each apartment and by a pumping system it will be sent to flush toilets.

Outputs

Wastewater: Drinking water that has been used in activities such as dish washing and toilets flushing cannot be reused. Therefore, it is discharged directly to the municipal sewer system. This sewer system transports wastewater until the wastewater treatment plant, called Cañaveralejo, where after treatment the water is reincorporated into the Cauca river.

Evapotranspiration and infiltration: Rainwater captured and irrigated to green areas is used by the vegetation for their metabolic processes and subsequently transpire water in vapor form. There is also a direct evaporation from the surface. Therefore, water vapor is transported into the atmosphere and by weather processes it is precipitated again in the area.

Solid Waste Management

In general terms, within the concept of sustainability it is also necessary to include the management of solid wastes in the Mihouse project. We propose to have two approaches, the first one cultural, which aims to raise awareness and educate the people who live in the apartment, and the second one, technical, to develop a proper disposal of solid wastes.

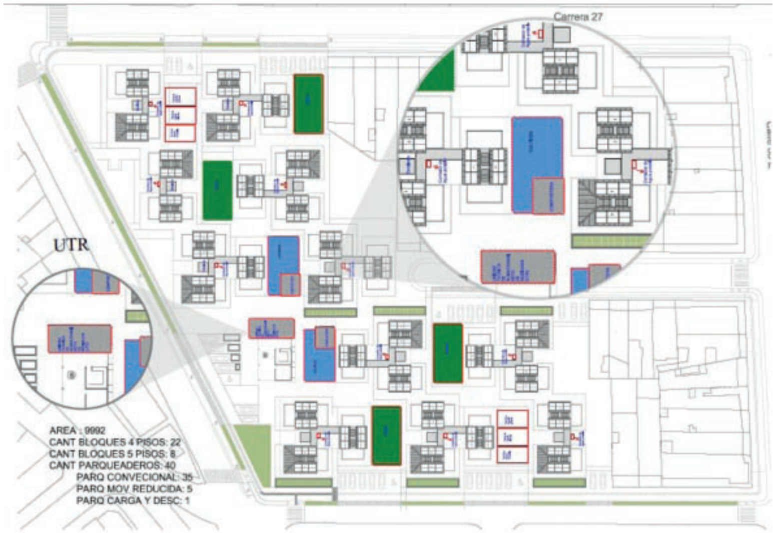
Within the framework of sustainable housing projection of the Mihouse team, we considered the solid wastes that will be generated by the inhabitants of the residential condo as well as those generated during the construction of the prototype house. The solid wastes that will be generated are made up of different types such as: organic, recyclable and ordinary. Their proper management involves separation at source, storage and reuse.

Culturally, the participation of citizens is a key element in the solid waste management, therefore a training should be offered in order to achieve careful and conscientious people, who are responsible for the separation of solid wastes at the source.

Considering the mentioned above, in the sustainable residential condo it is going to be a technical solid waste storage unit (UTR in spanish), also there are going to be two areas for the reuse of biowaste (food waste and pruning), processed through composting. We consider this residential composting process as an important element within the innovation proposals of the Mihouse team.

In order to develop what is mentioned above, the urbanization area will have 8,64 square meters for the reuse of bio-waste 2,4 * 3,6 m) and 12 square meters for the technical storage unit (UTR in Spanish). In the Figure 3.1. the location of the UTR and the area for the reuse of bio-waste are shown.

Figure 5.1. Location of the TSU and waste use areas.



Source: The Authors.

The sustainable residential condo will have a total of 128 apartments, distributed in 22 blocks of 4 floors and 8 blocks of 5 floors. In the following table an estimation of the amount of waste generated is presented (Table 3.6)

The use of bio-waste is carried out through two composting autonomous units of 3000 liters, reference SAC-3000, given by the company Earthgreen (considering that 100 % of the population does separation at source). The result of the composting process is an organic fertilizer for the soil, which improves soil characteristics and increases crop yields.

The autonomous composting units proposed for this project have the advantage of not requiring neither dumping processes as is commonly needed, nor chemical or bacterial addition and also it has not odor nor leachate generation. These aspects allow us to have vectors control such as flies and rodents. It has been calculated that in a term of approximately 25 to 30 days we can be obtain compost ready to be used in gardens or to be marketed.

According to Earthgreen, for each kilogram of organic solid waste separated and taken for composting, it is obtained about 0,4 to 0,5 kilograms of useful compost for parks, gardens, orchards and marketing as an amendment or organic fertilizer. This product has market values ranging between $ 120000 - 180000 / ton, which may represent an income for inhabitants of the houses, and thus we can reduce the solid wastes to be delivered to final disposal. Moreover, in the Mihouse project it is proposed an area where the garden compost resulting from this process is used.

In these gardens, it is proposed the development of organic gardens where residents can develop crop production and learning and marketing of farmed products.

Moreover, recyclable solid wastes (paper, plastic, cardboard and so on) will have a significant advantage to improve the quality of life for residents, as these materials have two main objectives; the first one is the use of solid wastes for the creation of crafts and objects encouraging innovative business creation and social inclusion. The second one will be the marketing of solid wastes to local authorities responsible. The budget earned will be invested in recreational areas of urbanization, road construction for cycling, community gardens, food network, among others.

Table 5.1. Estimation of the amount of waste generated in the residential condo

Variable	Value
Total population of the residential condo (Habitants)	640
Number of apartments	128
Number of people per apartment	5
Socioeconomic stratum	1 and 2
Ppc (kg/hab.Day)1	0,35
Specific weight (kg/m3)	250
Solid wastes generation (kg/day)	179,2
Solid wastes volume (m3)	1,67

Source: The Authors.

Mihouse Proposal Economic Benefits. GreyWater Reuse and Rainwater, Groundwater and Solid Waste Exploitation

In the months of August and September 2015, Cali has been confronted with a problem of water scarcity, especially in Cali and Melendez rivers, due to strong intensity of climatological phenomenon "El Niño", which caused climate change. This has caused restrictions on the continued supply of drinking water in the neighborhoods located in the mountainous areas of the city, affecting almost 25 % of the citizens in Cali. Considering the above, the use of alternative water sources is necessary, such as the reuse of greywater or rainwater and groundwater exploitation, for the development of domestic cleaning activities and irrigation of green areas. The following section provides an evaluation of the economic benefits of the Mihouse proposal, considering an integrated management of water resources and integrated management of solid waste.

Rainwater

Mihouse project has 960 m^2 of parkland and gardens, parks, etc., which require two liters of water per square meter, ie 1920 liters per day of water are needed to irrigate these areas. Usually for the irrigation of green areas is used in an inappropriate manner drinking water. This is a mistake, because the plants, trees and grass do not require excellent water quality as it is potable water, however, quality standards as presented by rainwater or groundwater, are enough to the water requirements of plants. Considering this, Mihouse project proposes the use of two alternative sources of irrigation water for green areas, rainwater and groundwater. The use of these two alternative irrigation water results in a cost savings for residential complex, by reducing the consumption of drinking water and environmental benefits to make rational use of water resource, according with water quality required for each type of activity.

The system of rainwater and groundwater exploitation, designed for Mihouse Project, propose a saving of 100 % of the amount of water required for irrigation of green areas, considering the use of rainwater with 12,43% of the total required and the use of groundwater with 87,57% remaining. In addition, it should be noted that the unit cost for using drinking water is 1 41.71 pesos / m^3, while the unit cost for using groundwater is 6.65 pesos / m^3 and the use of rainwater would have no associated cost. A cost-benefit analysis can observe that implementing the system of rainwater and groundwater exploitation in the project Mihouse will achieve annual savings of $ 974 513 for the concept of irrigation of green areas. Below in Table 5.2 is presented projected values when the system is implemented.

Table 5.2. Cost savings Mihouse complex, using the rainwater and groundwater exploitation system

	Residential Complex without exploitation (100% water)	Mihouse Residential Complex with exploitation (Rainwater, 12,43 %) of the total required using potable water)	Mihouse Residential Complex with exploitation (Groundwater, 87,57% of the total required using potable water)
Consumption for irrigation (m^3 / day)	1,92	0,239	1,681
Monthly consumption (m^3)	57,6	7,16	50,44
Tariff ($/$m^3$)	1415,71*	0	6,65**
Monthly Cost ($)	81,545	0	335,4
Anual cost ($)	978 539	0	4,025
Annual savings ($)	-	974 513	

Source: The Authors using the information from (*): Emcali Tariff adjusted to consumption levels over 20m^3, from February 2015 and (**) Rate adjusted by the Dagma, according to Resolution No. 950 of 2013.

Greywater

For the management of greywater will be built two underground collection tanks, located in the green areas. For the treatment of greywater, is proposed a treatment train comprising a grease trap, followed by a tank where the coagulation and flocculation is performed; then the distribution of treated water is performed by pumps, bringing the treated water on each apartment.

Currently the neighborhood El Paraiso is supplied by the municipal company of Cali, Emcali, which handles a flat rate of $ 1145,71 per m^3 (Emcali, 2015) for a strata 2 sewer From this value and the calculated values of water production on each apartment and urban levels, which can be seen in Table 5.3. The Mihouse project viability on saving resources is demonstrated as well as the viability of the project based on a saving resources.

Table 5.3. Mihouse project viability on saving resources

m^3 of greywater produced in property	m^3 / day of greywater produced at the urban level
0,405 m^3/day	56,7 m^3/day
12,15 m^3/month	1701 m^3/month

Source: The Authors.

That is, assuming five inhabitants by house in the neighborhood Paradise would save the following in pesos (Table 5.4) considering the rate mentioned and the production of greywater in the home and urban level:

Table 5.4. Savings in pesos of Housing and Urbanization

	Savings per house	Saving urban level
Monthly savings in COP	$13 920	$1 948 853
Anual savings in COP	$167 044	23 386 236

Source: The Authors.

Solid waste

Considering the number of inhabitants and the number of apartments of the project (128 apartments), in Table 5.5 is shown the quantity of waste that will be generated by the residential unit.

Table 5.5. Waste quantity generated by the residential unit

Category	Stratum (%)		% Average	Waste quantity (kg)	Waste type	Waste type per %
	1	2				
Food	61,3	61,9	0,616	116,27	Organic	0,65
Garden	4,31	2,26	0,033			
Paper	2,75	3,13	0,029	8,96	recyclable	0,05
paperboard	1,87	2,25	0,021			
Bags and Packaging	6,72	7,08	0,069	17,74	recyclable	0,10
Blown plastic	2,86	3,14	0,030			
metallics	0,94	1	0,010	5,51	recyclable	0,03
glass	2,19	2,02	0,021			
Rubber & Leather	1,56	1,38	0,015	30,71	Ordinary	0,17
Cloth	2,82	2,28	0,026			
Wood	0,68	0,93	0,008			
Ceramics	0,99	2,18	0,016			
Bones	0,32	0,31	0,003			
Hygienics	8,3	8,91	0,086			
Others	2,38	1,24	0,018			
Total			1	179,20		

Source: The Authors.

Mihouse proposes the use of different types of solid waste management strategies for its valorization. Below in Table 5.6 quantity values (weights) of the solid wastes to be utilized are:

Table 5.6. Quantity and valorization of waste to be exploited

Waste type	Waste type per %	Waste quantity per day (Kg/ day)	Waste valorization ($)	Exploitation value ($/day)	Exploitation value ($/ month)
Organic waste	0,65	110,38	-	-	
Paper and paperboard	0,05	8,96	250	2240	67200
Bags and Packaging Blown plastic	0,10	17,74	300	5322	159660
Metallics	0,010	1,79	200	358,4	10752
Glass	0,021	3,76	80	301,06	9031
Total				8221,45	246643

Source: The Authors.

Given the results in Table 5.6, it appears that a month can make a profit of $ 246 643 by making recycling inorganic waste such as paper and paperboard, bags and packaging, plastic, metal.

Type organic waste will be utilized by the composting process, with two composters 3 000 liters reference SAC-3000 Earthgreen Company. According to Earthgreen per kilogram of separated and taken to composting organic waste, is obtained from 0,4 to 0,5 kilograms of useful compost as fertilizer for parks, gardens, orchards and marketing as an amendment or organic fertilizer, with market values ranging between $ 120 000 to 180 000 / ton.glass.

Through the use of solid organic waste, it is estimated to stop disposal production of approximately 6,54 tons / month and can also reduce the rate of cleanliness of a 25-35 % additional to the reduction achieved with the use of recyclable waste.

Materials

Sustainability is about meeting the needs of the present generation without compromising the ability of future generations to meet their own needs; the term linked to the action of man in relation to its surroundings; then the sustainability of the main products that are part of Mihouse project:

Lightweight Concrete with Addition of Stone Coal (PC)

The challenge of this prototype is to ensure that the implications of their activity in the city and the environment are positive and contribute to sustainable development of the project. Mihouse sustainability can only serve this cause if they help to develop interdisciplinary skills, raising awareness to green thinking in the local community, preserve ecosystems and economize resources

In this way, the project goal is became in the formalization and structuring of future to ensure the discernment of green thinking and social awareness of the rule of the 3 Rs, leaving the targets related to increasing production to companies only profit regardless basic needs and sustainable behavior.

Only a permanent and argued growth identified in the needs of continuous improvement, regardless of the size of its scope, and university projects, growth can guarantee positive contributions to the industry.

The exploitation of non-renewable aggregate generates an imbalance of socio-environmental sustainability, this is because the building products such as concrete, asphalt, bases and sub-bases, represent a fundamental part of the regional economy, however, as it was mentioned before there are several environmental impacts to take into consideration. The forecast growth for this industry during 2005 showed an increase of 21,6 % in production of stone aggregates. Also, the concession area for mining operations now amounts to 5 % of the national territory, which represents consumption of 5,71 million Colombian hectares in the mining sector.

According to the Asociación Colombiana de Productores de Agregados Petreos for 2015 4,3 million tons would be exploited to replace 10 % of traditional aggregates stone coal residue of paper industry, representing a reduction of 430 thousand tons of aggregates.

The population growth of the major cities of Colombia, predicts an increase of 5 % regarding the use of building materials between the years 2014 and 2015.

Calculation of Ecological Footprint

The calculation of the ecological footprint is used to estimate the environmental impact of the construction and use of sustainable housing developed by the Mihouse group. For its calculation the most important construction materials were considered, such as tables or rings and motherboards, which are manufactured with restressed concrete, pipes made from PVC plastic and photovoltaic solar panels made of silicon.

Besides, according to each stage of the life cycle of the project outputs, the following assumptions were made:

- At the stage of production and transportation of some building materials only the finished product is considered until its final disposal and not from the obtaining of natural resources that supply the raw material of this.
- In the construction phase no indirect impacts associated with transport and feeding of the assembly personnel will be considered.
- The maintenance phase of housing will not be taken into consideration as it will be a prototype.

For the calculation of emissions generated using the materials at each stage of the life cycle consumption data, was considered, such as expenditure on energy, water and transport. Additionally, CO_2 emission factors were considered for the transport of materials and data footprint developed by the doctoral thesis of researcher Solís Guzmán (2010); later the calculation of the ecological footprint was conducted.

Life Cycle Stage Analysis

Making of materials

The calculation of the ecological footprint generated in the construction phase of the materials used in the prototype can be seen in the following table:

Table 5.7. Calculation of the ecological footprint generated in the construction phase

Light concrete		Material Quantity (ton)	He (ha)
Light concrete	Cement	1,5	0,15
	Sand	4,7	0
	Stone coal	1,7	0
	Gravel	1,7	0
	Water	0,9	0
Iron		4,5	4,95
PVC		0,0704	0,27
Solar Panel		0,222	1,51
TOTAL H.E			6,88

Source: The Authors.

For the calculation of the Ecological Footprint a value of 0,1 ha / year of one ton of cement was considered; 1,1 ha / year and ton of iron and 3,8 ha / year and a ton of plastic for the case of PVC. In the case of the construction of the solar panel a study by N. Stylos C. Koroneos in 2013 was taken as reference, in this a value of 6,31 g CO_2 / KWh consumed for their production is presented.

In the case of sand and gravel only the emissions generated by transport from Cauca river are taken into account, this river is located in the limits of the municipality of Candelaria and Cali, in the place known as Juanchito until the LV structures in concrete company SA. In the case of water consumption for the production of concrete the CO2 emission is zero, because the water is drawn from underground wells located in the area of precast company.

Transportation. At this stage transport was considered from the production of material to LV Structures; the production companies are Argos (cement), Sidoc (iron), Pavco (pipelines), Rio Cauca (fine aggregate), Rocales (coarse aggregate). Then it is transported to Univalle from LV structures. Additionally, emission factors in distance traveled and tree 2 CO_2 absorption factor of 5,21 ton of CO_2 / ha of trees were considered.

In the case of water transportation CO_2 emission calculation is not considered because the water used for the manufacture of concrete is drawn from the underground wells in the area of LV concrete structures.

Table 5.8 Calculation of the ecological footprint generated by transporting supplies and raw materials

Construction material		Starting point	Arrival Point	Distance Traveled (km)	CO_2 emission factor (kg/km)	CO_2 emission (kg)	He (ha)
Light Weight Concrete	Cement	Argos	LV Estructuras en concreto S.A.	13,5	0,5	6,75	0,0013
	Sand	Río Cauca (Juanchito)		9,7		4,85	0,00093
	Stone coal	Propal Yumbo		8,7		4,35	0,00083
	Gravel	Rocales		8,2		4,1	0,00078
	Water	N/A					
Iron		SIDOC	LV Concret structures S.A.	6,2	0,5	3,1	0,0006
PVC		PAVCO		8,7		4,35	0,00084
Solar Panel		Singapur internacional Airport	Alfonso Bonilla Aragón Airport	NA		3080	0,59
HE TOTAL							0,5945

Source: The Authors.

To calculate CO_2 emission an emission factor for trucks of 0,5 kg 0,5 kg CO_2/km was considered, and distance traveled provided by Google Maps taking into account the starting point and arrival shown in Table 5.8. With this information the calculation of emission is done as follows:

$$E\left(\frac{kg}{d}\right) = FE\left(\frac{kg}{km}\right) * D(km)$$

(15)

Where:E: Carbon Dioxide Emission
FE: Emission factor for distance
D: distance traveled

It should be noted that the transport of stone coal materials provided by Propal and of iron provided by Sidoc, transport of these is considered only from these companies to LV concrete structures. Additionally, a carbon footprint calculator was used for calculating CO_2 emissions due to transport of solar panels.

Construction. Construction waste will be generated in a large percentage in LV Concrete Structures and will be transported to the Palmira city dump located in Coronado neighborhood. Based on this information it is considered that CO_2 emissions will be generated by transporting of this waste to the disposal site, and another issue due to the disposal of these wastes on this site. Below, in the next table calculating CO_2 emissions generated by the transportation of waste is shown.

Table 5.9. Calculation of the ecological footprint generated by transporting construction waste

Starting point	Arrival point	Traveled distance (km)	CO_2 emission factor (kg/km)	Emission CO_2 (kg/d)	He (ha)
LV Concrete Structures S.A.	Palmira Dump	24,1	0,5	12,05	0,0023
TOTAL HE					0,0023

Source: The Authors.

Use. In this phase house transport data from Valle University to San Buenaventura University will be considered as well as maintenance of the prototype for academic purposes. Moreover, the determination of the emission of water consumption and solid waste generation is discarded because no food will be consumed in the house nor any service will be provide (Table 5.10).

Table 5.10. Calculation of the ecological footprint generated using the prototype

Starting point	Arrival point	Traveled distance (km)	CO_2 emission factor (kg/km)	Emission CO_2 (kg/d)	He (ha)
Universidad del Valle	Universidad San Buenaventura	6	0,5	3	0,00057

Source: The Authors.

Demolition. Since this prototype will be used for academic activities for a period of approximately 40 years, once this time is over it will be demolished and disposed in the dump of Cali on 50th street, because of this transport emission is also considered (Table 5.11).

Table 5.11. Calculation of the ecological footprint generated by the use of the demolition of prototype

Starting point	Arrival point	Traveled distance (km)	CO_2 Emission Factor (kg/Km)	Emission CO_2 (kg/d)	He (ha)
Universidad San Buenaventura	Dump of Cali (50th street)	9,3	0,5	4,65	0,00089

Source: The Authors.

Calculation of total HW. Considering the ecological footprint values calculated above the sum of these is done, thus obtaining the total footprint of the materials based on the life cycle of each one (Table 5.12).

Table 5.12. Calculation of the ecological footprint of building materials associated with the life cycle analysis

CV phase	He (ha)
Making of materials	6,88
Transport	0,5945
Construction	0,0023
Use	0,00057
Demolition	0,00089
Total he	7,48

Source: The Authors.

Solar Facilities

Solar energy avoid the production of Greenhouse gases (GHG), reduces CO_2 emissions and the excessive consumption and burn of fossil fuels. According to that, here is presented a calculation of Mihouse CO_2 emissions.

CO_2 emissions: For Colombia, each kWh generated produces almost 120 g of CO_2

Table 5.13. CO_2 Emission FACTOR per kWh

Country	Emission factor generation [gCO_2/kwh]
China	764
Usa	542
Bolivia	498
Mexico	467
Chile	375
Spain	361
Ecuador	354
Argentina	343
Panamá	300
Perú	135
Colombia	120
Brazil	81

Source: IEA. (2011).

Between different solar energy technologies or cell types, CO_2 emission change as it is presented on the following table:

Table 5.14. Emission per Technology

Technology	CO_2 g emissions per kwh
Polycrystalline silice	37
Monocrystalline silice	45
Thin film (cdte)	12 – 19

Source: Erik A. Alsema., Mariska J. de Wild-Scholten. (2006).