ECOLOGICAL FOOTPRINT IN INDIRECT COSTS OF CONSTRUCTION

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ABSTRACT

For the environmental analysis is employed the ecological footprint indicator, which is defined as "the area of ecologically productive land (crops, pastures, forests and aquatic ecosystems) needed to produce the resources used and to assimilate the wastes produced by a given population with a level of specific life indefinitely”. In our case this environmental indicator is applied to indirect costs of the building project, allowing calculate the footprint generated by different sources of impact (energy, water, food consumption, mobility and waste). In the budgets of building costs that are attributable directly (direct costs) and indirectly (indirect costs) are identified. These latter costs are all elements that can’t be attributed to a particular unit of work because they are tasks that serve multiple elements simultaneously within the work. A clear example of this type of cost is the foreman (as it acts in the various phases of the work during the performance of all jobs) or crane (which shall work of moving materials, hoisting loads, unloading products from vehicles, etc.). These costs are not usually included in the environmental analysis because they are difficult to quantify. In this analysis the following impacts are taken into account (analyzing and focusing them so that the results can be quantified by this environmental indicator): labor, aids and equipment, installations and works booths, and consumption of energy and water on site. It draws on the Andalusia Construction Costs Database (ACCD), thus adding an environmental party to this baseline, which will produce the ecological footprint produced by these costs along with your budgeting.

Keywords: ecological footprint, indirect costs, database of construction costs, budget.

1.- Introduction and backgrounds

In 1993, the World Wildlife Fund (WWF) defines sustainable construction, not only the buildings themselves but also including its environment and the way they "behave" to form cities. Construction and other agents involved directly or indirectly, have significant environmental impacts in terms of consumption of natural resources and energy or emission of greenhouse gases, hence the need to consider the environmental dimension as key in building approach sustainable. Construction is responsible for over 40% of natural resources, more than 30% of energy consumption and 30% of emissions of greenhouse gases. In addition it is also responsible for a significant part of the consumption of wood and water in the world [1].

The reason for such a large impact must be sought in the process of building, from the manufacture of materials through its construction and subsequent use, and ending with the demolition phase. Currently, in Europe we are faced three major challenges that will shape certainly the development of future generations: the economic crisis, insecurity of energy supplies for its strong external dependence, and climate change caused mainly by increased CO_2 concentrations atmospheric.

Faced with the problem of climate change and the constant needs to implement improvements in the environmental aspect in construction, two professors from the University of British Columbia, Wackernagel and Rees defined the concept of ecological footprint. These researchers created an indicator that allowed the comparison of the environmental footprint caused by continents, countries, regions, etc. They defined the ecological footprint as "the area of ecologically productive land (crops, pastures, forests and aquatic ecosystems) needed to produce the resources used and to assimilate the wastes produced by a given population, with a level of specific life indefinitely " [2].

The indicator ecological footprint (EF) is applied for the first time, the building project by Solis Guzman [3], where calculates the footprint generated by different sources of impact (energy, water, food consumption, mobility, building materials, waste and floor area).

The previous model in determining the ecological footprint of existing indirect costs in construction projects is developed. Machinery, labor and consumption of electricity and water on site: Therefore, the analysis of the different components that form part of these addresses.

2.- Indirects costs

Indirect costs are all those elements that can not be attributed to a single activity within the construction works due to perform functions within the work, such as site supervisor (as it acts in the various phases of the work during the completion of all jobs) or crane (which shall work of moving materials, hoisting loads, unloading of goods from vehicles ...). Taking the Andalusia Construction Costs Database (ACCD), has undertaken a study of indirect costs attributable to a project, collecting all the elements of this group of costs, Table 1.

Each concept of indirect costs is transformed into useful data to calculate the HE, which are shown in Table 1 (effective annual hours of labor, fuel consumption by machinery, consumption of water and electricity in the worksite, etc.), indicating the various coefficients to be used to perform the aforementioned calculation.

CODE	CONCEPT	UD	COEFFICIENTS		
C12	**INDIRECTS COSTS OF IMPLEMENTATION**		**Staff**		
C121	**INDIRECT MANPOWER**		h/month		
C1211	*Manager*	*month*	127,08		
C1212	*Foremen*	*month*	127,08		
C1213	*Storekeeper*	*month*	127,08		
C1214	*Guard*	*month*	127,08		
C122	**ASSISTANT RESOURCES**		**Staff**		
C1221	*Assistant Labor*		h/m^2		
C12211	Personal inland transport	m^2	0,02		
C12212	Cleaning and watered personal	m^2	0,05		
C1223	*Machinery, Equipment and Tools*		**Staff**	**Power Consumption**	**Fuel Consumption**
C12231	Lifting Means		h/month	kWh/month	l/month
C122311	Crane	*month*	127,08	1.525,00	
C122312	Crane assembly and disassembly	u.			
C122313	Telehandler	*month*	101,67		1.830,00
C122314	Lifting platform	*month*	101,67	305,00	
C122315	Elevator	*month*	101,67	305,00	
C12232	Concrete mixer	*month*	101,67	149,450	
C12233	Cutter	*month*	101,67	162,667	
C123	**ANCILLARY AND COMPLEMENTARY FACILITIE**		**Staff**	**Power Consumption**	**Water Consumption**
C1231	*Worksite*		h/u	kWh/m^2	m^3 water/m^2 worksite
C12311	Oficces	m^2		208,00	0,16
C12312	Meeting rooms				
C12313	Stores	m^2		208,00	0,16
C12321	Electric rush	u	1,31		
C12322	Water and sewerage rush	u	0,26		
C12323	Power lines	u	0,00		
C12324	Provisional wáter system	u	0,00		
C1233	*Vials, location and stake*	*u*	0,76		
C124	**STAFF**		**Staff**		
C1241	*Technical Affiliated to Work*		h/month		
C12411	Site Manager	*month*	127,08		
C12412	Production Manager	*month*	127,08		
C12413	Aids Technicals	*month*	127,08		
C1242	*Administrative Permanently Assigned to Work*	*month*	127,08		
C125	**SEVERAL**				
C12531	*Lighting*	m^2		1,49	
C12532	*Testing Facilities Service*	m^2		1,11	

Table 1 “Table to convert initial data in data HE”

Once the initial data are processed in insertable concepts in the methodology for calculating the HE, we obtain the following elements: manpower, machinery, electricity and water consumption for worksite, lighting in the area of work and initial testing service facilities, which will be explained below.

2.1.- Machinery

At this point the footprint caused by the use of machinery, specifically for their energy, linking the engine power is studied. For fuel it uses the "Manual Machine" prepared by SEOPAN [4], where the technical data of different models and types of machines on the market are collected, and can be summarized as follows:

- Oil: 0.15 to 0.20 liters consumed in 1 hour per kW installed.
- Gasoline: 0.30 to 0.40 liters consumed in 1 hour per kW installed.

The previous coefficient is applied to power the engine for each liter of fuel consumed, differentiating whether the machine uses gasoline or diesel oil.
After obtaining the liters of fuel consumed, fuel energy intensity (MJ / l) representing the energy produced per liter of fuel is applied. This figure is multiplied by the corresponding energy productivity, which is in turn the amount of forest land required to absorb the emissions produced per 1 MJ of energy, being all collected in the following expression [5]:

$$EF_f = ((C \times IE)/Pc) \times FEb \qquad (1)$$

Where:
Ef_f: Fuel consumption footprint (fossil) Machinery (ha)
C: fuel consumption (liters)
IE: energy intensity (MJ / liter)
Pc: energy productivity of diesel or gasoline (MJ / ha)
FEb: equivalence factor of forests (gha / ha)

2.2.- Manpower
An analysis of the impacts generated by workers at work is performed: food consumption, generation of municipal solid waste (MSW) and mobility, as shown in Figure 1, entering each defined below.

- **EF caused by food**

For the trace produced by the power of workers, it is necessary to obtain the total number of hours of labor needed in the development project and hem coefficient, which represents the footprint per meal made during the workday, reflecting all in the following equation [5]:

$$EF_{food} = (EF_m / h_m) \times h_{total} \qquad (2)$$

Where:
EF_{food}: EF produced by food consumption (gha / year)
EF_m: EF each meal served expressed in hag / year / food
h_m: is 8 hours / food. A meal is assumed for labor day
h_{total}: total hours worked by all employees

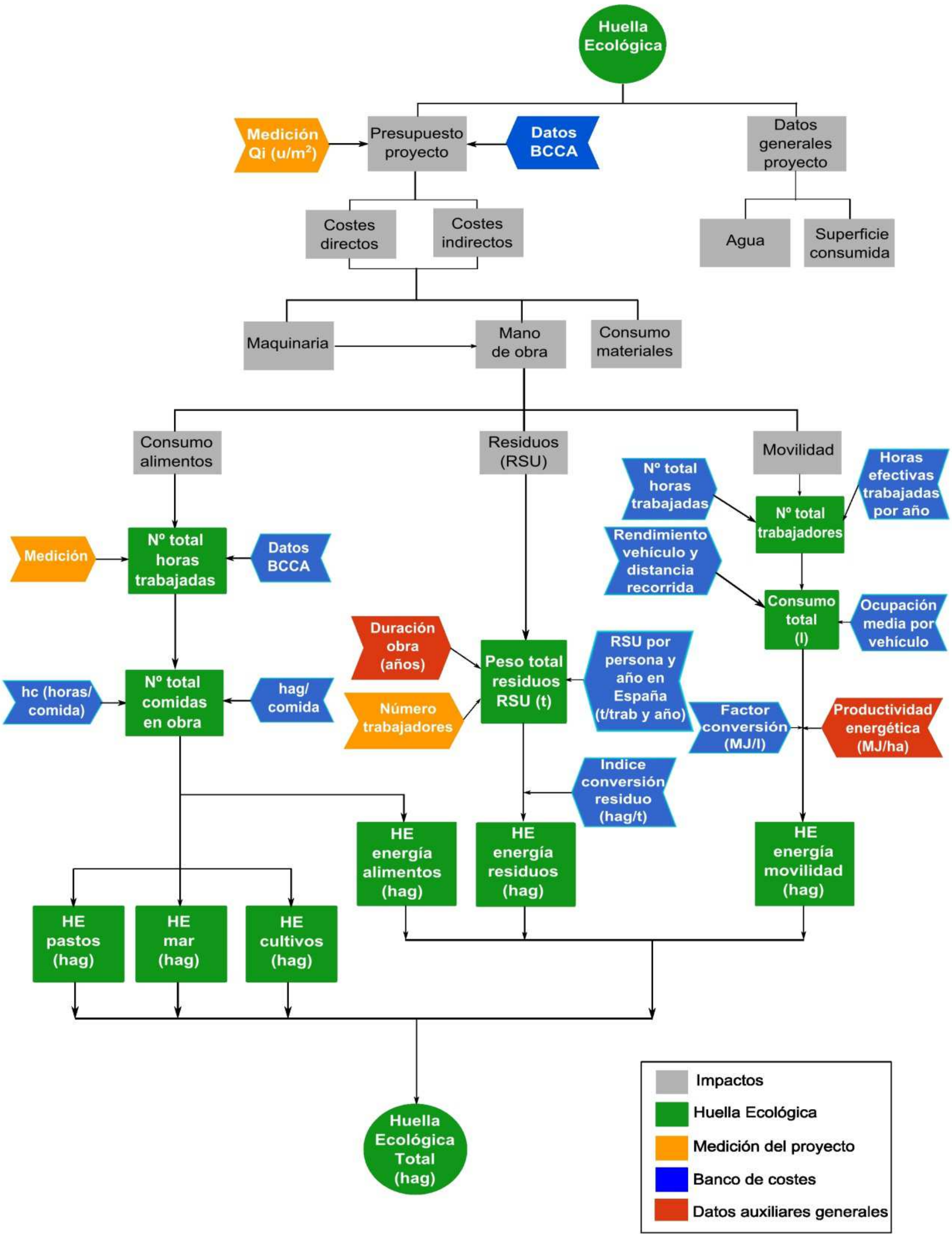

Figure 1 “Scheme for calculating the HE produced by labor”

Therefore, it is necessary to get the HEM factor of various types of foods that make up the daily food of each worker [6], which generate four types of productive land: pasture, cropland, productive sea and forests. Each food produce two types of trace, that caused by the consumption of the food itself (meats generate HE pasture, fish will generate HE productive sea, cereals will generate HE farmland ...), and produced by handling and food processing throughout the process.

Each coefficient will join based on their productive territory obtaining footprint caused by each food. The four categories are added in turn to obtain a general coefficient that relates the total footprint produced by each meal made. Applying these data served menus, which in turn depend on the hours of working, the HE is obtained caused by consumption of food.

- **Mobility EF**

To analyze the mobility of workers, the hypothesis that the work is located at a distance of 30 km from where they live operators and four workers share a car to go to work is established. The performance of the vehicles used by the distance traveled generates liters consumed, and its footprint is obtained as in the case of machinery.

- **EF of municipal solid waste (MSW)**

In assessing waste generation rate average municipal solid waste (MSW) of the Environmental Report in Andalusia [7] is used; so applying this indicator the number of workers on site the amount of MSW generated is obtained. This amount is divided into type organic waste, paper, plastic, glass and other (where metals are included); to which they apply conversion rates; based Wackernagel studies [8], which take into account the energy intensity required for treatment, the amount recycled, energy productivity and factor equivalence of forests than be responsible for absorbing the CO2 produced by all processes . Thus a coefficient indicating HE produced per ton of MSW is obtained. Thus a coefficient indicating HE per tonne of waste produced is obtained, the above steps are summarized in the following equation [5] and reflected in Table 6.

$$EFpr = \Sigma_i \, IC_{RNPip} \times Ci \qquad (3)$$

Where:

EFr: ecological footprint of waste (gha)

IC_{RNPip}: weighted index conversion (gha / t)

Ci: consumption (t)

2.3.- Electricity and water consumption

For the energy consumption of the houses, has been considered as enshrined in the ITC-BT-10 [9] established a consumption of 0.10 kW / m2 for use in commercial and office buildings. Taking this and the total hours of use of office (it has been hypothesized to take eight hours a day for 5 days a week and 52 weeks a year) can get the kWh of electricity they have consumed.

To enter the electricity consumption for lighting plot, the small equipment and service testing; was first elected to apply on the surface of the plot Royal Decree 486/1997 [10] of April 14, laying down minimum safety and health are set out in the workplace, where the level indicated lighting least 100 lux (lumen / m2). With this data set and hours of operation (half hours booth), we obtain that generate electricity consumption lighting work area.

Thus, the lighting plot work remaining to be determined initial testing service new facilities contemplated executed. To resolve these issues, have been analyzed electric bills 30 projects provided by the company ENDESA, obtaining the total kWh consumed by type of work and the plot area where he acted. It has generated a coefficient that relates the kWh consumed with m^2 plot can obtain the total power consumption of the work. Comparing this data with elements already calculated (power consumption of the booths and electrical machinery) we can see that the discrepancy is 15% (as shown in Table 2); defining this amount as consumption testing facilities for project completion.

ENDESA CALCULATION		
CONCEPT	**kWh**	**gha**
Electrical Consumption	*123.797,74*	*12,517*
EF Total	***123.797,74***	***12,517***

C.IND+MACHINERY CALCULATION		
CONCEPT	**kWh**	**gha**
Electrical Machinery	*33.689,78*	*3,40*
Indirect Cost (Electrical)	*71.411,43*	*7,22*
EF Total	***105.101,21***	***10,62***

Table 2 “Real consumption and prediction model”

Are assigned to testing commissioning of the facilities power of 1.11 kWh per m2 of floor area, and duration of the tests the same as the lighting, allowing establish a power level surface plot.
It also takes into account the system performance electric production is 33% [11], and the amount of primary energy is calculated. Such consumption (in GJ) becomes hectares of energy footprint by applying the equivalence factor of forests, which will be responsible for absorbing these emissions. It has established a division according to the energy source (coal, oil, natural gas or nuclear power) with data provided by the Ministry of Industry in 2013 [12]. All these steps are reflected in the following equation [5]:

$$EF = (C / (\Sigma i \; Pci \times \%i)) \times FEb \quad (4)$$

Where:

EF: ecological footprint of electricity consumption (gha).

C: consumption (GJ).

Pci: energy productivity of fuel i (coal, natural gas ...) (GJ / ha).
% i: percentage of fuel i in the energy mix of the Ministry
FEB: equivalence factor of forests (gha / ha).

To get water from the toilets and changing rooms placed in work has analyzed Table 3.1 of CTE-DB-HE [13] "Demand reference to 60" establishing a domestic hot water consumption per person per day. This figure has increased by 25% for the use of the toilets, and applying the number of employees and total days worked liters of water consumed are obtained.
To this total amount of water is applied the concepts of productivity of forests, equivalence factor and factor productivity for the forest footprint. All this is reflected in the following formula [5]:

$$EF_{water} = (C/Pb) \times FEb \quad (5)$$

Where:
EF: Forestry ecological footprint (ha).
C: consumption (m^3).
Pb: Productivity (m^3 / ha).
FEb: equivalence factor of forests (gha / ha).

3.- Results
3.1.- Practical cases
To validate the proposed methodology and see the sensitivity level indicator HE in development work, the analysis of two development projects arise, the first residential plot in La Palma del Condado with a budget of material execution of 187

613, € 37 and a surface area of 7123.78 m2 [5]. The second corresponds to a proposed development of an industrial zone in Écija with a budget of material execution of € 13,427,115.05 and a plot of 620,256 m2 [14].

CODE	CONCEPT	UD	QUANTITY	ECOLOGICAL FOOTPRINT
C12	**INDIRECTS COSTS OF IMPLEMENTATION**			
C121	**INDIRECT MANPOWER**			
C1211	*Manager*	*month*	3,00	2,7642
C1212	*Foremen*	*month*	3,00	2,7642
C1213	*Storekeeper*	*month*	2,00	1,828
C1214	*Guard*	*month*	3,00	2,7642
C122	**ASSISTANT RESOURCES**			
C12211	*Assistant Labor*	m^2	16.000	2,8521
C12212	Personal inland transport	m^2	16.000	5,2783
C12213	Cleaning and watered personal	m^2	16.000	4,7400
C123	**ANCILLARY AND COMPLEMENTARY FACILITIES**			
C12311	Oficces	m^2	20,00	0,1131
C12313	Stores	m^2	80,00	0,4524
C12321	Electric rush	u	1,00	0,2380
C12322	Wáter and sewerage rush	u	1,00	0,0476
C12323	Power lines	u	1,00	0,1585
C12324	Provisional water system	u	1,00	0,0317
C1233	*Vials, location and stake*	*u*	1,00	0,1376
C124	**STAFF**			
C12411	Site Manager	*month*	3,00	2,7642
C1242	*Administrative*	*month*	3,00	2,7642
C125	**SEVERAL**			
C12531	*Lighting*	m^2	16.000	2,4036
C12532	*Testing Facilities Service*	m^2	16.000	1,8027

Table 3 “Footprint of indirect costs in the residential project”

In the first project have been defined analyzed indirect costs according to the data shown in Tables 3 and 4, obtaining an ecological footprint of 32.167 gha. In total, the resulting ecological footprint of urbanization is 260 gha.
In the project we are analyzing are defined indirect costs according to the data shown in Tables 5 and 6, obtaining an ecological footprint of 1275.38 gha. The resulting total EF of industrial urbanization is 12834.46 gha

Ecological Footprint (gha)	Fossil	Forests	Pastures	Sea	Crops
Indirect Costs	8,03	0,04	11,77	8,01	4,26
Total	**8,03**	**0,04**	**11,77**	**8,01**	**4,26**

Tabla 4 “Huella ecológica en el proyecto residencial”

CODE	CONCEPT	UD	QUANTITY	ECOLOGICAL FOOTPRINT
C12	**INDIRECTS COSTS OF IMPLEMENTATION**			
C121	**INDIRECT MANPOWER**			
C1211	*Manager*	*month*	24,00	22,6347
C1212	*Foremen*	*month*	24,00	22,6347
C1213	*Storekeeper*	*month*	12,00	11,3173
C1214	*Guard*	*month*	12,00	11,3173
C122	**ASSISTANT RESOURCES**			
C12211	*Assistant Labor*	m^2	1.074.812,00	196,1067
C12212	Personal inland transport	m^2	1.074.812,00	362,9355
C12213	Cleaning and watered personal	m^2	1.074.812,00	362,9355
C123	**INSTALACIONES, ACCESORIAS Y COMPLEMENTARIAS**			
C12311	Oficces	m^2	20,00	1,0741
C12313	Stores	m^2	80,00	4,2965
C12321	Electric rush	u	1,00	0,2436
C12322	Wáter and sewerage rush	u	1,00	0,0487
C12323	Power lines	u	1,00	0,1624
C12324	Provisional water system	u	1,00	0,0325
C1233	*Vials, location and stake*	*u*	1,00	0,1409
C124	**STAFF**			
C12411	Site Manager	*month*	24,00	22,6347
C1242	*Administrative*	*month*	12,00	11,3173
C125	**SEVERAL**			
C12531	*Lighting*	m^2	1.074.812,00	161,4656
C12532	*Testing Facilities Service*	m^2	1.074.812,00	121,0992

Table 5 “Footprint of indirect costs in the industrial project”

Ecological Footprint (gha)	Fossil	Forests	Pastures	Sea	Crops
Indirect Costs	357,13	1,16	389,64	265,26	141,10
Total	**357,13**	**1,16**	**389,64**	**265,26**	**141,10**

Table 6 “Ecological Footprint in the industrial project”

4.- Discussion y results

Then, the results of the two cases discussed above are shown by graphics (figure 2), where is represented the trace produced by the indirect costs within the overall footprint.

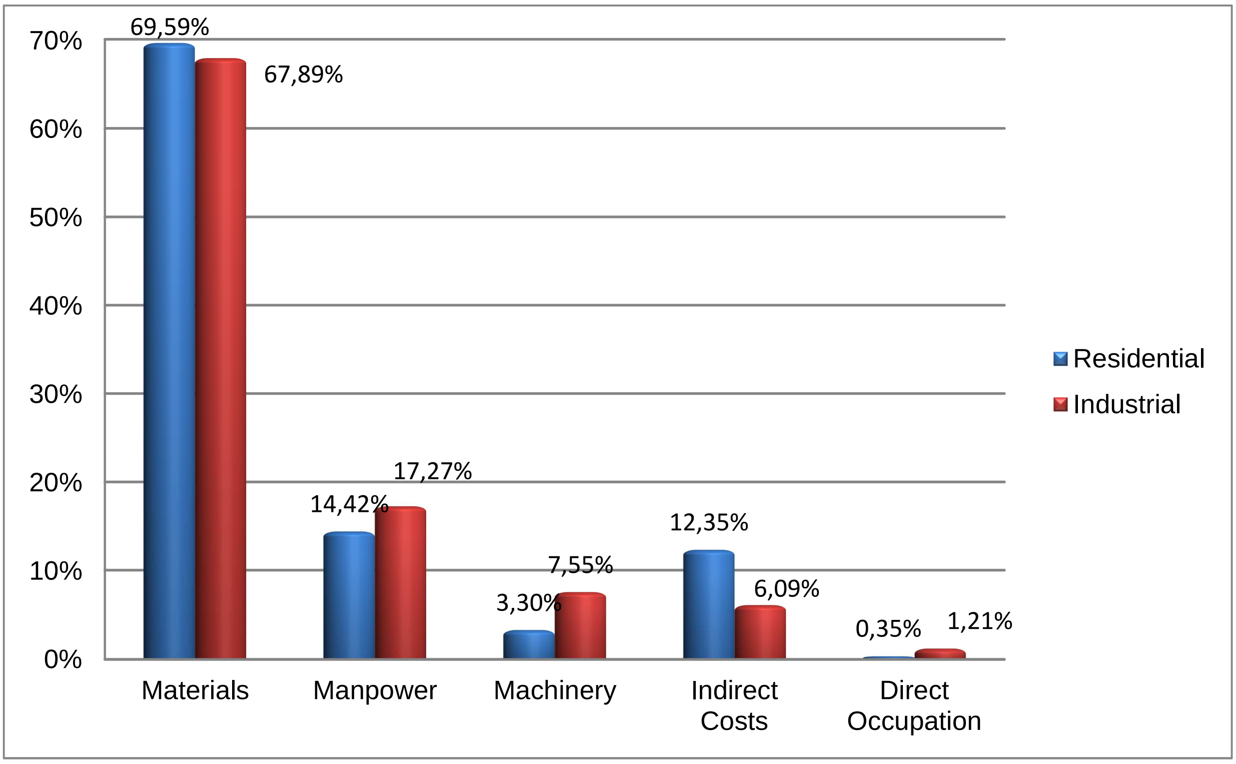

Figure 2 "Percentage of Indirect Costs within the total footprint"

5.- Conclusion

Noting the results obtained in the two cases analyzed, it may indicate that the footprint produced by the indirect costs represent between 11% and 12% of the total project footprint.

Thus, it is reflected that the environmental importance of indirect costs is similar almost to the economic, as in the projects is often attributed to them by 13% of those costs.

The methodology to calculate the HE produced by the indirect costs, referencing with the Andalusia Construction Costs Database, showing that it is possible to add the environmental aspect to the budgets of the work, since all the developed methodology is perfectly extrapolated to any project budget to follow a systematic classification of work.

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