ASSESSING SUSTAINABILITY WITHIN THE CONSTRUCTION INDUSTRY BY MEANS OF A COMPOSITE INDICATOR

EVALUACIÓN DE LA SOSTENIBILIDAD DE LA INDUSTRIA DE LA CONSTRUCCIÓN MEDIANTE UN INDICADOR COMPUESTO

OSCAR O. ORTIZ-RODRÍGUEZ

PhD., Universidad de Pamplona. Pamplona, Colombia, oscarortiz@unipamplona.edu.co

RAFAEL G. GARCÍA-CÁCERES

PhD., Escuela Colombiana de Ingeniería "Julio Garavito". Bogotá, Colombia, rafael.garcia@escuelaing.edu.co

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ABSTRACT: As a result of the Agenda 21, presented nearly two decades ago, the Millennium Development Goals (MDG) were set and must be met by the year 2015. Nowadays, governments, researchers, engineers, environmental scientists and other stakeholders involved in the industry are working more jointed for improving environmental and socio-economic indicators for sustainability of the Building Industry. The relevance of the residential building sector is evident for its fast growing rate during the last two decades. This paper presents an analysis on the sustainability of the residential building sector in two different countries: Colombia and Spain, by measuring and evaluating a composite indicator (CI). A factor analysis (FA) with principal components extraction was employed to calculate the CI in order to evaluate the evolution of the residential building sector in two core aspects: socio and economic conditions.

KEYWORDS: Composite indicator, sustainability, building sector

RESUMEN: Como resultado de la Agenda 21, planteada cerca de dos décadas atrás, fueron fijados los Objetivos de Desarrollo del Milenio que deben cumplirse para el año 2015. Hoy día, gobiernos, investigadores, ingenieros, ambientalistas y otros actores involucrados en la industria han unido esfuerzos para mejorar indicadores socioeconómicos y medioambientales para la sostenibilidad de la Industria de la Construcción. La relevancia del sector de la construcción residencial se manifiesta en su fuerte tasa de crecimiento durante las últimas dos décadas. Este trabajo presenta un análisis de la sostenibilidad mediante la medición y evaluación de un indicador compuesto que puede influir en las condiciones socioeconómicas de dos países: Colombia y España. Se utilizó un análisis factorial con extracción de componentes principales para calcular el indicador compuesto y evaluar la evolución del sector de la construcción residencial en los dos países en dos aspectos claves: sociales y económicos.

PALABRAS CLAVE: Indicador compuesto, sostenibilidad, sector de la construcción.

1. INTRODUCTION

There have been plenty of definitions of sustainability and sustainable development, but most agree that both terms can be described as enhancing quality of life and thus allowing people to live in a healthy environment and improve social, economic and environmental conditions for present and future generations [1]. Since the World Commission on Environment and Development (WCED), published the work "Our Common Future in 1987", sustainable development has gained much attention in all nations. This report called for a strategy that united development and the environment through of a declaration that define Sustainable Development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs [Ibid]. The United Nations Commission on Sustainable Development (CSD) was created in 1989 to promote an action plan on the progress of the Agenda 21. The Agenda 21 is a strategic document adopted by the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in 1992, for which indicators for monitoring progress towards sustainable development are needed in order to assist decision-makers and policy-makers at all levels and to increase focus on sustainable development [2].

The construction industry is a worldwide key sector and a highly active one in both developed and developing countries, which is particularly relevant in these days of economic renewal activities by governments. This sector is gaining attention through the practice of environmental building performance assessment, in which sustainable development has emerged as one of the key issues due to the significant effects of building on the environment [3], in particular due to its energy intensity, with corresponding Greenhouse Gas (GHG) emissions, and its land use. Therefore, improving social, economic and environmental indicators for sustainable development are drawing attention to the construction industry [4, 5].

Research studies explicitly dedicated to sustainability indicators have been done, linking sustainability issues and exploring their usefulness as a concept and the different types of indicators that might be used for different things [6, 7, 8].

Within the construction industry there is considerable research done on indicators of sustainability. A relevant research to measure the sustainability indicators of buildings is the work "*Leadership in Energy and Environmental Design*", done in the United States by the Green Building Council (USGBC) [9, 10]. In Europe, the Building Research Establishment (BRE) provides a Sustainability Checklist for Developments, whilst Comprehensive Project Appraisal provides an interesting attempt at a generic form of assessment for sustainability within development or regeneration schemes [11,12]. In Latin America the framework of the Energy and Sustainable Development Project being conducted jointly by the Latin American Energy Organization (OLADE), the Economic Commission for Latin America and the Caribbean (ECLAC), and the German Technical Cooperation Agency (GTZ), conducted a series of case studies focusing on a wide range of countries in the region, essentially to examine how energy policies contribute to enhancing sustainable development [13].

The development of indicators for the (comprehensive) wealth of a nation (or a region) is a useful way towards securing sustainable development at the national or regional levels [14]. An indicator in essence is simply a signal or a group of signals that relay a complex message, from potentially numerous sources, in a simple and useful manner [15]. An indicator should both help communities identify how current practices are performing through policy relevant, and scientifically valid measurements [16]. Furthermore, an indicator can perform many functions. This can lead to better decisions and more effective actions by simplifying, clarifying, and making aggregated information available to policy makers. They can help incorporate physical and social science knowledge into decision-making, and they can help measure and calibrate progress toward sustainable development goals. They can provide an early warning to prevent economic, social and environmental setbacks. They are also useful tools to communicate ideas, thoughts and values [17, 18].

Hence, data availability plays an important role to measure sustainability performance of a country or region, as it enables a nation or region to be described through quantitative tools [19]. Resource and researcher time availability dictate the number of indicators which may be included in a study: if too few are employed, important information is excluded, but if too many are included, adequate time is often not available for data collection and analyses [20] and communities should ask, "What sort of things do we need to measure to form a sensible picture of sustainable development?" [16]. Therefore, this paper aims to contribute to the composite indicators (CIs) studies, in order to address sustainability indicators integrating environmental, and socio-economical aspects to analyse the impact of sustainability, within the residential building sector.

2. METHODOLOGY

A composite indicator (CI) is a mathematical aggregation of a set of individual indicators that measure multi-dimensional concepts that usually have no common units of measurement [21]. Despite the ceaseless debate on its use, CIs have been increasingly used for performance monitoring, benchmarking, policy analysis and public communication in wide ranging fields, e.g.economy, environment and society, by many national and international organizations [22]. The number of CIs in existence around the world is growing year after year to provide simple comparisons of countries, that can be used to illustrate complex and sometimes elusive issues in wide ranging fields, e.g., environment, economy, society or technological development [23-25].

The CI has been calculated using the "*Handbook on constructing CIs: methodology and user guide*" using the following steps [21]:

1. Theoretical framework which provides the basis for the selection and combination of variables into a meaningful CI.

2. Data selection which is based on the analytical soundness, measurability, country coverage and relevance of the indicators to the phenomenon being measured and relationship to each other.

3. Multivariable analysis is used to study the overall structure of the dataset, assess its suitability, and guide subsequent methodological choices. Factor analysis (FA) is used as a multivariable analysis technique in order to reduce and reveal how different variables change in relation to each other, and how they are associated. The main objective of FA is the orderly simplification of a large number of inter-correlated measures, to a few representative constructs or factors. The FA has three basics steps which are presented in the sections 2.1 to 2.3 [26]:

2.1. About of the correlation matrix

The FA is based on correlations between measured variables, so a correlation matrix containing the inter-correlation coefficients for the variables must be computed. In this work was used the most popular FA technique, Principal Components.

2.2. Extraction of initial factors

In this phase, the number of common factors needed to adequately describe the data is determined. To do this, the researcher must decide the method of extraction, and the number of factors selected to represent the underlying structure of the data. If the purpose is no more than to "reduce data" to obtain the minimum number of factors needed to represent the original set of data, then Principal Component Analysis is appropriate for determining the number of initial unrotated factors to be extracted. Only factors with eigenvalues of 1 or greater are considered to be significant; all factors with eigenvalues less than 1 are disregarded. An eigenvalue is a ratio between the common (shared) variance and the specific (unique) variance explained by a specific factor extracted. The rationale for using the eigenvalue criterion is that the amount of common variance explained by an extracted factor should be at least equal to the variance explained by a single variable (unique variance) if that factor is to be retained for interpretation. An eigenvalue greater than 1 indicates that more common variance than unique variance is explained by that factor.

2.3. Rotation of the extracted factors

Factor analysis has been used because the goal of the CI is no more than to "reduce the variables" to fewer factors, although sometimes the number of factors could be equal, but without reducing the relevant information contained in these. In the FA the factors obtained are uncorrelated. The rotation is usually used because this procedure allows a better view of the data. The rotation procedure used in this work is Varimax, which minimize the number of variables with high loadings on each factor, and thus simplifying the interpretation of factors. A factor loading structure can provide suggestions in this regard as loads higher than 0.6 are considered important, and those under 0.4 are low.

The final step for calculating the CI is visualization. This shows the results that should receive proper attention in order to enhance interpretability.

3. DATA

Historical data were taken in the period 1990 to 2007. This time series was then used as the basis for evaluating the CI within the residential building sector in both countries. The main sources of information have been taken from national database statistics; in Spain from the Spanish National Statistics [27] and the Official Statistics website of Catalonia, 2009; and in Colombia, from the National Administrative Department of Statistics, 2006, and the Mining and Energy Planning Unit, which is a special administrative entity assigned to the Ministry of Mines and Energy, 2009. Also an international database from the International Energy Agency (IEA), 2006 has been used [28].

4. RESULTS AND INTERPRETATION

4.1. Results of the CI

In this paper we have attempted to demonstrate the usefulness of this method in the construction sector by downsizing data, i.e. variables were used to represent the construction and building sector.

Examination of the correlation matrix concluded that there are high correlations between the nineteen Spanish variables and the seventeen Colombian variables. For example, in Spain the inter-correlations between the variables of *natural_growth*, *GDP_construction* and *housing_finishing* are greater than 0.90. Similarly, the inter-correlations between *cement_production*, *energy_consumption* and *housing_finishing* are also greater than 0.90. In Colombia the inter-correlations between the variables of *natural_growth*, *total_exportation* and *primary_energy* are greater than 0.85. Similarly, the inter-correlations between *electricity_generation*, *GDP_construction* and *GDP_services* are also greater than 0.85.

We analyze the communalities in order to present the proportion of variance in each variable accounted by the common factors. As can be seen in Table 1, for the Spanish case, the worst variable is *cement_import*, meaning that the model is only capable to represent a 65.1% of the original variability. Meanwhile, for the Colombian case the worst one was *initial_*m^2 *built* with 61.4%.

Using the criterion of retaining only factors with eigenvalues of 1 or greater, the first three factors will be retained for rotation. For the Spanish case, there are three factors with eigenvalues greater than 1, meaning that 92.52% of the total variance is attributable to these three factors.

Table 1. Communalities for the Spanish and Colombian case studies.

	Spain		Colombia	
	Initial	Extraction	Initial	Extraction
Year	1.000	0.951	1.000	0.981
Natural_growth	1.000	0.991	1.000	0.982
Employment_sector	1.000	0.995	1.000	
Housing_Starting	1.000	0.888	1.000	
Housing_Finishing	1.000	0.978	1.000	
GDP	1.000	0.899	1.000	0.903
GDP_Construction	1.000	0.894	1.000	0.940
Index_price_clinker	1.000	0.892	1.000	
Clinker_production	1.000	0.979	1.000	
CO2_Clinker	1.000	0.978	1.000	
Clinker_Export	1.000	0.740	1.000	0.735
Clinker_Import	1.000	0.965	1.000	0.973
Index_price_cement	1.000	0.928	1.000	
Cement_production	1.000	0.991	1.000	0.980
Cement_export	1.000	0.893	1.000	0.937
Cement_import	1.000	0.651	1.000	0.833
Cement_ Consumption	1.000	0.994	1.000	
Emissiones_CO2	1.000	0.991	1.000	
Energy_ consumption	1.000	0.980	1.000	0.948
Initial_m2			1.000	0.614
Total_Expor_FOE			1.000	0.969
Total_Impor_FOE			1.000	0.966
Consumption			1.000	0.964
Consump_Construc			1.000	0.849
Primary_energy			1.000	0.949
Final_PE_ consumption			1.000	0.918

Extraction Method: principal component analysis

The remaining sixteen factors altogether account for approximately 7.48% of the variance. In Colombia, the first three factors accounted for 90.83% (56%, 21.34% and 13.47%, respectively) of the total variance. Thus, a model with three factors can be adequate to represent the CI.

So, the rotation component matrix presents the three factors after varimax (orthogonal) rotation, which has the main purpose to achieve a simpler, theoretically more meaningful, factor pattern. Varimax was applied because of it widespread use as it seems to give the clearest separation of factors. It does this by producing the maximum possible simplification of the columns (factors) within the factor matrix as shown in Table 2 and Table 3.

Comparing the component matrix, which represents the unrotated component analysis factor matrix, that presents the correlations that relate the variables to the three factors, it can be seen that in Spain, the first component is supported for variables such as: *employment_sector*, *housing_finishing* and *cement_production*. The second factor is composed of both GDP indexes which represent the economic aspect within the building sector, The last factor shows that the variables are not related to factor 3. In Colombia, see Table 3, variables as *total_Expor_FOE* weighted highly on factor 1; variable *consumption*, on factor 2; and variable *final_PE_consumption*, on factor 3.

Examination of these factors shows that in Spain thirteen of the nineteen variables weighted highly on the first factor. Meanwhile, in Colombia four of the eighteen variables weighted highly on the second factor.

Figure 1 shows the CI within the Spanish and Colombian building sector from the first and second factor respectively. In Spain, as a result of the multivariable analysis, from nineteen indicators including socio-economic indexes, the percentage of variance of the first factor was 73.03%. All of the explanatory variables are correlated with *housing_finished* except for *cement_import*. The Spanish indicator showed the crisis occurred between 1993 and 1996, and its latter growth in 1997. Results show that there is a strong correlation between the *housing_finished* and the other variables studied, except for exportation of cement. It can be concluded that as the Spanish economy becomes more active, with its population increasing and building new buildings, electricity consumption will also increase. As the correlation between electricity consumption and cement exportation is weaker, there is an indication that such end-uses are more dependent on GDP than price. Then, as more electricity is consumed by its inhabitants the higher GDP production will be. In Colombia the CI was determined from a total of seventeen indicators, from this the evolution within the construction industry during the last ten years can be clearly seen. It is possible to observe two main periods with different growth rates (1991 – 1994 and 2001 – 2007).

Table 2. Rotated component matrix [(a)] for the Spanish scenario.

	Component		
	1	2	3
Natural_growth	0.993		
Energy_consumption	0.980	0.137	
Employment_sector	0.977	0.142	0.146
CO2_Clinker	0.966	0.210	
Clinker_production	0.966	0.213	
Housing_Finishing	0.963	0.179	0.138
Year	0.957	0.153	-0.107
Clinker_Import	0.952	0.167	0.175
Index_price_cement	0.952		-0.146
Index_price_clinker	0.922		-0.193
Cement_production	0.919	0.338	0.182
Emissiones_CO2	0.918	0.339	0.182
Cement_Consumption	0.914	0.311	0.249
Housing_Starting	0.772	0.520	0.151
Cement_export	-0.723		-0.608
GDP_Construction		0.944	
GDP	0.150	0.923	-0.157
Cement_import	-0.184	-0.120	0.776
Clinker_Export	-0.502	-0.453	-0.532

Extraction method: principal component analysis

Rotation method: Varimax with Kaiser normalization [(a)]
Rotation converged in 5 iterations

The low growth rate from 1998 to 2002 was due to economic problems that drove the country into a recession.

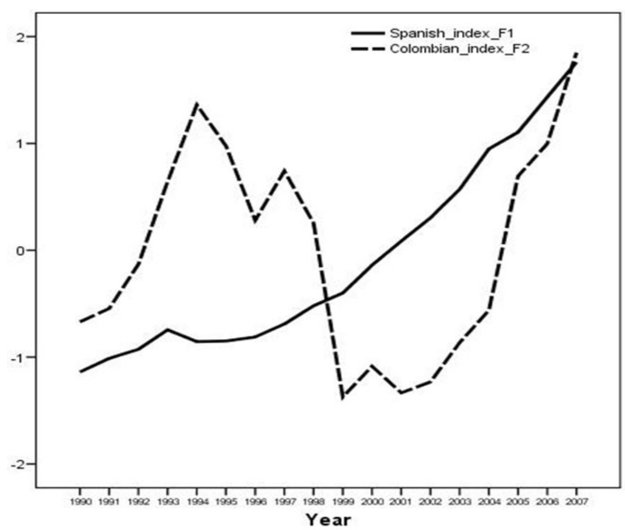

Figure 1. CIs for Spain and Colombia.

Table 3. Rotated component matrix [(a)] for the Colombian scenario.

	Component		
	1	2	3
Year	0.985		
Natural_growth	0.980		-0.132
Cement_Expor	0.959	-0.130	
Primary_energy	0.957		-0.177
Electricity_generation	0.918	0.319	
Total_Expor_FOE	0.875	0.403	0.201
GDP_Services	0.815	0.419	0.253
Total_Impor_FOE	0.800	0.569	

	Component		
	1	2	3
GDP_Construction	0.656	0.653	0.290
Clinker_Expor	-0.635	-0.574	
Clinker_Import	0.320	0.932	
Cement Consumption	-0.306	0.930	
Cement_Prod	0.421	0.894	
Initial_m2		0.774	
Final_PE_consumption		0.350	0.889
Consump_Construc	-0.245	-0.124	0.879
Cement_Impor	-0.450	0.404	-0.684

Extraction method: principal component analysis

Rotation method: Varimax with Kaiser normalization
[(a)] Rotation converged in 5 iterations

Finally, as a result of the scores analysis, Table 4 shows the coefficient matrix which contains the weighting coefficient of each variable in the calculation factor. Combining each of these coefficients, explanatory variables were chosen to estimate the factorial scores for the Spanish and Colombian index:

From nineteen Spanish variables and seventeen Colombian variables, the regression equation attains the adjusted coefficient of determinations. Thus the prediction **(1)** is:

$$Y' = A + B_1X_1 + B_2X_2 + \cdots + B_nX_n \quad (1)$$

Where Y' is the predicted dependent variable, A is a constant value, B is the unstandardized regression coefficient, and X is the value of the predictor variable.

Therefore, looking at the component coefficient matrix in Table 4, two linear equations **(2.1; 2.2)** can be built, based on the calculation of the factor score.

$Y_{(\text{Spanish CI})}$: -1.13900 X_1 - 1.01182 X_2 - 0.92724 X_3 - 0.74408 X_4 - 0.85500 X_5 - 0.84893 X_6 - 0.81131 X_7 - 0.68992 X_8 - 0.51988 X_9 - 0.39987 X_{10} - 0.13997 X_{11} + 0.08528 X_{12} + 0.30367 X_{13} + 0.57124 X_{14} + 0.94905 X_{15} + 1.10554 X_{16} + 1.43451 X_{17} + 1.76108 X_{18} + 1.87666 X_{19} ***(2.1)***

$Y_{(\text{Colombian CI})}$: -0.66989 X_1 - 0.54482 X_2 - 0.13236 X_3 + 0.64147 X_4 + 1.36130 X_5 + 0.97627 X_6 + 0.28045 X_7 + 0.74207 X_8 + 0.25255 X_9 - 1.37236 X_{10} - 1.08515 X_{11} - 1.33429 X_{12} - 1.23256 X_{13} - 0.86379 X_{14} - 0.56218 X_{15} + 0.69500 X_{16} + 0.99754 X_{17} + 1.85076 X_{18} ***(2.2)***

Table 4. Summary for the linear equation of the factor score [(a)]

	Spanish	Colombian
	REGR factor score 1 for analysis 1	REGR factor score 2 for analysis 1
1	-1.13900	-0.66989
2	-1.01182	-0.54482
3	-0.92724	-0.13236
4	-0.74408	0.64147
5	-0.85500	1.36130
6	-0.84893	0.97627
7	-0.81131	0.28045
8	-0.68992	0.74207
9	-0.51988	0.25255
10	-0.39987	-1.37236
11	-0.13997	-1.08515
12	0.08528	-1.33429
13	0.30367	-1.23256
14	0.57124	-0.86379
15	0.94905	-0.56218
16	1.10554	0.69500
17	1.43451	0.99754
18	1.76108	1.85076
19	1.87666	

[(a)] Limited to the first 100 cases.

In summary, it can be concluded that FA helped in the identification of three factors from the list of nineteen variables in the Spanish case, and seventeen variables in the Colombian case. Mainly, the first principal component for the Spanish and the second principal component for the Colombian case were mainly represented by the original variables that reflect the evolution of the residential building sector in both countries, e.g. Consumption of cement for Construction, Cement Imports, see Table 2. Energy and cement can be used as suitable proxies to capture the global development of the building sector and are significant inputs for any construction, especially for housing to get a real vision about the operation of the building sector.

4.2. Comparison of results in energy and materials consumption

Regarding building materials, in Spain a direct measure of the evolution of the building sector can be seen in the number of houses built, which increased from 187165 units in 2000 to 209752 units in 2005. Furthermore, in 2005 the construction industry took a lead growth rate of 6%, which accounted for 17.8% of Gross Domestic Product (GDP), and contributed almost 11% to the Gross Value Added (GVA). Indirect measures within the industry can be seen in the trends of steel and cement consumption. In Spain about 1200 kg of cement and 400 kg of steel were consumed per capita, due to the growth in investment in housing and road construction during the last five years. In Colombia, the DANE (National Administrative Department of Statistics) confirmed that in 2006 the construction sector represented 6.2% of the total GDP and also that about 85000 dwellings had been built. Furthermore, in 2007 Colombia had a lower consumption of cement (approx 208 kg) and steel (41.6 kg) per capita.

Table 5. shows some socio-economic and materials indexes during the last five years.

According to energy demand management and supply index, the challenge for the global energy sector is twofold: first, to dramatically increase access to affordable, modern energy services in countries that lack them, especially for poor communities; and second, to find the mix of energy sources, technologies, policies, and behavioural changes that will reduce the adverse environmental impacts of providing necessary energy services [29], meaning that first we must find out what makes up the electricity supply in each country.

Hence, Table 6 shows the electricity mix generation taking into account the data from the Spanish Electricity System (REE) and the data published in Colombia from the Ministry of Mines and Energy.

Table 6. Electricity mix generation in Spain in 2009 and Colombia in 2008

Production from	**Spanish Electricity Mix**		**Colombian Electricity Mix**	
	(GWh)	**%**	(GWh)	**%**
Coal	49647	16.36	4084	7.60
Oil	10691	3.52	118	0.21
Gas	95529	31.48	6710	12.50
Nuclear	58973	19.44	0	0
Hydro	25845	8.51	42742	79.69
Wind	31777	10.47	0	0
Other no-renewable	23314	7.68	0	0
Other renewable	7645	2.21	0	0
Total Production	**303421**	**100**	**53618**	**100**

Observation: 1GWh = 8.60E-02 ktoe

The energy analysis included the amount of fossil and non-fossil fuels required to generate the energy used to provide the goods and services consumed by the inhabitants of the country. This included the primary energy, energy input, internal energy transformations and energy use.

Table 5. Global-index and trends in the use of cement and steel in the period 2006 to 2009

SPAIN	**2009**	**Variation % 2009 – 2008**	**Variation % 2008 - 2007**	**Variation % 2007 - 2006**
Total area (km²)	504030			
Population	45200737	1.1%	1.3%	2.1%
GDP per capita (US$)	27400	4.5%	16.5%	5.6%
Cement (Mton)	56.1	7.7%	6.8%	3.7%
Steel (Mton)	18.9	2.2%	1.7%	8.0%
Number of units for residential use (approved)	135659	-55%	-8%	5%
COLOMBIA				
Total area (km²)	1141748			
Population	43222037	1.9%	1.9%	1.9%
GDP per capita (US$)	397	5.5%	5.3%	8.2%
Cement (Mton)	9.0	3.8%	26.0%	5.3%
Steel (Mton)	1.8	20.0%	8.3%	36.4%
Number of units for residential use (approved)	94.617	9%	19%	7%

The energy demand management considerations in both countries are summarized in Figure 2. It illustrates a Sankey diagram that shows the graphic representation of the energy flow considering the methodology of the International Energy Agency (IEA).

It can be seen in Figure 2 that, in 2009, Spain had a primary energy consumption of 146779 kilotons oil equivalent (ktoe) of which 7% was based on renewable energy and non-renewable accounted for 93% (mainly oil accounted for 49%, natural gas represented 21%, coal 13%

and nuclear 10%). The annual energy consumption was 108197 ktoe of which the final consumption of petroleum products was 61826 ktoe, natural gas 17779 and coal 2267. In 2008 in Colombia, the primary energy consumption was 81073 ktoe, of which approximately 10% came from renewable energy and 90% from non-renewable fossil fuels. Furthermore, in Colombia there is an annual final energy consumption of 34047 ktoe which is about 3 times lower than Spanish consumption. In 2008 the Colombian foreign trade represented a total of 45879 ktoe, of which the exportation of coal accounted for 76% and oil for 24%. Meanwhile, in Spain there is energy dependence on fossil fuel from overseas, specifically oil (48%), natural gas (21%) and coal (10%), making Spain very vulnerable to potential supply crises. Therefore, it can be stated that Colombia is self-sufficient and less vulnerable than Spain in a potential supply crisis. But in fact, there is uncertainty regarding energy supplies in coming years due to high levels of industrial and economic investment, oil prices worldwide, and energy consumption [30].

In Spain, the final energy consumption within the transport sector represented 38%, 34% within the industry sector, and 28% within the buildings, service and commerce sectors, of which 56% accounted for the residential building sector. In Colombia the highest final energy consumption was for the building, service and commerce sectors with 40%, and the net electricity production was about 4669 ktoe. The second most important was the transport sector with 34%, followed by the industry sector with an average of 26%. Finally, in Spain the consumption of electricity for end-uses was equivalent to 26839 ktoe, while in Colombia this total was 4669 ktoe.

5. CONCLUSIONS

A composite indicator for evaluating socio-economic conditions in the building sector of both Spain and Colombia was developed, which allowed the identification of critical factors that influence the building sector in both countries. The study focused the analysis on relevant factors for the building sector such as energy and material consumption, and environmental impact. According to the analysis of the obtained data, the building sector in Colombia, in comparison to that of Spain, would be more resilient to a possible supply shortage, and has a lower environmental impact. However the number of energy alternatives used in the building sector at Colombia is lower in comparison with the Spain case, especially in green sources of energy.

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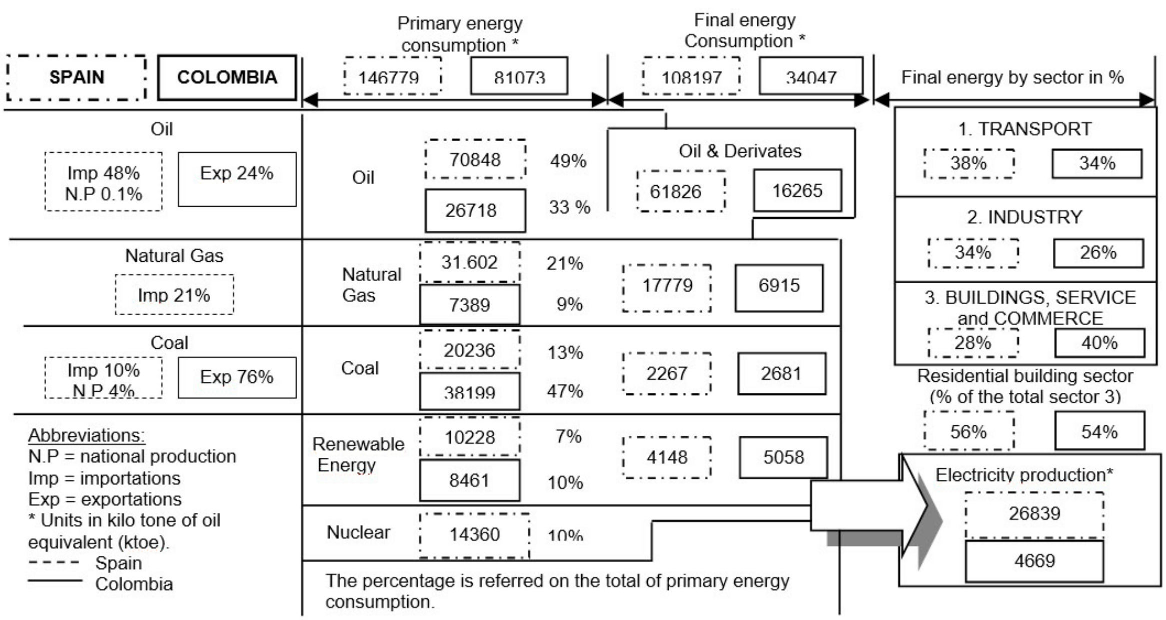

Figure 2: Sankey diagram (the energy demand management considerations in both countries).

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