SUSTAINABLE PRACTICES IN MEXICAN HOUSING PROJECTS TO REDUCE EMISSIONS EFFECTING CLIMATE CHANGE

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Abstract: Construction has been identified as a major contributor to climate change due to the great amount of resources this industry requires. The impact of construction projects on the environment is defined throughout the different phases of a project, but mostly during planning and design. Sustainable practices should be implemented through this phases in order to prevent or reduce impacts on the environment. Construction agencies from different countries have delivered a number of codes and guidelines in order to disseminate sustainable practices to construction practitioners. Sustainable construction in Mexico has been mostly focused on housing construction because, in developing countries, it is a relevant factor for the attainment of sustainable development. For instance, the National Housing Board has delivered Criteria and Indicators for Sustainable Housing, while the Institute of the National Fund for Workers´ Housing has implemented the Green Mortgage Program in order to contribute to the efficient use of natural resources and to environmental protection. In this context, however, very few information regarding sustainable practices implemented in housing construction has been reported. The study described in this work attempted the assessment of the extent to which sustainable practices are implemented in housing construction. Because of its global relevance, climate change is of particular interest when discussing sustainable practices in construction and, therefore, this study focused on assessing practices which aim is reducing emissions causing climate change.

The climate change-related practices used in this study were sourced from four existing and proved sustainability assessment systems: Guidelines for Sustainable Housing Building in the Basque Country (Spain, 2011), Code for Sustainable Homes: Technical Guidance (United Kingdom, 2010), Criteria and Indicators for Sustainable Housing Developments (Mexico, 2008), and the Handbook for Designing Sustainable Housing Developments (Mexico, 2010). Considering local applicability, 53 practices were selected from such four systems and categorized according to seven action areas, which include: Reduction of energy demand (14 practices), Improvement of energy performance (5), Use of renewable energy sources (3), Other energy saving practices (14), Transporting of materials and products (6), Pollution of the atmosphere (6), and Public Transit availability (5). Action Areas refer to project-related aspects in which human beings are able to intervene in the search of reducing Green House Gases that cause climate change. Most of these selected practices (27) should be implemented during the design phase of the project and the rest of them during the construction (12), operation or use (10), and planning (4) phases.

These selected practices were integrated into a system that was used to assess the degree (in percent) with which such practices are implemented in housing construction projects. The implementation of each practice was assessed as a percent value (i.e. from 0 to 100%). In addition, based on the original sources from which the practices were selected, each practice was weighed using a scale from 1 to 5 in order to represent the relevance of the given practice on the prevention of climate change. The assigned weight was then applied to weigh the implementation percent value of the practice. A degree of implementation was obtained for each of the seven action areas by summing the weighed results of every practice within an action area and dividing this by the maximum possible result for the area.

Six housing projects in the state of Yucatan, Mexico, on construction at the time of this study, were selected as case studies. These projects featured typical construction methods and materials but were aimed at clients from different socio-economic levels: low, medium, or high; two projects for each level were studied. The assessment of the selected practices was primarily based on the review of the project documents, including drawings, specifications, codes and regulations. However, direct observation to construction sites and interviews to personnel were carried out for practices which assessment was unfeasible with the information contained in the project documents.

The average implementation degree was 27.50% in the low-level projects, 37.08% in the medium-level projects, and 39.17% in the high-level projects. The results in the six projects agreed that the action areas with the lowest implementation degree include Use of renewable energy sources (average of 0.0%) and Transporting of materials and products (average of 15.15%). On the other hand, the areas with the highest performance include Public Transit availability (average of 50.00%) and Improvement of energy performance (average of 45.66%). The high level projects excelled in Pollution of the atmosphere and Reduction of energy demand (averages of 64.71% and 62.96% respectively).

The results evidenced housing projects developers in this context should increase their focus on the use of renewable energy sources; however, it should also be recognized that this kind of technology is still not available in Mexico. Transporting of materials during construction also represents another opportunity to reduce emissions causing climate change; improving the planning of logistics could be attempted in this case.

Keywords: Sustainable practices, Housing projects, Climate change, Mexico,

INTRODUCTION

According to the Intergovernmental Panel on Climate Change (IPCC), "climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity." On the other hand, the United Nations Framework Convention on Climate Change (UNFCCC), which addresses problems associated with climate change, considers climate change "is attributable directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods" [i]. Under the UNFCCC assumption climate change is due to global warming caused by emissions of greenhouse gases (GHGs), which primarily include: of carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6). The increase of GHG concentration in the atmosphere prevents a normal release rate of solar radiation absorbed by land, which contributes to global warming. [ii]

The research work described in this paper focused on climate change attributed to human activities. Under this point of view, climate change is largely a consequence of unsustainable consumption and production patterns and is widely recognized as a serious threat to the world's environment [iii]. According to the United Nations, climate change may entail extreme weather patterns that will cause floods and droughts with adverse environmental and socio-economic consequences, especially on the agriculture, forests, marine ecosystems, and small island states. [iv]

The Kyoto Protocol, signed in 1997 and in force since 2005, is one of the initiatives of the UNFCCC that contains guidelines for reducing GHG emissions. This protocol established emission reduction targets for developed countries that agreed reducing their collective emissions of GHGs by at least 5 per cent below 1990 levels in the commitment period from 2008 to 2012. In order to meet its objectives, the protocol proposed a Clean Development Mechanism that encourages joint implementation and emissions trading among developed countries, as well as cooperation between developed and developing countries by sponsoring projects that seek to reduce GHG emissions [v]. The results of this agreement are still to be seen. However, since the creation of such international agreements as well as the growing scientific evidence of global climate change, governments of numerous countries have initiated actions on the sustainable development of their economies, including the construction sector [vi].

Construction has been identified as a major contributor to climate change due to the great amount of resources this industry requires [vii]. For example, buildings and construction use a great amount of energy that is mostly produced from fossil fuels, which entails emissions of greenhouse gases (GHG). It has been estimated that buildings directly use between 25% and 40% of total energy, and as much as 50% when indirect use is taken into account [viii]. Cement production is another major source of GHG emissions due to the burning of fossil fuels and the mining of raw materials. According to the United Nations Environment Programme (UNEP), based on current trends, CO_2 emissions from the cement industry will quadruple by 2050 [ix]. The

International Council for Research and Innovation in Building and Construction and the International Environmental Technology Centre (UNEP) have estimated construction's contribution of global anthropogenic CO_2 emissions range from 5% to 7%, while the built environment contributes with some 40% of world GHG emissions [x]. However, these figures differ from country to country (e.g. while transport is the single largest source of GHG emissions in the United States, the built environment is in Europe) [xi].

The construction of human settlements and infrastructure that supports development includes the extraction of raw materials, the manufacturing of construction materials and components, the construction project cycle from feasibility to final disposal, and the management and operation of the built environment [xii]. The impacts of construction projects on the environment are defined throughout these different phases and, therefore, sustainable practices should be implemented when executed in order to prevent or reduce such impacts. Construction agencies from different countries have delivered a number of codes and guidelines in order to disseminate sustainable construction practices to practitioners. Sustainable construction is deemed "a holistic process aiming to restore and maintain harmony between the natural and built environments, and create settlements that affirm human dignity and encourage economic equity" [xiii]. Sustainable construction in Mexico has been mostly focused on housing construction because, in developing countries, housing is a relevant factor for the attainment of sustainable development [xiv]. For instance, the National Housing Board has delivered Criteria and Indicators for Sustainable Housing, while the Institute of the National Fund for Workers´ Housing has implemented the Green Mortgage Program in order to contribute to the efficient use of natural resources and the environmental protection in Mexico [xv].

In the Mexican context, sustainable housing refers to construction of dwellings that takes into account sustainability aspects such as bioclimatic design and energy efficiency. Energy efficiency is addressed by implementing sustainable technologies dealing with three basic household resources: gas, electricity, and water, which allow savings on energy consumption, utility expenses (gas, electricity and water) and CO_2 emissions. Moreover, sustainable housing aims at integrating the supply chain associated with the production of dwellings in order to consider the carbon footprint of dwellings life cycle, including the production and transportation of construction materials, the building and furnishing of housing developments and dwellings, as well as the operation and maintenance during use [xvi].

Mexico has been acknowledged as a country that has been improving its capability for delivering sustainable housing; however, construction of sustainable housing is still in short supply since most of housing developments constructed in Mexico have not implemented minimum practices in favor of sustainability. As yet, only 596,268 sustainable dwellings have been built in Mexico; however, it has been estimated each of these dwellings saves 1 to 1.5 tons of CO_2 emissions every year. [xvii]. The National Board for Housing, from Mexico, has estimated that 40 million homes will be the total in 2030, while at that time 600 thousand more will be built every year. This means a number of dwellings equivalent to the 35% of the present total will be built the next 30 years [xviii].

According to the previous background, housing construction in Mexico depicts a good opportunity to mitigate or reduce emissions causing climate change. However, very few information regarding sustainable practices addressing climate change in housing construction has been reported. The study described in this work attempted the assessment of the extent to which such sustainable practices are implemented in housing construction in order to reduce emissions causing climate change.

METHODS

An instrument was put together in order to the extent to which such sustainable practices addressing climate change are implemented in housing construction projects. This instrument includes a number of sustainable practices addressing climate change that were sourced from four instruments that have been proved effective to guide and evaluate sustainable construction of housing projects. These four instruments included: the Guide for Sustainable Building and Restoration of Housing in the Basque Country (Spain) [xix], the Code for Sustainable Homes: Technical Guidance (United Kingdom) [xx], Criteria and Indicators for Sustainable Housing Projects (Mexico) [xxi], and the Guide for Designing Sustainable Housing Projects (Mexico) [xxii]. Each of these instruments includes a number of sustainable practices that are proposed as indicators for sustainability assessment of housing projects. The sustainable practices address diverse sustainability aspects, mostly related to the environment. The instruments consistently group the sustainable practices in categories, according to the sustainability aspects they are related to (e.g. energy, water, and materials). Table 1 features these four instruments with corresponding categories and total number of sustainable practices. For the purposes of this study, it was then necessary to select those sustainable practices exclusively addressing climate change.

Table 1: Instruments with corresponding categories and number of sustainable

Instrument	Source	Categories of Sustainable Practices		Total Number of Sustainable Practices
Guide for Sustainable Building & Restoration of Housing in the Basque Country	The Basque Country, Spain	Energy	Demand Performance Renewable Others	97
		Materials	Consumption Transportation Waste	
		Resources	Land Water Atmosphere Ecosystems	
		Mobility	Urban Transit	
		Health	Indoor air quality Comfort & Health	
Code for Sustainable Homes: Technical Guidance	United Kingdom	Energy and CO_2 emissions		34
		Water		
		Materials		
		Surface water run-off		
		Waste		
		Pollution		
		Health and Well-being		
		Management		
		Ecology		
Criteria and Indicators for Sustainable Housing Projects	Mexico	Location, Land densification, and Utilities		71
		Energy use efficiency		
		Water use efficiency		
		Waste management		
Guide for Designing Sustainable Housing Projects	Mexican Northern Border	Urban aspects, Environment, and Security		125
		Urban-Architectural design and Eco-Technologies		
		Energy use efficiency		
		Water use efficiency		
		Waste management		
		Community integration and Membership sense		

Considering local applicability, 47 practices were then selected based on the review of all the sustainable practices the four instruments include. The selected practices were categorized according to six action areas that were determined based on the categories the Guide from the Basque Country [xxiii] proposes. Since categories of practices in this guide clearly specify what environmental impacts they attempt to prevent, they were deemed suitable as a basis for determining the ones used in this study. By following the scheme proposed by the Guide from the Basque Country the categories used in this study were named as Action Areas, which, in this case, refer to project-related aspects in which project decision makers are able to intervene in order to reduce GHG emissions that cause climate change. Table 2 contains the list of the established action areas, along with a brief description and the number of practices each one of them include. Most of the selected practices (23) should be implemented during the design phase of the project and the rest of them during the construction (10), operation or use (10), and planning (4) phases.

Table 2: Action Areas with corresponding number of practices they include

Action Area	Number of Practices	Description
Reduction of energy demand	14	The aim of the practices included in the action areas related to energy is to limit GHG emissions arising from the operation of a dwelling and its services. Energy saving is fundamental for attaining the reduction of GHG emissions, since most of the energy used nowadays is based on fossil fuels. However, some practices are related to the use of new technologies that enable the exploitation of renewable energy sources, such as the sunlight.
Improvement of energy performance	5	
Use of renewable energy sources	3	
Other energy saving practices	14	
Optimization of materials transportation	6	Transportation of materials used during construction of dwellings is an important source of GHG emissions due to the use of oil based fuels. That is the reason some of the practices refer to reduction of transport needed during construction, such as favoring the use of locally produced materials.
Public Transit availability	5	Transportation is nowadays a basic need as it facilitates mobility of dwellers. However, emissions produced by most motor transports pollute the atmosphere and cause global warming because of the use of oil based fuels. The massive use of private vehicles to travel from home to work is a major source of emissions and energy consumption.

Table 3: Illustration for calculating the implementation degree in an Action Area category of a given project

Action Area	Sustainable practice	Relevance weighting (A)	Proportion of compliance (B)	Weighed relevance (C = A*B)	Implement. Degree (D)
Use of renewable energy sources	Incorporate a solar thermal system for water heating, which complies with the National Board for Energy Efficiency, in every dwelling of the project.	5	60%	3	D=(Total A/Total C) * 100 D=(6/15)*100
	Incorporate a photovoltaic system that allows the exploitation of solar energy in the dwelling.	5	20%	1	
	Incorporate heat release systems such as double walls, embrasures, solar chimneys, discharge ducts, or wind units installation.	5	40%	2	
	Total	**Σ 15**		**Σ 6**	**40%**

Table 4: Weighting Factors of Action Areas

Action Area	Number of Practices	Category Total Weighting	Category Weighting Factor
Reduction of energy demand	14	57	36%
Improvement of energy performance	5	21	13%
Use of renewable energy sources	3	15	9%
Other energy saving practices	14	30	19%
Optimization of materials transportation	6	11	7%
Public Transit availability	5	24	15%
Total		**Σ 158**	**Σ 100%**

Table 5: Illustration for calculating the global implementation degree in a given project

Action Area	Total of Weighed Relevance (A)	Category Total Weighting (B)	Category Implement. Degree (C=A/B*100)	Category Weighting Factor (D)	Weighed Implement. Degree (E=C*D)
Reduction of energy demand	34.0	57	62.96%	36%	22.7%
Improvement of energy performance	9.0	21	42.86%	13%	5.6%
Use of renewable energy sources	0.0	15	0.00%	9%	0.0%
Other energy saving practices	9.4	30	31.33%	19%	6.0%
Optimization of materials transportation	2.0	11	18.18%	7%	1.3%
Public Transit availability	13.0	24	54.17%	15%	8.1%
Total		**Σ 158**	**Global implementation degree: Σ 43.7%**		

Table 6: Implementation degrees of sustainable practices in six projects

Action Area	Low level		Medium level		High level		Average
	Project L1	Project L2	Project M1	Project M2	Project H1	Project H2	
Reduction of energy demand	38.4%	54.1%	35.3%	44.6%	77.8%	63.0%	52.2%
Improvement of energy performance	66.7%	100.0%	66.7%	66.7%	88.2%	52.9%	73.5%
Use of renewable energy sources	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other energy saving practices	35.7%	28.6%	46.4%	33.9%	36.7%	31.3%	35.4%
Optimization of materials transportation	0.0%	14.5%	27.3%	44.5%	13.6%	18.2%	19.7%
Public Transit availability	45.8%	64.6%	50.0%	75.8%	31.3%	54.2%	53.6%
Global implementation degree	**36.1%**	**48.6%**	**39.6%**	**45.6%**	**52.1%**	**44.9%**	**44.5%**

The assessment of the extent to which the selected practices were implemented involved two different scales: (a) Proportion of compliance: used to assess the proportion of the project that complies with the relevant assessment criterion established for the given practice. This was done using percentage values ranging from 0 to 100%. The application of this scale considered the number of aspects, involved in the assessment of the practice, that meet the criteria established. This was done assuming these aspects are equally weighted. For example, a project with fifty houses in which ten do not meet the criteria for appropriate orientation, would entail an 80% of the project meets this criteria. The criteria used to assess practice compliance were based on those established by the original source from which the practices were elicited. The proportion of compliance was measured by reviewing the project drawings and interviewing personnel involved in realization of different phases of the project. (b) Relevance of practices: used to depict the relevance of a given practice on the prevention of climate change. This relevance was made explicit with a weighting factor defined as a discrete value between 1 and 5. The relevance of practices was mostly based on the weighting factors proposed for practices in the Basque Country Guide, which are also weighted 1 to 5; while for practices sourced from the three other instruments relevance was estimated by normalizing the weights proposed by the original source. For example, a practice weighted 10 from the Code for Sustainable Homes (UK), in which practices are weighted as with 1 to 15, would be weighted 3 in the scale 1 to 5.

For a given project, an implementation degree was obtained for each of the six action areas categories by summing the weighed proportion of compliance of every practice included in the action area and dividing this total by the corresponding total of relevance weightings of practices in the action area. Table 3 illustrates the calculation of the implementation degree of sustainable practices in a given action area.

Relevance weightings were also used for weighting the six action areas categories used in this study. The relevance weights of practices in each action area were summed in order to determine the category total weighting, as shown in Table 4. It is necessary to clarify not all practices apply to every project and the category total weighting of any given action area should be obtained only with the practices it includes. The category weighting factors of action areas (see Table 4) were used for determining the global implementation degree in a given project, as illustrated in Table 5.

RESULTS AND DISCUSSION

Six housing projects in the state of Yucatan, Mexico, on construction at the time of this study, were selected as case studies. These projects featured typical construction methods and materials (i.e. mostly concrete) but aimed at clients from different socio-economic levels: low, medium, or high; two projects of each level were studied. All these projects featured single-family detached houses except for one of the high level projects, which featured a condominium complex consisting of ten tower buildings. It is also important to note that no one of these projects was on purpose planned or designed as to attain an environmental or sustainable target, but they were all built with methods and materials commonly used in this context.

Sustainable practices that were deemed applicable to the given project were selected before the assessment of the project. The assessment of the selected practices was primarily based on the review of the project documents, including drawings, specifications, codes and regulations. However, direct observation to construction sites and interviews to personnel were carried out for practices which assessment was unfeasible with the information contained in the project documents.

Table 6 includes the results obtained for the action areas assessed in each of the six projects. As from results in this table it is evident that the implementation of sustainable practices was mediocre in these six projects since the average implementation degree resulted in 44.5%. It is also patent there was no significant difference among the global implementation degrees obtained in these projects.

The low-level housing projects (i.e. L1 and L2) accomplished an average implementation degree of 42.4%. As seen in Figure 1 the Action Areas in which these projects featured the lowest performance include: Use of Renewable Energy Sources (average of 0.0%) and Optimization of Materials Transportation (average of 7.2%). On the other hand, Improvement of Energy Performance (average of 83.4%) stands out as the action area in which these projects attained the highest performance. The medium-level housing projects (i.e. M1 and M2) accomplished an average implementation degree of 42.6%. As seen in Figure 2 the Action Area in which these projects featured the lowest performance is the Use of Renewable Energy Sources (average of 0.0%); while the one with the highest performance is Improvement of Energy Performance area (average of 66.7%). The high-level housing projects (i.e. H1 and H2) accomplished an average implementation degree of 48.5%. As seen in Figure 3 the Action Areas in which these projects featured the lowest performance include: Use of Renewable Energy Sources (average of 0.0%) and Optimization of Materials Transportation (average of 15.9%). On the other hand, the areas with the highest performance are Improvement of Energy Performance (average of 70.6%) and Reduction of Energy Demand (average of 70.4%). Both of the high-level projects assessed in this study had implemented a higher number of practices related to bioclimatic designs than in low- and medium-level projects, thanks to which they attained some better performance on energy savings. Due to sufficiency of land area high-level housing projects are able to incorporate features such as drying space, cycle storage, and home office.

As seen in Table 6, the results in the six projects agreed that Use of Renewable Energy Sources (average of 0.0%) and Optimization of Materials Transportation (average of 19.7%), are the action areas with the lowest implementation degree; while Improvement of Energy Performance (average of 73.5%) turned out as the action area with highest performance. Regarding the use of renewable energy sources it is necessary to point out technology permitting the exploitation of such resources is still inaccessible in the studied context due to limited budgets. However, due to the great amount of sunlight available in this location solar radiation seems to be a potential source of energy. In fact, solar technologies such as solar hot water systems for water heating and photovoltaic cells for converting light into electricity are already available, though they are still uncommon in housing projects.

Insufficiency of practices related to Materials Transportation was also common in the housing projects assessed in this study. Project developers and contractors in this context usually neglect the planning of responsible sourcing of materials, especially of those related to wood. A significant amount of timber is required for scaffolding and formwork during the construction phase of housing projects, which in the studied context has to be delivered from distant provinces as there is no local wood production. Developers and contractors have shown some apathy regarding the implementation of environment friendly methods for construction. Further planning is also necessary to reduce the need for carrying soil and debris respectively resulting from excavations and materials waste generated during construction.

Regarding the other action areas in which the projects also obtained a mediocre performance, it is important to emphasize Reduction of Energy Demand since this category features the highest weighting factor (36% as seen in Table 4). As mentioned before, performance of high-level housing projects was not as poor as in low- and medium-level projects. A common characteristic of projects classified within these two last levels is budget limitation, so projects in this case failed to include design features such as appropriate layouts, enough space for garden, decks, home office, laundry drying, storage for bicycles, etc., as well as high ceilings, which are appropriate for the warm and humid climate prevailing in the region. Appropriate designs are the best approach to incorporate environment friendly features to buildings that would reduce the need for systems to cool or heat indoor environments.

The category with the second highest weighting factor, i.e. Other Energy Saving Practices (19% as seen in Table 4), include practices regarding the implementation of environmental management systems and energy efficiency auditing, the addition of water and energy saving devices such as water saving toilets, faucets, and valves, as well as the optimization of indoor natural lighting. The projects in this case mostly failed on the practices regarding the managerial aspects of projects, which is a common drawback in Mexican organizations dedicated to developing housing projects. In these organizations is common to observe very limited efforts for assuring the consideration of environmental aspects during the planning, design, construction, and operation of projects.

Public Transit Availability was also assessed with a mediocre performance basically due to the absence of appropriate facilities for pedestrians and cyclists, which is a common situation in housing projects in Mexico. This usually causes an increased reliance on the use of private cars for transporting to locations that are not really far from homes.

Regarding the action area in which the highest implementation degree was attained, i.e. Improvement of Energy Performance, it should be remarked this was mostly thanks to the use of lighting fixtures and air conditioning devices featuring high levels of energy efficiency. In this context home lighting is mostly through energy-saving light fixtures such as fluorescent and LED lamps, which provide appropriate indoor lighting with low power consumption. On the other hand, it is also necessary to highlight that the use of air conditioning systems is usually exclusive to homes with high incomes because price of electricity is high in this context; therefore low- and medium level housing projects usually do not include this kind of amenities.

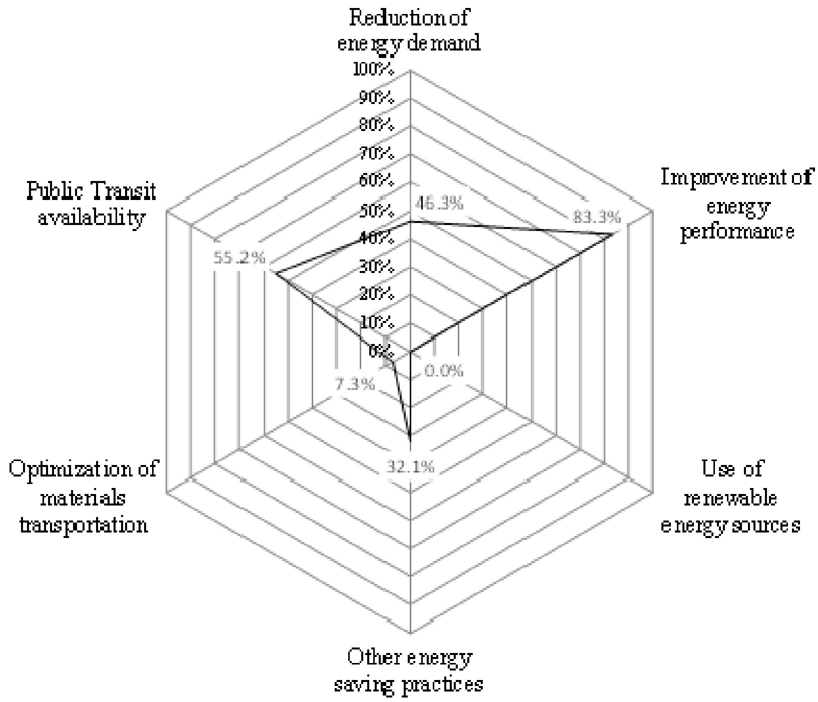

Figure 1: Averages of implementation degrees in low-level housing projects

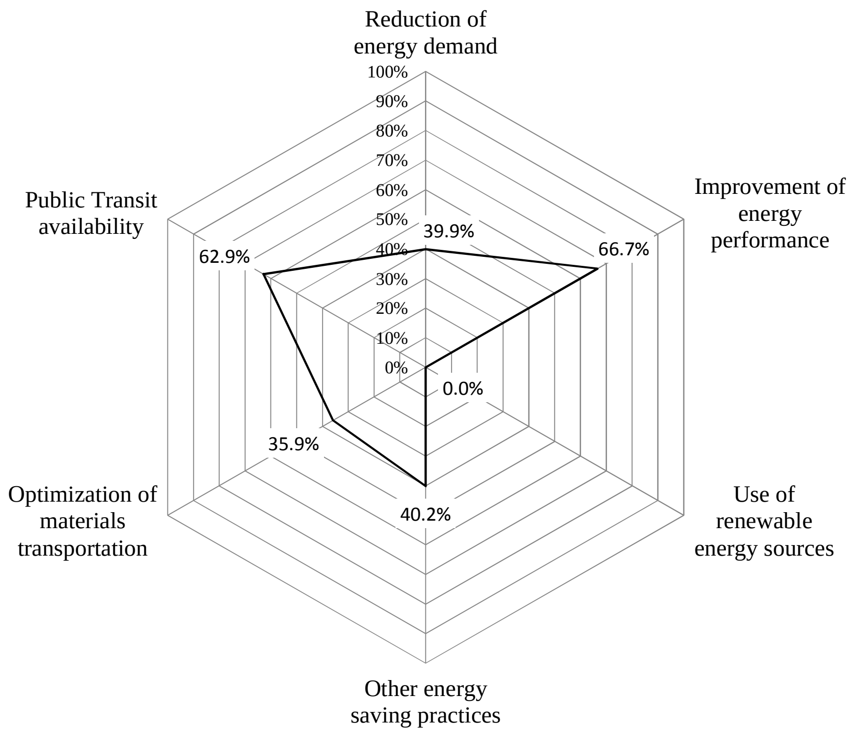

Figure 2: Averages of implementation degrees in medium-level housing projects

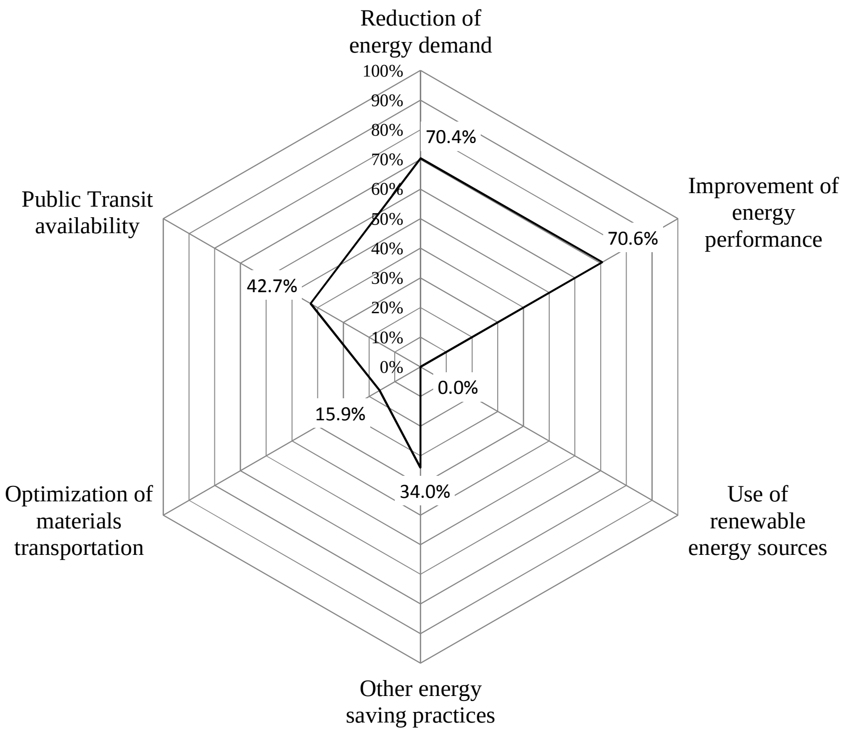

Figure 3: Averages of implementation degrees in high-level housing projects

CONCLUSIONS

The research reported in this paper features an approachable methodology that can be used by developers and contractors dedicated to housing construction to learn about sustainable practices aimed at reducing GHGs emissions. The housing projects used as case studies for the purpose of this research were not intended to achieve an environmental or sustainable target and the results evidence this. However, the instrument proposed in this study could be useful as guidelines for establishing targets on the implementation of sustainable practices.

According to results, the implementation degree of sustainable practices was low since the average obtained with the six projects assessed in this study was below 50%. The results also evidenced developers and contractors of housing projects should put more effort in planning and designing these projects in order to attain a proper reduction of GHGs emissions. According to the weighting factors used in this study, these efforts should focus on practices related to Reduction of Energy Demand and Other Energy Saving Practices since these categories feature the largest factors while resulted with mediocre implementation degrees. Developers of housing projects should include design features that reduce the need for systems to cool indoor spaces of dwellings and the use of water and energy.

There are also great opportunities to reduce emissions by taking advantage of renewable energy sources, especially sunlight since the area in which this study was carried out features a great amount of insolation throughout the year. Though solar technologies such as solar hot water systems for water heating and photovoltaic cells for converting light into electricity are already available in Mexico, they are still uncommon in housing projects.

REFERENCES

1. Intergovernmental Panel on Climate Change (IPCC) (2002). *Climate Change and Biodiversity*, IPCC Technical Paper V.

[ii]. United Nations (2007). *Indicators of Sustainable Development: Guidelines And Methodolog*ies, Third edition, New York: United Nations publication.

[iii]. *Ibid*.

[iv]. *Ibid*.

[v]. United Nations (1998). Kyoto protocol to the United Nations Framework Convention on Climate Change, Available at

http://unfccc.int/resource/docs/convkp/kpeng.pdf, downloaded January 2013.

[vi]. Winch, Graham M. (2002). *Managing Construction Projects: An Information Processing Approach*, United Kingdom: Blackwell Science.

[vii]. Du Plessis, C. (2002). *Agenda 21 for Sustainable Construction in Developing Countries: A discussion document*, Report prepared for the International Council for Research and Innovation in Building and the Construction (CIB)/United Nations Environment Programme – International Environmental Technology Centre (UNEP-IETC), Pretoria, South Africa: CSIR Building and Construction Technology.

[viii]. United Nations Environment Programme-Division of Technology, Industry and Economics (UNEP DTIE) (2003). *Sustainable building and construction*, Industry and Environment, April-September, Paris, France.

[ix]. *Ibid*.

[x]. Du Plessis, C., *op. cit.*

[xi]. Confederation of International Contractors' Associations/United Nations Environment Programme (2002). *Industry as a partner for sustainable development: Construction*, United Kingdom: The Beacon Press.

[xii]. Du Plessis, C., *op. cit.*

[xiii]. *Ibid*.

[xiv]. Du Plessis, C. (2007). "A strategic framework for sustainable construction in developing countries", *Construction Management and Economics*, 25:1, 67 – 76.

[xv]. National Board for Housing (Comisión Nacional de Vivienda) (2008). *Criteria and Indicators for Sustainable Housing in Mexico* (Criterios e indicadores para los desarrollos habitacionales sustentables en México), Mexico City: CONAVI.

[xvi]. Secretariat of Environment and Natural Resources (Secretaría de Medio Ambiente y Recursos Naturales, Mexico) (2012). *Vivienda Sustentable en Mexico*, Mexico City: SEMARNAT.

[xvii]. *Ibid*.

[xviii]. National Board for Housing, *op. cit.*

[xix]. Administration of the Autonomous Community of the Basque Country – Department of Housing, Public Assets and Transportation (Administración de la Comunidad Autónoma del País Vasco Departamento de Vivienda, Obras Públicas y Transportes) (2011). *Guide for Sustainable Building and Refurbishing of Housing in the Autonomous Community of Basque Country (Guía de Edificación y Rehabilitación Sostenible para la Vivienda en la Comunidad Autónoma del País Vasco),* Third edition, The Basque Country, Spain: Servicio Central de Publicaciones del Gobierno Vasco.

xx. Department for Communities and Local Government (2010). *Code for Sustainable Homes: Technical Guidance*, London, UK.

[xxi]. National Board for Housing (2008). *Criteria and Indicators for Sustainable Housing Projects in Mexico (Criterios e indicadores para los desarrollos habitacionales sustentables en México)*, Mexico City: CONAVI.

[xxii]. Border Environment Cooperation Commission (Comisión de Cooperación Ecológica Fronteriza) (2010). Guide for Designing Sustainable Housing Projects (Manual para el Diseño de Desarrollos Habitacionales Sustentables), Ciudad Juarez, Mexico: COCEF.

[xxiii]. Administration of the Autonomous Community of the Basque Country, *op. cit.*

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