

# QUALITATIVE ANALYSIS OF SUSTAINABLE VERTICAL DWELLING IN NUEVO LEON, MEXICO

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## 1 ABSTRACT

*Climate change has become a big concern nowadays since the effects of fluctuation in the weather are more notable every day. In Mexico construction industry generates around 33% of the countries CO<sub>2</sub> emissions, and 7.64% amount for housing alone. Sustainable Vertical Dwelling was considered as a suitable solution to cover the housing shortage and lower the impact to the environment. An assessment of awareness of sustainability was carried out in the housing sector including government, developers and institutions. Two interviews were designed one for each kind of interviewee. According with the outcome of the interviews, guidelines to address sustainability in the housing sector were proposed. An ongoing project was selected and a qualitative comparison analysis was established, making green improvements and discussing the impact of such improvements.*

*As an outcome we observed that sustainability is getting attention from the government and developers. The Housing Found has launched the Green Mortgage to promote green housing for the low income families, this program could be expanded to higher income classes and for vertical dwelling. There is not a proper regulatory framework for the condominium regimen neither for the construction of green dwellings, thus, problems arise for the condominium users.*

*Some developers are implementing some green features on their projects, but not as a mean to address sustainability, but as a marketing strategy. Finally, vertical dwelling represents a greener way to build by the fact that it requires less land space, vacant lands within urban areas can be recovered, thus the use of existing infrastructure and services make the projects efficient and less expensive.*

## KEYWORDS

sustainability, vertical dwelling, condominium

## 2 INTRODUCTION

Climate change has become one of biggest concerns in contemporary times since the effects of fluctuations in the weather are more notable every day. One of the many causes to this climatological event is the destructive action of mankind on nature. The greenhouse effect is one of the many by-products of human's unconscious interaction with nature. The National Institute of Ecology (INE in Spanish) (2006) states that dwellings contribute 7.64% of the CO<sub>2</sub> emissions in Mexico. Mayagoitia (2006) states that in general, construction generates 33% of the total CO<sub>2</sub> emissions in the country.

Therefore, we should promote the reduction of this adverse activity, implementing sustainable criteria in the designing and construction of new housing developments. This will have

a positive impact in the economy, on society, and on the ecology of Mexico. The economy will be favored because dwellings with sustainable parameters represent lower expenses in utilities, mainly in water and electricity bills. Vertical dwelling developments possess a lower environmental impact than horizontal structures due to their reduced footprint, concentration of services, and re-use of land among many others. They are therefore more efficient and cheaper to run during their life cycle.

According to CONAVI data, between 2006 and 2012 the national housing requirements amount to over 4,427,000 new dwellings and more than 2,930,000 home improvements. In its National Development Plan (NDP) 2007–2012, the Mexican government has taken into account sustainable aspects in

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its planning for this massive production. Specifically stated in its second objective is to: “Promote a sustainable housing development”, broken down further into strategies including: “Promote the construction of housing developments with sustainable characteristics”. This strategy also includes the promotion of certification and registration of emblematic models that enhance verticality, sustainability, efficient equipment, climate change protection policies and the optimum use of current infrastructure, water and energy.

Considering the aforementioned situation, sustainable vertical dwelling is a suitable solution to cover one part of the housing shortage in the country, as well as the land shortage in the urban areas, and at the same time it will provide better quality living quarters to its residents and a lower impact to the environment.

## 2.1 Objectives

The objectives of this research are to:

- Assess the awareness of sustainability in the housing sector, which includes construction companies and developers, and government boards and associations or institutes related to the construction industry.
- Propose guidelines to solve the main problems identified in the awareness assessment to work forward green vertical dwelling.
- Perform a qualitative analysis of a traditionally constructed high-rise versus construction of the same building with sustainable features, emphasizing the added value and the potential cost savings.

## 3 CONCEPTUAL FRAMEWORK

### 3.1 Sustainable Construction and green dwelling

#### *Sustainable Construction*

Sustainable construction involves using best-practices, clean and resource-efficient techniques, from the extraction of the raw materials to the demolition and disposal of its components (Ofori, 2000).

Green building has now become a flagship of sustainability, that takes the responsibility for balancing long-term economic, environmental and social health. It offers an opportunity to create environmentally efficient buildings by using an integrated approach of design so that the negative impact of building on the environment and occupants is reduced (Hikmat, 2008).

Sustainable building design includes formal and informal initiatives advanced by governments, professional organizations, and private industry. These efforts have focused on the development of building design guides, improved energy codes, the use and development of low environmental impact building materials, renewable energy and resources, and the

concept of analyzing the effects of design choices over the complete lifecycle of a building (Bunz, 2006).

The typical features of a green building includes (USGBC): Sustainable sites, Water Quality and Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality (IEQ), Innovative Design, among others.

Eco design or passive design is a tool to reach sustainability in any kind of construction, it consist in making the most of natural conditions of the building site, such as orientation, wind patterns, use of local resources, just to mentions some.

Green buildings have a significant economic advantage; some experiences show that it was possible to reduce both, or one of the capital and operating costs by becoming a green building. That is the case of Toyota Motor Sales, South Campus Facility, which was labeled a LEED Gold Certified facility without a first cost premium (Lapinski, A, et al, 2006). This is a notable accomplishment compared to an industry average 5-10% cost premium often needed to deliver LEED certified buildings. This success was accomplished through the implementation of Lean Processes for Sustainable Project Delivery.

Jackson (2008) performed a study of Energy Budget at Risk investment analysis of an energy efficiency option for a office building in Austin Texas. Two efficiency options were considered; the first was a package of lighting technology upgrades and the second was an HVAC redesign including an energy management and control system. The payback calculation was 2.3 years and this investment would reduce the building's annual energy cost by 38%.

Ofori (2000) stated that construction contractors can derive savings from the minimization of resource use and improve their corporate image. The enterprise's compliance with regulations and codes would be facilitated, and risk and uncertainties reduced.

#### *The concept of green dwelling*

The most significant end user demands for energy use in building are the heating of space and water, air conditioning, lighting, refrigeration and the service of building equipment, such as domestic appliances, computers, lifts and office equipment (CONAFOVI, 2006). A green dwelling can also be known as a passive dwelling, for the implementation of passive design and technologies (eco-technologies) to increase the energy use performance and improve comfort (Voss and Kramp, 2007). Green dwellings contribute significantly to the reduction of fossil energy consumption and the related green house gas emissions.

For purposes of this research a high-rise is considered a building over 3 stories, that includes medium density housing developments (very common in central cities in Mexico) as well as over 10 stories apartment buildings (found in downtown areas in big Mexican cities, as well as in new modern urban areas).

### 3.1.1 New Urbanism and sustainable development

The New Urbanism Organization defines this concept as “Giving people many choices for living an urban lifestyle in sustainable, convenient, and enjoyable places while providing solutions to peak oil, global warming, and climate change.” Managing growth, reducing traffic, creating sustainable development, and making smart transportation investments are all challenges we face today. New Urbanism is a development strategy that addresses these issues and others by creating communities that are livable, walk-able, and sustainable, while raising the quality of life. (See Figure 1).

The principles of urbanism can be applied increasingly to housing projects at the full range of scales from a single building to an entire community. Those principles are stated in figure 2 (New Urbanism Organization):

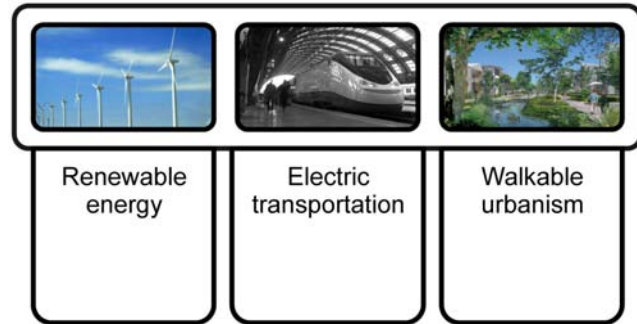
### 3.2 International Achievements in Sustainable Construction

During the past several decades, many endeavors had been undertaken to address sustainability in construction. The actors had been governments from different countries, pri-

vate owners committed to the care of the environment, and research institutes. A wide range of actions have been implemented, such as:

- Creation of laws and building codes
- Implementation of Rating Systems to assess sustainability
- Development of eco-friendly materials

**FIGURE 1.** Parts of New Urbanism. Source: Katz 1994.



**FIGURE 2.** Principles of New Urbanism. Source: New Urbanism Organization.



- Development of energy efficient system
- Development and implementation of new building procedures and technologies
- Implementation of Environment Management Systems, as part of Total Quality Management
- Construction of sustainable buildings in different cities

We present in this research some examples of these actions taken to address sustainability.

### 3.2.1 LEED and other Assessment tools

LEED is an internationally recognized green building certification system, providing third-party verification that a building or community was designed and built using strategies aimed at improving performance across all the metrics that matter most: energy savings, water efficiency, CO<sub>2</sub> emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts (USGBC).

LEED points are awarded on a 100-point scale, and credits are weighted to reflect their potential environmental impacts. Additionally, 10 bonus credits are available, four of which address regionally specific environmental issues. It can be stated that vertical dwellings contribute with LEED in the creation of sustainable sites, by the reclamation of brown-fields, thus, the incorporation of vacant lots to the city, availability of public or alternative transportation, storm water control, etc.

The building sector has witnessed the development of two types of assessment tools. The first group of assessment tools include those which are based purely on the criteria system. The second group includes tools that use lifecycle assessment (LCA) methodology.

The criteria-based tools can be defined as a system of assigning point values to a selected number of parameters on a scale ranging between “small” and “large” environmental impact (Hikmat 2008; Yokoro 2002). These tools are considered comprehensive environmental assessment schemes. Some of the criteria-based tools are shown in table 1.

It is important to mention that there is not a ‘best’ rating system; it depends on the local conditions and level of development of the country or region. A comparison analysis should be carried out before choosing a rating system, consid-

ering different variables such as implementation cost, climate adaptability, and construction processes.

### 3.3 Vertical Sustainable Dwelling

Vertical housing is presented as an alternative for sustainable development, due to its advantage on mitigating environmental impact. Some of those characteristics are:

- Reducing footprint, i.e. less land is required due a higher density
- Use of existing infrastructure, or the new infrastructure required is less and thus cheaper than for a horizontal development
- Utilization of vacant spaces within urban areas reduces sprawl
- The concentration of services in the same building makes its distribution more efficient
- Easy application of eco-design

There are also some disadvantages of living vertical, we can mention some:

- The concentration of services could be a hazard, it something fails, affects to all the tenants.
- The traffic in urban areas increases, especially when urban transportation is deficient.
- The tenant has to adapt to internal regulations, so its freedom is restricted.
- Privacy could be a problem, depends of the kind of neighbors living in the building.

Around the world now had been implemented some actions regarding the promotion of vertical dwelling. Is our intention to present some cases of implementation of sustainability in the development of sustainable dwellings.

#### 3.3.1 Dockside Green, Victoria BC

This project is intended to be one-of-a-kind, mixed-use harbour front development supported by unique on-site amenities. It is located in a 15 acre community adjacent to the Upper Harbor and downtown Victoria, British Columbia.

A model for holistic, closed-loop design, Dockside Green will function as a total environmental system in which form, structure, materials, mechanical, and electrical systems will be interrelated and interdependent; a largely self-sufficient, sustainable community where waste from one area will provide fuel for another.

Targeting LEED® Platinum certification and striving to be greenhouse gas neutral, Dockside Green will showcase a variety of sustainable innovations including:

- Biomass heat generation
- Onsite storm-water and sewage treatment
- Water conservation
- Energy conservation
- Healthy spaces
- Materials and resources
- Alternative modes of transportation

**TABLE 1.** Current assessment tools available.

Assessment Tool	Country
BREEAM	Great Britain
GBTool	Canada
LEED – USGBC	United States
LEED – CGBC	Canada
EcoProfile	Norway
HQE	France
Environmental Status	Sweden
Green Housing A-Z	Japan



**FIGURE 3.** Dockside Green has greater space for pedestrians and bicycles than for vehicles.



### 3.3.1 The Solaire, New York

This residential project includes 380 apartments and incorporates numerous sustainable design features. It is located in Battery Park City, in New York. This project is considered to be the first high-rise residential building in America to obtain a LEED Gold Rating from the US Green Building Council in 2004. The main features of this development are:

- Fresh filtered air to remove 85% of particulate matter. Continuously humidified or de-humidified depending on climate conditions, capable to maintain a minimum 30% relative humidity during the heating season. Building materials and paints with low or no off-gassing and low in VOCs.
- Water Quality and Conservation is reached by a central water filtration system for entire building. Waste water and storm water reuse system provides water for toilet flushing, landscape irrigation and cooling towers, therefore 50% reduction in potable water use vs. a traditional building of comparable size.
- Energy conserving building design that's 35% more energy efficient than code requires, resulting in a 67% lower electricity demand during peak hours. Photovoltaic panels incorporated into the building's façade which convert sunlight to electricity, those panels will generate 5% of peak electricity for the core-and-shell building. Energy star appliances installed in every apartment to ensure maximum energy efficiency. Spectrally selective, low-e glass, which reduces solar heat gain while retaining a high visible transmittance

Figures 5 and 6 show the characteristics of this project.

### 3.3.2 Iconos, Monterrey Mexico

Iconos is a housing project in Monterrey, Mexico, intending to be the first to achieve LEED certification in the country. This development includes the construction of 4 towers, with 239 apartments in total.

**FIGURE 4.** Water front park and access to public small boat launch/Harbor Ferry stop.



**FIGURE 5.** The Solaire, to the right, at Battery Park, New York.



**FIGURE 6.** The Green rooftop, one Green characteristic of the condominium.



**FIGURE 7.** Iconos, in Monterrey, Mexico.



It is located in a lot previously home to old warehouses, so it will regenerate the zone and will use the current infrastructure for communication and services. The design of the project was based on LEED requirements and its aim is to achieve around 32 points.

The apartments will have LED lighting, low pressure shower heads, water saving faucets, and dual flush toilets among other characteristics. In terms of materials, the condo will have Duovent windows (double glass) and Hebel walls (insulated bricks). Every tower will have a green roof that will be part of the rain water management system which will be integrated for 11,000 m<sup>2</sup> of green areas to reduce runoff and filter water to the subsoil.

### **3.4 Current Housing situation in Mexico**

In 2005, Mexico's population was 103.3 million people and was estimated at 106 million in 2008 (INEGI). There are currently over 25.7 million dwellings in the country. On the other hand there is a goal to create over 1 million dwellings per year (CONAVI 2007) to cover the current deficit and serve the demands of the new settlers in high-growth areas (CIDOC 2007).

The country has followed a fast trend to urbanization, helping to attend to the housing needs, however the uncontrolled growing of the cities has overtaken the proficiency of water resources, potential for infrastructure and utility, availability of suitable land for this purpose, the capacity of institutions to control habitable conditions, and any sustainability housing principles. (CONAVI 2007).

The lack of control of land usage and rules for real estate developments still is encouraging the horizontal expansion in the cities, thus creating the unfeasibility of transportation systems, more expensive utility infrastructure, excessive use of cars, and a shortage of land that directly impacts the house prices and hinders low cost housing accessibility for the demographics in need (CONAVI 2007).

Promoting the creation of sustainable housing development requires actions in three main areas: first, the gradual

correction of anarchic expansion, through mechanisms like densification of urban spaces, and the promotion of improved housing and increased housing stock. Secondly, the promotion of new developments that support verticality include the correct use of current infrastructure, rational energy use, water treatment and provision of green areas. Finally, the promotion to new urban centers with full sustainability settled in assigned lands for this purpose (CONAVI 2007).

The single family houses represent 86.5% of the housing stock market in Mexico, whereas only 8% are apartments and the remaining 5.5% are other types of properties such as rooms on rooftops or tenement houses.

#### **3.4.1 Current situation of the construction industry in Mexico**

According with INEGI data (Informatics, Geographical and Statistical National Institute), the construction sector generated close to 6.8% of the GDP in the first quarter of 2008, 0.2% below its share during the same period a year earlier. Within the sector, 55% represents building (housing, schools, commerce, hospital, etc), 18.9% is transportation (highways, roads, railways, etc), and 9.6% is oil and petrochemicals (drilling, refining, petrochemicals, storage and distribution, and pipe conduction systems). The remaining is represented by water, irrigation and sanitation, electricity and communications, and others (INEGI data).

#### **3.4.2 Estimates of housing needs and demand**

For the 2006-2012 period, the housing needs throughout the country are estimated at around 4 million—427,000 new dwellings and over 2,930,000 home improvements. On average, an annual 633,000 new dwellings are necessary. The main challenges that our country will face over that period of time regarding housing are:

- Having adequate land reserve to meet the annual needs for the construction of housing units.
- Consolidating a housing policy with sustainable spatial planning criteria that will revert the strong urban concentration and rural spatial dispersion trends.
- Ensuring the supply of basic services to the dwellings, such as drinking water, sewage, and electricity.
- Serving the lower-income segments of the population as they require a response that will match their income level related to their saving capacity.

#### **Projected housing demand 2008-2013**

The estimated demand for the period amounts to a little over 7 million dwellings (including expansions and remodeling) (See table 2). Year over year, demand grows at a slower pace mainly due to the reduction of housing backwardness.

#### **3.4.3 Infonavit and the 'Green Mortgage'**

Infonavit (National Fund for Housing) is a third-party institute founded in 1972 whose main function is to give workers credit for home acquisition.

**TABLE 2.** Estimated housing demand for 2008-2013. Source: CIDOC 2008.

Structure of housing demand					
Year	New Household Formation	Housing backwardness	Housing rotation	Origination cure	Accrued
2007	24.11%	67.98%	5.99%	1.93%	1,217,515
2008	25.87%	65.99%	6.17%	1.96%	2,376,894
2009	28.11%	63.49%	6.41%	1.99%	3,467,051
2010	30.91%	60.35%	6.70%	2.03%	4,479,940
2011	34.36%	56.49%	7.07%	2.08%	5,411,019
2012	38.53%	51.80%	7.53%	2.13%	6,259,301
2013	43.47%	46.24%	8.09%	2.19%	7,027,484

**Green Mortgage**

In collaboration with researchers and various companies, the Mexican government through Infonavit has developed the ‘Hipoteca Verde’ (Green Mortgage) Project, a plan that would help residents in the country acquire homes with environmentally friendly technologies. In its initial phase, the project has been a success boding well for sustainable living in the country.

According to calculations by the Mexican government, homes consume 16.5% of the energy generated in the country. Due to that, officials and others are betting on building new family homes that save energy and which are environmentally friendly.

It is a loan between 800 and 1,100 USD, in addition to the regular mortgage loan, for the installation of an accessory package with such equipment as solar heaters, low energy bulbs, and low water consumption toilets and faucets. The program began in March 2008 and currently only applies to homes that cost less than 43,000 USD and can be located in any state in the country. However, Infonavit has only identified 10 bioclimatic regions in the country that have suitable characteristics (such as the annual quantity of direct solar energy) for its development.

Currently, 17,240 ecological homes in 22 states are registered and being offered (INFONAVIT). More than 3,000 homes are in the process of being linked to such ecological mortgages and 1,159 operations, homes being used or listed as ready to live in, have been formalized. The goal is to have at least 1 million sustainable homes by 2012.

**Achievements of the Green Mortgage**

The results of Hipoteca Verde had been successful, and recently the National Housing Commission and Infonavit got an Energy Efficiency Award 2009 from the Energy Star Insti-

tute in the United States. The event was held in 17th Annual Evening with the Stars of Energy Efficiency Awards Dinner in Washington DC.

The CONAVI is currently leading Mexico’s 2007–2012 national housing program titled “Towards a Sustainable Housing Development.” CONAVI has served as a leader in initiating Mexico’s energy efficient housing policies. The Commission’s main areas of work are: restructuring of the national regulatory framework, research and development of energy-efficient technology, system indicators, certification schemes and financial incentives, and the contribution to mitigating the effects of climate change.

**4 RESEARCH METHODOLOGY**

To achieve the objectives of this research, the following methodology was proposed:

**Background Review**

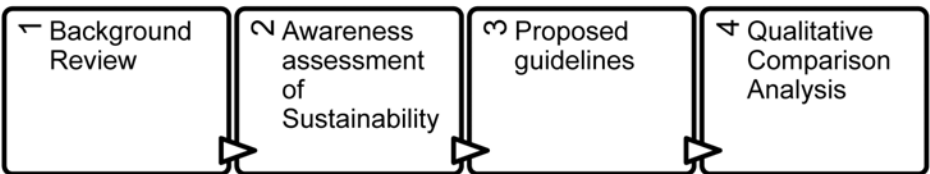
In order to know what has been done regarding sustainable construction in the world, a literature review was carried out, addressing the following topics: Sustainable development and smart growth of the cities, International achievements in sustainable construction, Vertical housing dwelling and Current Mexican housing situation.

**Awareness Assessment of Sustainability**

To assess the awareness of sustainability in the housing sector two different interviews were designed, one for construction companies and developers and the other for the government boards and institutes related to the construction industry.

Those interviews were intended to know if the interviewees knew about the term ‘sustainable construction’, its advantages in the application to the construction of vertical dwellings, if

**FIGURE 8.** Proposed research methodology.





their projects (in the case of the developers) have any sustainable characteristics, as well as other open questions such as the acceptance of this kind of construction by society in general. The questions asked in the interviews were:

*Developers, Construction Companies, Government and Institutes*

1. What do you know about 'Sustainable Construction'?
2. Do you think the use of sustainable construction criteria is convenient for the construction of vertical dwellings?
3. Do you think that the implementation of sustainable characteristics would make your projects more expensive or less expensive? In the short term, medium term and long term?
4. Is it convenient to build on hillsides and slopes, rather than the spaces defined by the urban areas?
5. Do you consider society ready to live in a sustainable condominium? Which adequacies should be done to the condominium norms and regulations to foster healthy co-existence?
6. Which benefits does your company get from the development of Vertical Sustainable Dwellings?
7. Which is the paper of the government regarding Vertical Sustainable Dwelling? Which are its responsibilities?
8. Do you have a specialized department for sustainability within your company?
9. What is needed to have experts in Vertical Sustainable Dwellings (Government, Developers and Institutes)?

*Developers and Construction Companies*

10. Currently, what percentage of your projects have any sustainable characteristics?
11. Have you ever implemented bio-climatic design (passive design) in any of your projects (solar orientation, cross ventilation, natural lighting, etc)? Comment on your experience.
12. Have you ever used any water, electrical energy, gas saving systems, low impact materials, waste management, or other saving and low-impact techniques? Comment on your experience.
13. What is needed to start the implementation of sustainable characteristics in your projects?

*Government and Institutes*

14. Is the Regulatory Framework suitable for the construction of sustainable dwellings?
15. From the following sustainable characteristics: water, energy, and land, which is the most important for the government? What is being done to address that characteristic?
16. What changes should be done to the Urban Development Plans?

After the interviews were done, they were analyzed qualitatively and the answers were gathered in a map diagram to identify main ideas and streamlines. This map was the basis for the next step.

## Proposed Guidelines

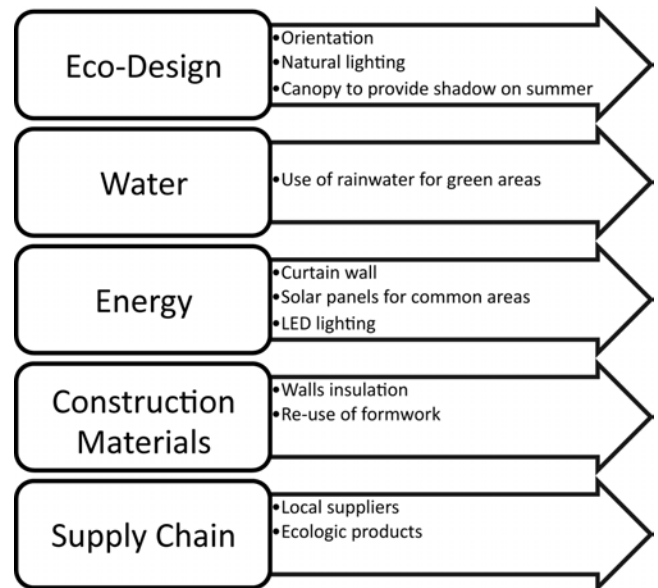
According to the outcome of the interviews and the analysis, solutions were proposed for each guideline found in the previous step. Some of these solutions were based on the recommendations and comments of the interviewees. A final map was presented with the key actions that can be undertaken to address sustainability in the construction of the new housing developments.

## Qualitative Comparison Analysis

For the qualitative comparison analysis, a developer was contacted and asked for the implementation of this qualitative analysis in one of their on-going projects. The main characteristics of the project were identified and then improvements were proposed in order to provide sustainable characteristics, and therefore, a sustainable condominium.

The following improvements were proposed and analyzed:

**FIGURE 9.** Proposed improvements for the building.



Subsequently the proposal was analyzed and discussed.

## 5 INTERVIEWS OUTCOME AND GUIDELINES

### 5.3 Description of the Interviewees

The interviewees were divided in two groups:

#### 1. Construction companies and developers

Eight construction companies and developers were contacted via e-mail or phone to arrange an interview, only four responded affirmatively representing a 50% response rate.

Two of the interviewees were Project Managers and two were the owners of the company, so the reliability of their



answers was considered high. All of those companies are located in Monterrey Mexico; three of them are all building approximately 25-story high-end condominium towers, and one was a consulting firm specializing in sustainable architecture (eco-design) and landscaping.

#### **Government boards and Institutes**

To cover this part of the research, the main government parties involved in the provision of housing and environmental regulations were identified, as well as some institutes dedicated to the research and consultancy of sustainable construction.

In total, seven institutions were contacted and four accepted the interview, representing a 57% response rate. The persons interviewed were mostly directors and program managers. Table 3 shows the government agencies, the position of the person interviewed, and the location.

#### **5.4 Interviews outcome**

The answers were gathered in a matrix for each type of respondent to allow for comparison. Only the main ideas were stated in the matrix, the interviews were recorded on tapes and then written in a document to allow for easy sorting of information. The question number was the same as established in step 2 from the methodology.

#### **5.5 Discussion**

Table 4 discuss the main outcomes from the answers that were asked to both, developers, construction companies and government agencies.

#### **Developers and Construction Companies Opinion**

##### **Implementation of green building criteria by developers**

It is surprising that developers are already implementing green characteristics in their new developments. They are doing so to fulfill municipal regulations and secondly as a strategy to offer a different product from the rest of their competitors. Two of the companies used green design as a base to develop their projects. However, even though there has been something done to address sustainability on projects, there is still a big need for the implementation of those characteristics on a larger scale.

##### **Green principles and techniques used by developers**

Some of the green characteristics the industry has implemented are: double glazing windows, green roofs, eco-design, wall insulation, balconies to provide shadow in summer, cross ventilation, and the use of native vegetation. Industry also has implemented energy saving systems such as electric heaters and LED bulbs, and water saving elements such as low pressure showerheads and faucets.

##### **Needs to implement sustainable characteristics on new projects**

Finally, to set off the construction industry towards sustainability, we need to change the culture and foster respect for the environment and spread the advantages of green construction. Two developers said that for the implementation of sustainable technology in their projects they need it to be less expensive and readily available to them. This means suppliers should promote their ecologic products and offer special rates to the developers.

#### **Government's Opinion**

##### **Suitability of the current regulatory framework**

The answers about the suitability of the current regulations to address sustainability revealed a general consensus that the actual legal framework is insufficient and inadequate and that regulation should be kept away from political interests. This new regulation should address environmental issues, social welfare, urban expansion and construction itself.

##### **Importance of resources for the government**

For the Government, land seems to be the most important issue, therefore re-densification is one alternative that government looks at to implement change. Water is other important resource. This is running out due to pollution and the growth of the population, so the implementation of efficient system is needed in the development of green housing. Energy is another resource, and in this regard the use of renewable energy should be promoted to change our reliance on oil.

##### **Changes needed for the Urban Development Plans**

Finally, the changes that need to be done to the UDP are, in first instance, updating many of them. Such updating should consider the deployment into partial plans where detailed

**TABLE 3.** Interviewees from Government Boards.

<b>Institution</b>	<b>Position of person interviewed</b>	<b>Location</b>
Infonavit (National Found for Housing)	Director of Green Mortgage	Mexico City
USAID (United States Agency for International Development)	Director of USAID Mexico	Mexico City
CANADEVI (National Board for the Promotion and Development of Housing Industry)	General Manager	Mexico City
SEMARNAT (Environment and Natural Resources Department)	Federal Representative in Nuevo Leon	Monterrey

**TABLE 4.** Discussion from the interviews outcome, including developers and government.

Question	Developers and Construction Companies	Government
Awareness of green building	With reference to the awareness of sustainability and green construction, all interviewees coincided on their definitions and their answers were convincing. Thus, it can be summarized that green construction is the creation of buildings which harmonize with the environment together with the coexistence of technology development, human beings, and nature. Green construction should also represent lower use of resources (materials, energy, water, land) and therefore provide economic savings in the short term but even more so in the long run.	Government agencies' respondents gave the same kind of answers about defining sustainable construction which lead to the conclusion that Mexican construction industry professionals acknowledge sustainable terms and criteria.
Using green building criteria for vertical dwelling	<p>According to the answers to the second question, all respondents agreed the implementation of sustainable criteria should be done for the design and construction of new housing developments. First of all, implementing eco-design or passive-design, and then implementing technologies to reduce initial costs. Actions should be implemented on 4 different groups or stakeholders:</p> <p><i>Government:</i> by the creation of a suitable regulatory framework, and implementation of plans for the provision of green housing to the population.</p> <p><i>Developers:</i> to obey green housing laws and invest in the construction of new green vertical dwellings.</p> <p><i>Universities and Research Centers:</i> conducting research for the development of new efficient technologies adapted to regional conditions. Promoting the new advances and providing training to the construction companies, developers, government members and anyone interested in sustainability.</p> <p><i>Population:</i> changing the culture and educating society towards sustainable development, and recognizing that living vertically is more sustainable.</p>	These respondents also considered the implementation of sustainable criteria in the development of new vertical housing very important. One person said that in real estate, location has an important value so re-densification in the city center should be fostered using current infrastructure. Therefore, vertical dwelling has more value than horizontal.
The cost of implementing green building criteria	The answers to the third question revealed that as a general consensus green buildings are more expensive at the building phase, but they represent important savings during their life cycle. This additional cost is due to the use of new technology. Nonetheless, two respondents said that this initial cost could be dropped and equal traditional construction costs by using natural resources available in the environment. This is the implementation of eco-design.	Regarding the cost of green housing, the respondents agreed that initial costs are still higher than conventional construction. But if we consider sustainability on a higher scale it could be cheaper. This means, if we considered a lump sum cost including land, infrastructure and services, vertical dwelling in central areas could be cheaper than horizontal dwelling in the outskirts.
The convenience of building on hillsides	Regarding the issue of building on hillsides and slopes, the respondents have different opinions, some of them contrasting. Certainly building on slopes causes ecological disruptions, but some areas on hillsides on the cities are intended to be development areas due to previous ecological impact studies and building characteristics. In the case of sprawling to productive areas, it's better to urbanize suitable areas on hillsides than changing the use of productive lands. And the best alternative is to use up all vacant lots in the cities, before moving to hillsides or to productive areas.	Now if we consider building on hillsides and slopes rather than in urban areas we benefit by using the same infrastructure, roads, transportation systems, services, and severe ecological impact is avoided. On the other hand, suitable areas for development are already stated in the UDP, also where parks and reserves are defined.

(continued on next page)

**TABLE 4.** (continued)

Question	Developers and Construction Companies	Government
Are people from Nuevo Leon ready to live in condominium?	There is a general consensus that the majority of the population are not ready to live in a condominium. There is a lack of condominium culture and education is needed for a harmonious co-existence in this new environment. Also, a regulatory framework should be developed to control the administration of the condominiums. However, there's one segment of the population composed of young professionals that are looking for this kind of dwelling.	Society is not ready to live in condominiums, vertical dwellings are incipient in the country, and coexistence regulations need to be developed. The advantages of a green condominium should be promoted, especially in cities with land shortage where re-densification could be a partial solution of the problem.
Green building benefits	If we talk about the benefits that developers would expect for the implementation of green characteristics and technology on new developments, they are aware of the advantages of this kind of construction but they don't see any direct benefit for them because the payback is often in the medium and long term, so the benefits are mostly for the end user. One developer said that sustainability is part of their marketing strategy but sales were not as high as expected.	The benefits that the government would expect from the implementation of green vertical dwelling are, in the first instance, the control over the growth of the cities; it would have adequate planning and efficient provision of services and the ecological impact would be lowered. It is also interesting to note the point of view of one respondent who said that with the development of green vertical housing government will have managed the population's basic needs by providing social stability and a decrease in social problems.
The paper of the government on sustainable dwelling	A paper by the government promoting green housing is sponsoring research for the development of new technology to promote a green culture in society. Also, the government should reward the implementation of sustainable criteria in housing projects, such as fiscal discounts, special rates for services, and subsidies in green technology.	The government's responsibility regarding sustainable dwelling is: determine suitable places for development through the creation of UDP which should have partial plans stating land use, densities, restrictions, etc. Government should promote the construction of green housing and the 'Green Mortgage' as a good beginning. Government also should support research for the creation of new technologies, adaptable to the country's conditions.
The need of a specialized department on green building	Regarding the need for a specialized department within construction companies, respondents said their teams are not large enough and creating a new department would not be cost effective, but they consider that it is important to have the knowledge of sustainable criteria. Some developers building a green project hired consultants to help them with the sustainable aspects of the project, and other developers considered it important to train their current employees.	Conventional construction will tend to disappear and sustainable concepts and practices will become more common. For that reason is important to update the knowledge, to change towards sustainable construction. These days universities are training new graduates in sustainable concepts so the new generations of professionals have this knowledge and they will be the ones to lead for a change and make the difference in the near future.
The need of experts on green construction	Experts on green construction are needed to boost the development of green housing. It should be the work of research institutes and universities to create and promote the knowledge and technology. Experts should be the ones to lead the creation of green regulation in the construction industry and training should be provided to managers and owners so they can spread the new culture of sustainability to the rest of the company.	Having experts on sustainable construction is necessary to have the expertise to make a difference. However, the creation of a new department specialized in sustainability would not be the best solution, instead we need to train the current personnel, especially leaders and regulatory makers.



**FIGURE 10.** General issues for the implementation of sustainable criteria on housing.

Developers	Government	Research Institutes	Society
<ul style="list-style-type: none"> <li>• There is a lack of investment on green projects.</li> <li>• Construction phase is still expensive.</li> <li>• Lack of fiscal incentives.</li> <li>• Green technology is not available and is expensive</li> </ul>	<ul style="list-style-type: none"> <li>• 'Green Mortgage' only available for horizontal housing.</li> <li>• Lack of proper regulation for green condominiums</li> <li>• Lack of a remuneration system to foster sustainability.</li> <li>• Obsolete UDP, need to adjust to the new conditions.</li> </ul>	<ul style="list-style-type: none"> <li>• Need support for research</li> <li>• Low development of new technologies</li> <li>• Lack of training and knowledge of sustainability.</li> </ul>	<ul style="list-style-type: none"> <li>• Coexistence problems</li> <li>• Rejects to live in condominium</li> <li>• Is unaware of green housing advantages.</li> </ul>

information of use, densities, and special considerations must be stated. Mixed-use buildings should also be fostered in the new UDP and the creation of larger scale plans could be implemented to consider not only the municipality, but the whole metropolitan area.

From the previous discussion, the following general issues regarding the implementation of sustainable criteria in the construction of vertical dwellings were summarized:

### 5.6 Proposed guidelines

Based on the main issues found in the previous discussions, some guidelines or actions to address these problems were proposed as follows:

With the aforementioned actions, the development of green vertical dwellings could be addressed in Mexico.

## 6 QUALITATIVE ANALYSIS

To carry out the qualitative analysis, a current project was selected in the city. It was analyzed to identify its main characteristics and define possible improvements to become a sustainable high-rise. The green improvements were based in the characteristics of the green condominiums presented on the framework review and passive features were given preference. The green improvements were also chosen according with the added value to the project.

**FIGURE 11.** Proposed guidelines to address sustainability on vertical housing.

Developers	Government	Research Institutes	Society
<ul style="list-style-type: none"> <li>• Implement eco-design in their projects.</li> <li>• Implement construction methods to generate savings for the company (Lean Construction)</li> <li>• Promote sustainability as a marketing strategy.</li> <li>• Look for training to their employees on sustainable construction.</li> </ul>	<ul style="list-style-type: none"> <li>• Needs to expand the 'Green Mortgage' to vertical dwelling.</li> <li>• Create proper regulation for green condominiums</li> <li>• Implement a remuneration system to foster sustainability.</li> <li>• Update UDP, making concious studies for new development areas .</li> </ul>	<ul style="list-style-type: none"> <li>• Offer training courses on eco-design.</li> <li>• Develop suitable technology according to the country's conditions.</li> <li>• Transfer the knowledge and technology to developers and government.</li> </ul>	<ul style="list-style-type: none"> <li>• Education programs to change the overview of living in condominium.</li> <li>• Implement coexistence codes.</li> <li>• Promote green housing and its advantages.</li> <li>• Offer them high quality developmetns.</li> </ul>

**TABLE 5.** Improvements proposal.

Characteristic	Status
Orientation	Available
Natural Lighting	Available
Canopy	Available
Collection of rainwater for irrigation	Not available
Solar panels for common areas	Not available
Hot water recirculating system	Available
Insulated walls	Available
Re-use of formwork	Not available
Local suppliers	Available
Ecologic products	Not available

These improvements were discussed with the Project Manager of the development and the suitable ones were selected and formed part of the improvements proposal. Then, the developer provided the needed information to perform the characteristics comparison.

Table 5 shows the sustainable elements that were analyzed, some of them where already present on the tower and they are shown in column ‘Status’ with the legend: Available. The rest of the elements where proposed as improvements and their contribution to the greenness of the tower was discussed.

We present the following description of the improvements:

**Orientation**

In this case a proper orientation of the building was used by the developer, having no effect on the cost of the tower. This helps to reduce isolation and provide comfortable temperatures in most of seasons, thus the energy consumption is reduced. The region of Monterrey gets very hot on summer and it gets cool in winter, therefore, a suitable solution to provide natural light without gaining heat was used, it is discussed in the next improvements.

**Natural lighting**

The apartments were provided with curtain walls to allow for natural lighting, and all the rooms in the apartments were designed to receive natural light. Therefore a reduction in energy consumption was guaranteed. The living areas were located facing south, and as in summer the isolation is high, the provision of overhangs to provide shadow was needed

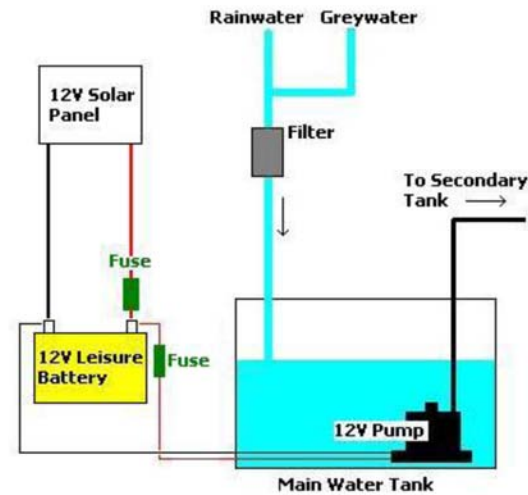
**Canopy**

As a result of having curtain walls, canopies were needed to provide shadow in the living areas of the apartments, reducing isolation and fostering energy savings. In this case, the canopies are currently available on the towers but were considered as a proposal.

**Rain water collection system**

A rain water collection system was proposed for irrigation of the landscaped area. It consisted of collecting pipes from the

**FIGURE 12.** Water storage and irrigation supply system.



rooftop of the building and the impermeable areas, and a concrete holding tank of 75m<sup>3</sup> (5×5×3m). This tank will supply water during some of the dry months, representing savings in use of potable water. The draft of the system to provide irrigation to the landscaped areas is shown in figure 12.

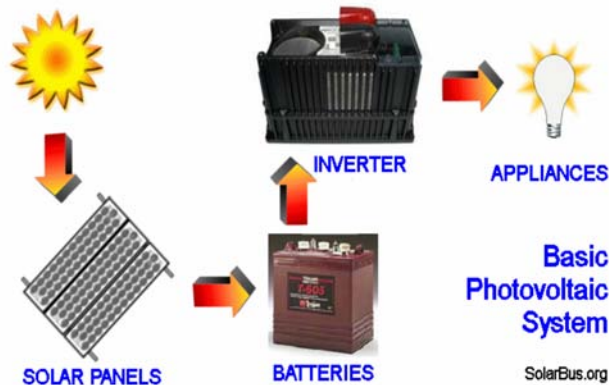
**Solar panels**

A Grid-tie Solar System (GST) was proposed, with an 8 modules array capable of producing 1400Watt. LED lighting was proposed for the common areas and landscaped areas, thus a reduction in the energy consumption for those items is guaranteed representing no cost for the next 25 years (GST warranty). Figure 5.3 depicts the function of the GST system, and figure 5.4 shows the type of lighting that will be used for common areas in the tower.

**Hot water recirculating system**

A hot water recirculating system is currently available in the tower, fostering energy savings and water use reduction. In terms of this study, this item was considered as a proposal for being a sustainable characteristic. This system has

**FIG. 5.3.** Diagram for the GST system.



a recirculating valve, which works with a thermostat where a temperature is set, when the water gets colder, a pump is activated to recirculate water through the pipes, providing hot water at all times and reducing water consumption.

### ***Insulated walls***

Pre-cast concrete walls were used for the building which provides some insulation. However, a layer of polystyrene insulation was proposed to reduce heat transmission (especially during the hot summer months.). Having a comfortable temperature in the apartment reduces energy use from cooling.

### ***Re-use of formwork***

During the construction of the tower conventional wood formwork was used, because a reasonable supplier was not found that would meet the sought after specifications and cost. However this technology is evolving constantly and is currently more accessible. Therefore a metal form was proposed for pre-casting exterior walls on site and for pouring columns and beams. In this case, the initial cost of acquiring this technology is expensive but is cheaper than using wood forming, if the whole building process time is considered.

### ***Local suppliers***

In this case local suppliers were used to provide all the most important materials, taking into consideration the delivery times. An integration of the supply chain means acquiring all materials from local suppliers, reducing transportation cost and gas emissions. It also means helping local markets, thus local welfare and development.

### ***Ecologic products***

In that tower, ecologic products were not used in any phase of the project. Therefore, the use of ecologic and recycled products was proposed such as recycled PVC for piping, recycled metal and glass. Those improvements don't represent a consequential increase in price, and despite their rare use they will soon be considered a need in the country and use will increase.

In Mexico there is not a wide spread of production of recycled materials. Despite the lack of recycling culture, in the country are already some companies that manufacture their products based on recycled materials, but in general they are small companies and don't have the money to invest on advertisement and promotion.

## **7 CONCLUSIONS**

Sustainability is becoming a focus of attention in the Government, Research Institutes and Education Centers in Mexico. The National Development Plan 2006-2012 contemplates a sustainable development of the country.

The Mexican government has launched the 'Green Mortgage' program to address sustainability in the construction of new housing for the low income class, however this program needs to become broader and include vertical housing and other income levels.

To fill the housing shortage in Mexico the Vertical Dwelling is a feasible option, especially in big cities where the availability of land for horizontal developments is very far from the city center and services.

Vertical dwellings represent a greener way to build by the simple fact that it requires less land space. Vacant lands within urban areas can be recovered, thus the use of existing infrastructure and services make the projects less expensive.

There is not a proper regulatory framework for the condominium regimen or for the construction of green dwellings. Therefore, the government should create a regulatory framework with the help of the Research Institutes and other experts.

The Mexican population is not ready to live in condominiums, but there are some exceptions, like in Mexico City, where the lack of land has privileged vertical living. However, a culture of condominium and coexistence should be fostered. Nonetheless, new generations are open and adaptable to different conditions; they are the key for success of sustainable development of the country.

If we take into consideration the overlook of government and developers of sustainability of the site, government consider the whole city and developers are focused in their developments only. Therefore the actions implemented are according to those scales.

The current green technology is still too expensive to be implemented massively in construction projects, therefore new research and development should be done to create suitable and reliable technology adapted to Mexican conditions.

Developers should foster sustainability in their projects, adding value to their clients through efficient and well constructed homes. They can also get benefits through the implementation of Lean Construction techniques and a good supply chain management.

In the qualitative analysis, we addressed the potential cost savings that green improvements can generate if passive design techniques were considered, such as bioclimatic design, use of ecologic materials, and integration of the supply chain.

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