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LOW IMPACT, AFFORDABLE, LOW INCOME HOUSES FOR MEXICO

Jose Luis Bermudez Alcocer
Ph.D. Student

Jeff S. Haberl, Ph.D., P.E., FASHRAE
Professor

Department of Architecture, Texas A&M University
College Station, Texas, USA

ABSTRACT

This paper discusses an effort to develop low impact, affordable, low income houses for Mexico. Low impact houses are defined as houses with energy and water needs that are substantially reduced below levels corresponding to code compliance. This paper includes an analysis of the population and energy consumption of the different climate regions in Mexico (Hot-Dry Deserts, Great Plains, Mediterranean, Semi-Arid, Temperate, Hot-Dry Jungles and Hot-Humid Jungles) versus the USA and concludes with advice on an approach for low impact housing.

INTRODUCTION

This article covers: a) population and energy consumption in the USA and Mexico and b) the different climate regions in Mexico.

POPULATION AND ENERGY CONSUMPTION IN THE USA AND MEXICO

The most significant literature review for this section covers building energy codes (ICC 2009; CONAVI 2006), census maps (INEGI 2008b, c, d; US Census Bureau 2010c), population reports (INEGI 2008a), energy use statistics (SENER 2007; US DOE 2009) and population studies (INEGI b; US Census Bureau 2010a, b, d, e, f).

To begin, there is a vast difference in population between the USA and Mexico. In 2008, the USA had 304.0 million people in 2008, whereas Mexico had 103.20 million people in 2005 (INEGI 2008a, p.5; US Census Bureau 2010a). However, aside from the approximate 3:1 difference in population, to learn more about housing differences it is usual to compare housing by state and city.

POPULATION DENSITY BY STATE

Figure 1 shows the population density by state in the USA in 2008 (US Census Bureau 2010b). In 2008, the District of Columbia had 9,638 people / sq. mile, which is ten times the density of the next highest states (e.g. New Jersey and Rhode Island). The states of New Jersey (1,170), Rhode Island (1,005), Massachusetts (828), Connecticut (722), Maryland (576), Delaware (446) and New York (412) range between 400 and 1,200 people / sq. mile. Figures 2 and 3 show the location of these states against the climate regions of the USA. The states with most population density (people / sq. mile) in the USA are in the Northeastern zone. These states fall in the cold (New York, Massachusetts, Rhode Island and Connecticut) and the mixed-humid (New Jersey, Delaware, Maryland and D.C) climates.

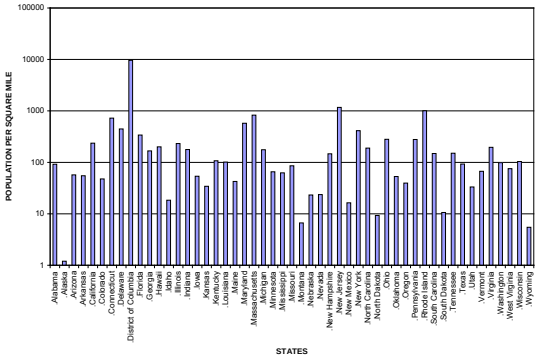

Fig. 1: Population Density by State in the USA (2008)

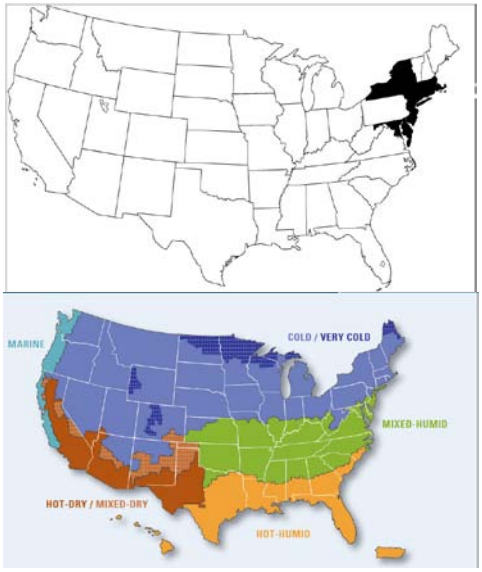

Fig. 2 and 3: Location of the States with higher Population Density and a Climate Region Map of the USA (modified from United States Map 2010; US DOE, 2007)

Figure 4 shows the population density by state in Mexico in 2005 (INEGI 2008b). The Federal District (*Distrito Federal)* [1], has the highest population with 15,210 people / sq. mile, which is also ten times the population of the second most populated state. *Mexico (*or *Estado de Mexico)* [2] (1,623), *Morelos* (854), *Tlaxcala* (693), *Aguascalientes* (491), *Guanajuato* (414) and *Puebla* (407) range between 400 and 1,200 people / sq. mile. Figures 5 and 6 show the location of these states in relation to the climate regions in Mexico. The states with most population density in Mexico are in the South-central zone. These states fall in the temperate *(Distrito Federal, Tlaxcala and some areas of Aguascalientes, Guanajuato, Mexico, Morelos and Puebla),* hot-dry jungle *(some areas of Mexico, Morelos and Puebla),* hot-humid jungle *(some areas of Puebla)* and semi-arid *(some areas of Aguascalientes and Guanajuato)* climate zones.

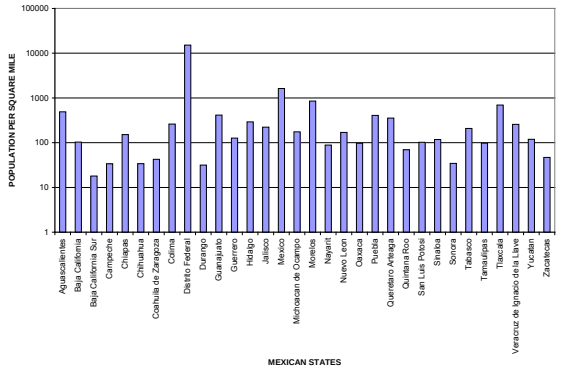

Fig. 4: Population Density by State in Mexico (2005)

[1] *Distrito Federal* is the capital from Mexico. It is the 32nd state in the country under the name of *Estado del Valle de Mexico* (State of the Valley of Mexico).

[2] *Mexico* (or *Estado de Mexico*) is a name given to the second most populated state in Mexico. The population of the Metropolitan Zone of Mexico City is formed by the *Distrito Federal* and 40 *municipios* (municipalities) within *Mexico* (or Mexico State), which include: *Acolman, Atenco, Atizapan de Zaragoza, Chalco, Chiautla, Chicoloapan, Chiconcuac, Chimalhuacan, Coacalco de Berriozabal, Cocotitlan, Coyotepec, Cuautitlan, Cuautitlan Izcalli, Ecatepec de Morelos, Huehuetoca, Huixquilucan, Ixtapaluca, Jaltenco, La Paz, Melchor Ocampo, Naucalpan de Juarez, Nextlalpan, Nezahualcoyotl, Nicolas Romero, Papalotla, San Martin de las Piramides, Tecamac, Temamatla, Teoloyucan, Teotihuacan, Tepetlaoxtoc, Tepotzotlan, Texcoco, Tezoyuca, Tlalmanalco, Tlalnepantla de Baz, Tultepec, Tultitlan, Valle de Chalco Solidaridad* and Zumpango and one *municipio* (municipality) from *Hidalgo: Tizayuca*.

Fig. 5 and 6: Location of the States with higher Population Density and Climate Region Map of Mexico (modified from *INEGI* 2010 and *CONAVI* 2005, p.18)

In summary, several differences can be seen in the distribution of population in different climate zones when compared to Mexico. In Figure 1 to Figure 6 it can be seen that the USA has one state (D.C.) with a density near 10,000 people / sq. mile, two (2) states (New Jersey and Rhode Island) with a density above 1,000 people / sq. mile, 22 states with a density between 100 and a 1,000 people / sq. mile, 22 states with a density between 10 and 100 people / sq. mile and four (4) states with less than 10 people / sq. mile. In other words, more than half of the states in the USA have population densities of 10 to 1,000 people per square mile. Only three states have a density in excess of 1,000 people / sq. mile.

On the other hand, Mexico has one state (*Distrito Federal*) with a density above 10,000 people / sq. mile, one state (*Mexico*) with a density above 1,000 people / sq. mile, 19 states with a density between 100 and a 1000 people / sq. mile, 11 states with a density between 10 and 100 people / sq. mile and none state with less than 10 people / sq. mile. In contrast to the USA, Mexico has all but two states with a population density of 10 to 10,000 people / sq. mile.

The states with higher population density in the USA and Mexico fall in very different types of climates: cold and mixed-humid in the USA and

temperate, hot-dry jungle, hot-humid jungle and semi-arid in Mexico. Therefore, based on this analysis low impact housing for the most populated regions of the USA are in very different climate zones than the most populated areas of Mexico. Also if low impact housing could be developed for the Mexico City area it would have a large impact on the whole country.

TOTAL POPULATION BY STATE

The second type of analysis is considered the total population by state. Figure 7, 8 and 9 show the population by state in the USA in 2008, which shows that California surpasses 35 million people; Florida, New York and Texas range between 15 and 25 million people, and Michigan, Ohio and Pennsylvania range between 10 and 14 million people. Georgia and North Carolina are close to 10 million people. States such as Arizona, Indiana, Maryland, Massachusetts, Minnesota, Missouri, New Jersey, Tennessee, Virginia, Washington and Wisconsin that range between five (5) and nine (9) million people. In contrast to looking at the population density the total population by state shows the USA population is fairly well distributed across different climate zones.

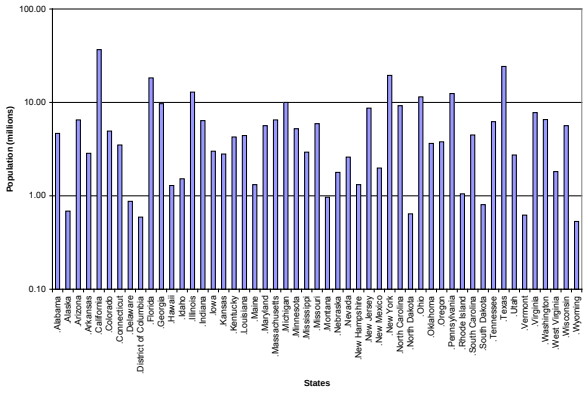

Fig. 7: Total Population in the USA by State (2008)

Fig. 8: Location of the most populated States in the USA (modified from United States Map 2010)

Fig. 9: Climate Region Map of the USA (US DOE, 2007)

In a similar fashion as the USA, Figure 10, 11 and 12 show the total population by state in Mexico in 2005. *Mexico* (or *Estado de Mexico*) (14.01 million) is the only state that surpasses the 10 million people in Mexico. *Distrito Federal* (8.72), *Veracruz de Ignacio de la Llave* (7.11), *Jalisco* (6.75) and *Puebla* (5.38) range between five (5) and nine (9) million people. However, in contrast to the USA, the population in Mexico is more concentrated in the South-central area in the valley that surrounds Mexico City.

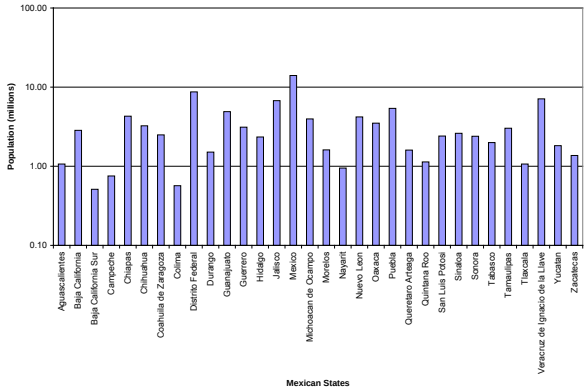

Fig. 10: Total Population in Mexico by State (2005)

Fig. 11: Location of the most populated States in Mexico (modified from *INEGI* 2010)

Fig. 12: Climate Region Map of Mexico (modified from *CONAVI* 2005, p.18)

A slightly different set of conclusions can be obtained from an analysis from Figure 7 to 12. These Figures show the total state population distribution in the USA is clearly more spread out than in Mexico. In 2008, the USA had seven (7) states with more than 10 million people, 36 states with a population between one (1) and 10 million people and eight (8) states with less than one (1) million. New York was the only state in the USA that shared high population density (people / sq. mile) and was one of the most populated states (population in millions) of the country. On the other hand, in 2005, Mexico had one state (*Mexico*) with more than 10 million people; 27 states with a population between one (1) and 10 million people; and four (4) states with less than one (1) million people. Three (3) states in Mexico share the highest population density (people / sq. mile) and are the most populated states (population in millions) of the country in contrast to the USA, all three (3) states *Distrito Federal*, *Mexico* and *Puebla* are in the South-central area of the country. Following these three (3) most populated states the other states in Mexico with high population, such as *Jalisco* and *Veracruz de Ignacio de la Llave*, are in different states with different climate zones. *Jalisco* has temperate, semi-arid and hot-dry jungle climates, and *Veracruz de Ignacio de la Llave* has temperate, hot-dry and hot-humid jungle climates. Therefore, if one were to try to include housing beyond the valley surrounding Mexico City one would need to consider some very different climate zones.

POPULATION BY CITIES

In the third analysis the population of the USA and Mexico is viewed by cities. Figures 13 and 14 show the cities with at least 500,000 people or more in the USA in 2008 (US Census Bureau 2010f). The only two metropolitan cities to surpass 10 million people are New York-North New Jersey-Long Island (NY-NJ) (New York City is 5,027 HDD65°F and 3,342 CDD50°F) and Los Angeles-Long Beach-Santa Ana (CA) (Los Angeles is 1,458 HDD65°F and 4,777 CDD50°F and Long Beach is 1,430 HDD65°F and 5,281 CDD50°F) with 19.0 and 12.8 million people, respectively (Stein et. al. 2010, p.1507-1515). In the USA, there are 26 metropolitan cities between two (2) and 10 million people such as Chicago-Naperville-Joliet (Chicago is 6,536 HDD65°F and 2,941 CDD50°F), Dallas-Fort-Worth-Arlington (Dallas is 2,259 HDD65°F and 6,587 CDD50°F, and Fort-Worth is 2,304 HDD65°F and 6,557 CDD50°F) and Philadelphia-Camden-Wilmington (Philadelphia is 4,954 HDD65°F and 3,623 CDD50°F). There are 22 metropolitan cities between one (1) and two (2) million people such as Las Vegas-Paradise (Las Vegas is 2,407 HDD65°F and 6,745 CDD50°F), San Jose-Sunnyvale-Santa Clara, and Columbus (Columbus is 5,708 HDD65°F and 3,119 CDD50°F). Finally, there are 46 metropolitan cities between one (1) and 500,000 people such as Honolulu (0 HDD65°F and 9,949 CDD50°F), Bridgeport-Stamford-Norwalk (Bridgeport is 5,537 HDD65°F and 2,997 CDD50°F), and Albany-Schenectady-Troy (Albany is 6,894 HDD65°F and 2,525 CDD50°F).

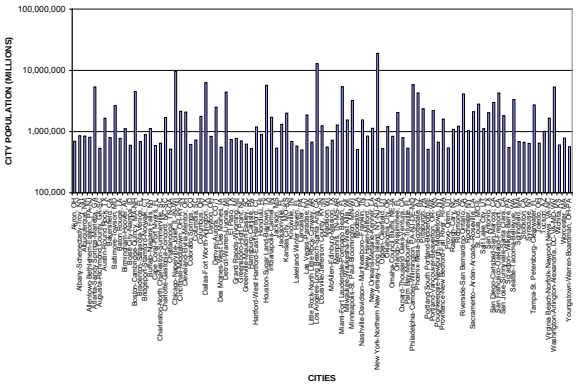

Fig. 13: Cities with at least 500,000 people or more in the USA (2008)

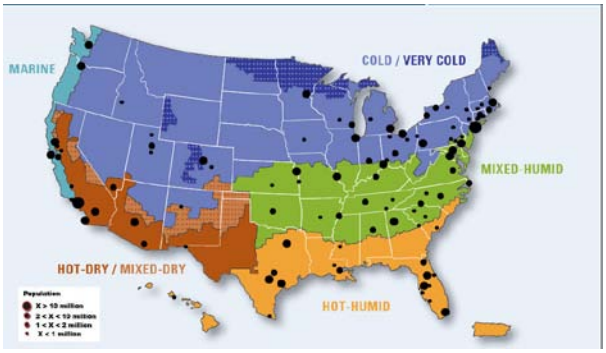

Fig. 14: Cities with at least 500,000 people or more in the USA (2008) (modified from US DOE, 2007)

Figures 15 and 16 show the cities with at least 500,000 people or more in Mexico in 2005: *Acapulco*, *Aguascalientes*, *Cancun*, *Chihuahua*,

Ciudad Juarez, *Cuernavaca*, *Guadalajara* (701 HDD65°F and 0 CDD50°F), *La Laguna*, *Leon*, *Merida* (10 HDD65°F and 11,112 CDD50°F), Mexico City (1,203 HDD65°F and 4,762 CDD50°F), *Monterrey* (844 HDD65°F and 8,326 CDD50°F), *Morelia*, *Oaxaca*, *Queretaro*, *Puebla-Tlaxcala*, *Reynosa-Rio Bravo*, *Saltillo*, *San Luis Potosi*, *Toluca*, *Tijuana*, *Tampico*, *Tuxtla Gutierrez*, *Veracruz*, *Villahermosa* and *Xalapa* (*CONAVI* 2006, p.33; *INEGI* 2008c, p.15-16; Stein et. al. 2010, p.1515). One additional feature can be seen by comparing housing counts with populations. For example, in Mexico the houses usually have extended families. In 2005, the average number of people in a house in Mexico is 4.0 (*INEGI* 2008a, p.7). In comparison, in 2000 the USA had an average of 2.5 people living in a house (US Census Bureau 2010b). This would imply that energy efficient residences in Mexico would need to focus more on occupant-related activities, such as cooking, clothes washing and lighting.

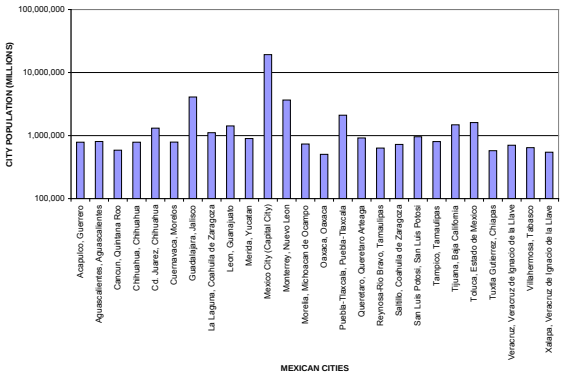

Fig. 15: Cities with at least 500,000 people or more in Mexico (2005)

Fig. 16: Cities with at least 500,000 people or more in Mexico (2005) (modified from *CONAVI* 2006, p.33 and *INEGI* 2008c, p.15-16)

The next facet of the analysis can be seen by comparing information for both countries from Figures 13 through 16. In Figures 13 and 14, the population of the USA cities above 500,000 can be seen in three (3) main areas: Northeast, Southeast and Southwest, with "isolated" cities like Seattle (4,908 HDD65°F and 2,021 CDD50°F) and Portland (4,522 HDD65°F and 2,517 CDD50°F) (Northwest), Denver (6,020 HDD65°F and 2,732 CDD50°F), Salt Lake City (5,765 HDD65°F and 3,276 CDD50°F) and Minneapolis (7,981 HDD65°F and 2,680 CDD50°F). These areas cover the cold, mixed-humid, hot-humid, hot-dry and marine climate zones. The USA shares three (3) climatic zones with Mexico: hot-humid, hot-dry and marine. The main cities located in the Southeast area with hot-humid climate are: Austin (1,688 HDD65°F and 7,171 CDD50°F), Houston (1,371 HDD65°F and 7,357 CDD50°F), San Antonio (1,644 HDD65°F and 7,142 CDD50°F), McAllen, Dallas (2,259 HDD65°F and 6,587 CDD50°F), New Orleans (1,513 HDD65°F and 6,910 CDD50°F), Baton Rouge (1,669 HDD65°F and 6,845 CDD50°F), Jacksonville (1,434 HDD65°F and 6,847 CDD50°F) and Tampa Bay (725 HDD65°F and 8,239 CDD50°F); cities in the Southwest area with hot-dry climate are: Phoenix (1,110 HDD65°F and 8,425 CDD50°F), Tucson (1,678 HDD65°F and 6,921 CDD50°F), El Paso (2,708 HDD65°F and 5,488 CDD50°F) and Las Vegas (2,407 HDD65°F and 6,745 CDD50°F), and cities in the Southwest area with marine climate are: Los Angeles (1,458 HDD65°F and 4,777 CDD50°F), Sacramento (2,749 HDD65°F and 4,474 CDD50°F) and San Francisco (3,016 HDD65°F and 2,883 CDD50°F). These cities represent one third of the population of the 90 cities shown in Figure 10. From a climatic perspective, the low income houses in these areas in the USA would be best to compare and analyze with those in Mexico.

In viewing Figures 15 and 16, it is clear that the population in cities over 500,000 in Mexico is mainly located in the South-central area (Mexico City (1,203 HDD65°F and 4,762 CDD50°F), *Puebla-Tlaxcala*, *Toluca*, *Cuernavaca*, *Guadalajara* (701 HDD65°F and 0 CDD50°F), *Morelia*, *Queretaro*, *Leon*, *Xalapa and Veracruz*) with some "isolated" cities such as *Tijuana*, *Ciudad Juarez*, *Monterrey* (844 HDD65°F and 8,326 CDD50°F), *Acapulco*, *Tuxtla Gutierrez*, *Oaxaca*, *Villahermosa*, *Merida* (10 HDD65°F and 11,112 CDD50°F) and *Cancun*. In contrast to the USA, the climates in Mexico with the most population in different climates, which include: *Tijuana* (marine), *Cancun* (hot-humid jungle), Mexico City (temperate), *Ciudad Juarez* (hot-dry), *Acapulco*, *Veracruz* and *Tuxtla Gutierrez* (hot-dry jungle), *Guadalajara* (semi-arid) *and Monterrey* and *Reynosa-Rio Bravo* (hot-humid).

ENERGY CONSUMPTION IN THE USA AND MEXICO

Figures 17 and 18 show that the total energy consumption in the USA in 2007 was 101.46 QBtu, of which the energy consumption for housing was 21.60 QBtu (US DOE 2009, p.3). On the other hand, Figures 19 and 20 show that the total energy consumption in Mexico in 2007 was 4.31 QBtu [3], and the energy consumption for housing was 0.70 QBtu (SENER 2007, p.43). In 2008, the USA had 304.0 million people, whereas Mexico had 103.20 million people in 2005, which equals to 71,052,632 Btu/person in the USA and 6,811,301 Btu/person in Mexico, based on the energy consumption in the respective housing sectors.

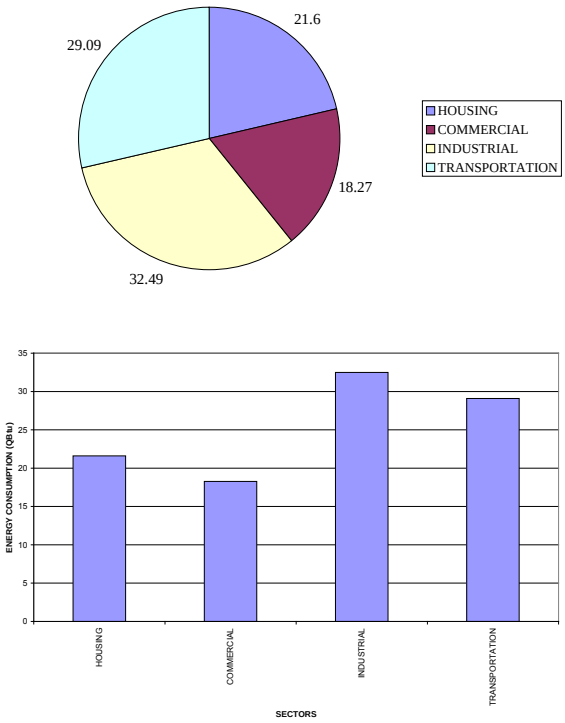

Fig. 17 and 18: Total Energy Consumption (Qbtu) in the USA in 2007 (US DOE 2009, p.3)

Clearly, the USA consumes more energy than Mexico and it would seem that Mexico would have little to learn from the USA. Unfortunately, the less affluent population in Mexico tends to buy electrical appliances for their houses when their income increases. Therefore, new houses in Mexico must be designed to be more energy efficient, affordable and use renewable energy or they face becoming as energy-consumptive as those in the USA. Some organizations, such as the US Department of Energy (US DOE) Residential Buildings Program, the National Renewable Energy Laboratory (NREL) and the Building America (BA) teams, are already working with Mexican officials to reduce residential energy use.

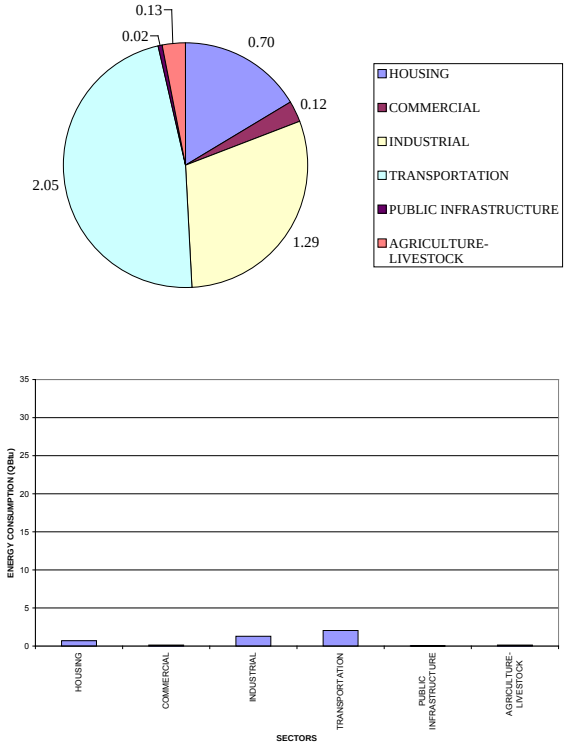

Fig. 19 and 20: Total Energy Consumption (Qbtu) in Mexico in 2007 (SENER 2007, p.43).

In contrast to the USA, the highest energy consumption elements in a house (by order of importance) in Mexico are: cooking, hot water, lighting and appliances (CONAVI 2006, p.16). Fortunately, there are energy efficient solutions that can be applied to Mexican houses such as: solar cook stoves, solar water heating, natural ventilation, daylighting, rainwater harvesting, biogas and very effective electric appliances to reduce energy use. Unfortunately, many of these solutions are not recognized by building codes. A dwelling constructed in the USA or Mexico should comply with the requirements of their energy codes: the International Energy Conservation Code (IECC) and the Energy-Efficient Housing Code, respectively (ICC 2009; CONAVI 2006). The 2009 IECC is the latest updated version, establishes the minimum regulations for energy efficient buildings. The

[3] The energy consumption sectors in Mexico are: housing, commercial, industrial, transportation, public infrastructure and agriculture-livestock (SENER 2007, p.43). The housing, commercial and public infrastructure (public lighting and water pumping) sectors function as a single group.

Energy-Efficient Housing in Mexico (EEH) is a guide created by the *CONAVI* in Mexico, which shows elements related to energy efficiency. Most of the elements in the EEH are climate-based design requirements. The EEH was the first official guide in Mexico to include sections for bioclimatic design and sustainability for each climate region. It represents an early stage design guide with some bioclimatic design and sustainability strategies.

CONCLUSIONS

In conclusion, the USA and Mexico differ in population and energy consumption. The population in Mexico, as shown in the previous figures, is concentrated in the South-central states with some "isolated" cities in comparison with the more spread out population through the USA. The energy consumption in the housing sectors for the USA and Mexico was 71,052,632 Btu/person (in 2008) and 6,811,301 Btu/person (in 2005), respectively. It would seem that Mexico would have little to learn from the USA. Nevertheless, the less affluent population in Mexico tends to buy electrical appliances for their houses when their income increases. Also, the need of more dwellings in the country is high. Thus, there are some lessons learned from the analysis, which include:

1) The USA and Mexico share three (3) climate zones (hot-humid, hot-dry and marine). The solutions given in the existing houses located in these climate zones should be considered and studied for the new houses in these areas.

2) The South-central area in Mexico has approximately the 50 % of the population of the country. The need for new houses is high and the area to build in the cities of the area is low (e.g. Mexico City). Therefore, the idea of multi family low income house should be considered for this area.

3) The new houses in Mexico must be designed to be more energy efficient, affordable and use renewable energy or they face becoming as energy-consumptive as those in the USA.

4) Optimal space solutions for the new houses for an average family of four members in Mexico, which is twice the USA average.

5) Mexico does not share the cold and the very cold climate zones of the USA. (The cold and the very cold climate zones are located in 50% of the territory of the USA). The houses for these climates in the USA relay on mechanical space heating, ventilating and cooling.

Therefore, we can conclude that new, low income houses for the climate zones in Mexico should have energy efficient solutions that emphasize solar cook stoves, solar water heating, natural ventilation, daylighting, rainwater harvesting, biogas and very effective electric appliances to reduce energy use.

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