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Energy Efficiency and Quality of Life: An Analysis of Mexico's Green Mortgage Program

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Energy Efficiency and Quality of Life:

An Analysis of Mexico's Green Mortgage Program

A dissertation submitted in partial satisfaction of the

requirements for the degree Doctor of Philosophy

in Urban Planning

by

Miriam Paloma Giottonini Badilla

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ABSTRACT OF THE DISSERTATION

Energy Efficiency and Quality of Life:

An Analysis of Mexico's Green Mortgage Program

by

Miriam Paloma Giottonini Badilla

Doctor of Philosophy in Urban Planning

University of California, Los Angeles, 2018

Professor Leobardo F. Estrada, Chair

Mexico's Green Mortgage Program (GMP) is the largest and fastest growing effort to increase residential energy-efficiency in low-income households in the world. Since its implementation in 2011, it has delivered more than three million dwellings with energy-efficient appliances to the low-income sector in Mexico. In this dissertation, the GMP serves as a case study to analyze energy efficiency as an instrument to improve quality of life of low-income neighborhoods. Using a multiple benefits framework, I explore the outcomes of the GMP beyond the reduction of electricity consumption. This is the first study that evaluates the effects of energy policy as an instrument to promote energy efficiency and an improvement of living conditions of the largest and fastest growing sector of the population of developing countries.

This dissertation is divided into two major sections: The first part tests the hypothesis that dwellings built through the GMP use less electricity than traditional households. I use bi-monthly utility bills to compare energy consumption between two GMP and two traditional neighborhoods. I find no statistically significant difference between neighborhoods, suggesting that the GMP is not delivering the expected results.

The second part explores how the GMP has improved the living conditions of people participating in the program. I compare different participation levels among members of the GMP and the traditional households in three main activities: recreation, skill-building, and additional educational activities. The hypothesis is that a reduction in electricity usage will reduce utility payment, allowing households to access new capacity-building opportunities. The analysis of survey responses shows no statistically significant difference between the living conditions of both groups, demonstrating that the GMP has had no effect on the living conditions of its inhabitants.

I conclude that the GMP requires a considerable review and transformation so it can deliver the expected results, or participation in the program must become optional. Additionally, governments of developing countries must reconsider the overall effects of climate change related policies, particularly those oriented at the lower-income sector of society.

The dissertation of Miriam Paloma Giottonini Badilla is approved.

Paavo Monkkonen

Vinit Mukhija

Magali A. Delmas

Leobardo F. Estrada, Committee Chair

University of California, Los Angeles

2018

Para Nicolás

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Chapter I. Introduction

How can governments guarantee equitable access to opportunities that could facilitate the improvement of living conditions, without compromising economic growth and environmental protection? This question is the main piece of the puzzle that scholars of sustainable development have been trying to solve for decades. While the economic and environmental components of sustainability have been vastly explored in the literature, the social component and particularly the issue of equity have been quite elusive (Colantonio, 2009; Sachs, 1999; Littig & Greisler, 2005). Urban planning has explored different strategies and tools, such as advances in policy-making, alternative governance models and innovative funding strategies that could facilitate a sustainable path of development for all urban areas.

Energy efficiency has been only one part of the solution, albeit an important one. A large proportion of energy demand is generated in urban areas, where industries, jobs and people congregate and interact. Despite many programs, policies and campaigns to reduce energy use over the past three decades, energy consumption in most industrial countries has risen continuously (Herring, 2006). Energy demand is expected to continue growing, particularly in developing countries, due to an expected success on poverty reduction efforts and the introduction of new technologies (Wolfram, Shelef & Gertler, 2012; US Energy Information Administration, 2017), as well as an expected population growth and increase in purchasing capacity.

Urban planners and architects have been involved in this debate, as the built environment is one of the largest energy consumers and, consequently, a large contributor of greenhouse gas emissions (GHG hencefort). Buildings are consumers of direct energy (required for the construction and maintenance of buildings) and indirect energy (represented by the daily requirements of building users, such as hygiene, food and transportation) (see Vringer & Blok, 1995 for a comprehensive explanation of each type of energy consumption). One of the foci of research of urban planners and architects is to improve energy consumption in the built environment in order to transform cities into more sustainable entities, that is, to follow an 'environmentally benign, economically viable and socially equitable development path' (Rees, 1997). Faced also with the additional challenges of climate change, which is recognized as one of the biggest threats of the 21st century, policy- and decision-makers expect to confront these challenges with adaptation and mitigation strategies. The challenge for urban planners is to transform these strategies so they are relevant at the urban scale.

Energy generation is one of the most polluting industrial activities. Efficiency in the use of energy offers a set of potential benefits to address the goals of climate change mitigation by reducing the demand for energy generation, and consequently reducing carbon emissions. At a smaller scale, the individual and household level, energy efficiency helps to reduce utility costs, allowing families and individuals to have more money to invest and improve their living conditions.

A key aspect of this dissertation is the analysis of the relationship between energy efficiency and living conditions. Both present challenges in operationalization and measurement. Energy efficiency refers to a reduction the amount of energy required to provide the same amount of products and services, also called the useful output (Patterson, 1996). It is a fairly simple concept whose effects have proven to be difficult to measure (IEA, 2017). The difficulties are found in the methodological complexity of the selection and analysis of the right indicators for measuring the effects of energy efficiency, and also in the definition of the boundaries for this analysis. Furthermore, the existing research has not been conclusive on the overall effects of policies aimed at improving energy efficiency at the micro-level, especially regarding their outcomes on energy consumption at the macro-level. So even when many policies and programs have been put in place advocating for more energy-efficiency at the household level as a way to reduce national-level energy consumption, there is very little empirical data to back them up (Herring, 1999). Leaving aside the technical aspects of energy efficiency, existing research is also inconclusive about what the best practices are for creating and implementing effective policies in order to guarantee that the benefits of energy efficiency are available to the largest number of people.

Meanwhile, the challenges for the operationalization of living conditions or quality of life fall into a similar conundrum. While many authors identify *quality of life* as a valuable outcome to which we all should aim for, very few actually describe what they mean by it. Some authors relate the concept to the idea of a "*good life*" and provide a materialistic perspective linking it to the access to more goods and services. While other authors equate the concept of quality of life to that of sustainable development, to well-being, welfare or livelihood. A third and more technical sector in the literature, refers to the potential benefits of improving thermal comfort indoors and much more scarcely outdoors, and the efficient use of energy (Brown & Gillespie, 1995). However, there is a dearth of empirical research on the relationship between energy efficiency and quality of life. While we can assume that energy efficiency improves certain aspects of daily life by reducing consumption and utility costs, it is difficult to argue that it can automatically improve quality of life.

Recent research has addressed this issue more explicitly. The International Energy Agency (2018) uses the term "multiple effects" to describe the potential benefits of energy efficiency, moving beyond the simplistic understanding of energy efficiency as the way to reduce energy consumption, and exploring the additional benefits that energy efficiency can facilitate to the economy, including "cost savings, cleaner air, energy security, productivity and trade balance improvements, and facilitating the integration of renewable electricity generation" (IEA, 2018a, p. 28). All these outcomes contribute to welfare and health, and "can be extremely valuable, in economic and social terms." (IEA, 2014, p. 28). The IEA adds that these outcomes, by sending positive economic and social signals, could facilitate larger-scale actions in terms of the creation and implementation of more energy efficiency programs, by increasing the public interest and public acceptance of such policies.

However, there are still many methodological challenges for the accurate measurement of the multiple benefits of energy efficiency. Apart from the analytical aspect, the collection, organization, distribution and availability of reliable data to conduct robust analyses is limited, particularly in developing countries.

In this dissertation, I study the role of energy efficiency as an instrument for improving the living conditions of low-income households. I also explore the effects of the introduction of energy efficiency devices into people's environmental knowledge, attitudes and perceptions. I use Mexico's Green Mortgage Program (GMP hereafter) as a case study. The GMP was implemented in 2007 as a pilot project by the Institute of the National Housing Fund for

Workers[1] (Instituto del Fondo Nacional de la Vivienda para los Trabajadores [INFONAVIT]), with the objective of reducing electricity, water and gas consumption, and consequently "improving the quality of life of its borrowers by reducing their family expenses, optimizing the use of these resources, and mitigating CO_2 emissions to the environment." (INFONAVIT, 2017).

The pilot program rapidly evolved to become standard of the INFONAVIT offerings in 2011, and its requirements became mandatory to all loans granted by the Institute. Every dwelling unit financed by INFONAVIT must now comply with their energy efficiency standards. The role of INFONAVIT as the institution that implemented this program is relevant in terms of scale and scope. INFONAVIT is the largest mortgage lender in Latin America, and leads the public sector's mortgage credit market in Mexico. Additionally, almost half of the credits conceded by INFONAVIT go to the lowest income bracket of the population (with incomes ranging from 1 to 4 VSMM[2]). The GMP benefits mostly low-income households, as the credits only apply to dwellings with a maximum market value of 350 VSMM. With more than 3 million credits granted to date, this is the largest and fastest growing energy efficiency program oriented at low-income households in the world. Even so, little is known about its actual effectiveness. Current evaluations are lacking in many fronts. Firstly, they are performed by an external evaluator with close ties to INFONAVIT, which reduces its reliability; secondly, their sample sizes are minimal (less than 1% of the population); thirdly, electricity, water and gas consumption are measured using self-reported information which is unreliable and can be

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[1] INFONAVIT is one of the largest funding institutions in Latin America. See Appendix G for additional information.

manipulated or simply forgotten; and lastly, the evaluations have not incorporated a control group for comparison.

Critics have argued (Harmelink, Nilsson & Harmsen, 2008; Davis, Fuchs & Gertler, 2014; Fowlie, Greenstone & Wolfram, 2015; Davis, Martinez & Taboada, 2018), that these types of programs are not performing effectively, particularly when analyzed from a single-benefit perspective of energy consumption reduction. However, a multiple-benefits approach may expose additional benefits in terms of living conditions, educational outcomes or other social benefits that are generally not included in traditional program evaluations. For example, if the GMP produces a reduction in overall energy consumption, then GMP families may now afford to keep their air-conditioning systems running for longer periods of time, or they may be able to take hot showers more often, two activities that undeniably improve their comfort and living conditions, but that are more difficult to quantify and measure. These types of outcomes are an important focus of this research.

The research questions that guide this project demand an evaluation of the effects of the GMP on electricity consumption in order to understand its effectiveness. While this dissertation is not an evaluation per se, I evaluate these effects to understand the potential effects on people's living conditions. The second research question explores the effects on people's knowledge and perceptions towards energy consumption and energy efficiency after being exposed to energy efficiency devices. A third research question follows up the second question, by exploring the effects of the GMP on general environmental attitudes, perceptions and behaviors. These two questions are relevant as they have never been explored in existing research, which generally explores knowledge and attitudes *before* the acquisition of energy efficiency devices. An additional set of questions explore certain pre-conditions for the success or failure of the program, such as the availability of information, training and technical support for homebuyers; as well as the inhabitant's overall perceptions and satisfaction with the GMP.

Summary of Findings

This dissertation is an analysis of four neighborhoods in a city in Northern Mexico with an extreme hot and dry climate (Köppen climate classification subtype Bwh: Tropical and subtropical desert climate). Two neighborhoods are part of the GMP and the other two are very similar but not part of the program. They serve as the control group. I find no statistically significant difference between the electricity consumption of GMP neighborhoods and that of the control group. In terms of their living conditions, operationalized as participation in recreational activities, investment in skill-building workshops and extracurricular education courses, the inhabitants of the GMP neighborhoods have no statistically significant differences in their participation in any of these activities. Moreover, the participation in these activities is extremely low for the inhabitants of both groups. They also present no statistically significant difference in self-reported concerns over their own wellbeing.

Furthermore, and consistent with previous research, inhabitants in both types of neighborhoods do not pay much attention to their own electricity consumption, even when it represents a considerable proportion of their income. This finding suggests that electricity consumption is not a major concern in their daily lives. In the neighborhoods studied, people have very low levels of knowledge about the energy efficiency of common household appliances, with slightly better knowledge about those that they are more familiar with or that have been present in recent governmental programs, such as the replacement of incandescent lightbulbs for compact fluorescent lightbulbs (CFLs). Participants in both neighborhoods have overall low environmental attitudes scores, which suggest a disconnect between large-scale problems (such as global environmental degradation or climate change) and people's participation or responsibility toward them. Surprisingly, very few inhabitants of the GMP neighborhood are aware that they live in an energy efficient home, suggesting that the implementation process of the GMP has been lax in the communication of its functioning and potential benefits to the home buyers. An alternative explanation could be the high level of illegal occupation of units in one of the GMP neighborhoods studied, and the presence of illegal sharing of electricity between dwelling units. These findings suggest that the GMP has not been effective at accomplishing any of its goals: reduce energy consumption, reduce GHG emissions, improve quality of life and promote a change in environmental awareness. The physical and legal conditions found in all the four neighborhoods of study also highlight the need for prioritizing other problems that are currently not addressed by the existing GMP.

Significance of the Study

This dissertation contributes to the understanding of energy-efficiency policies targeted at low-income households of developing countries, both in terms of effectiveness at reducing energy consumption and improving living conditions. Research on energy efficiency is abundant in developed countries, but is sparse in the developing world (Friedmann & Sheinbaum, 1998). Furthermore, the majority of existing research focuses only on the financial returns of energy efficiency, while the relationship between energy efficiency and living conditions has seldom been explored. Scholars have suggested that due to the limited availability of resources and the high needs of developing countries, adaptation policies and programs must be coupled with development strategies (Hardoy & Romero-Lankao, 2011; Dodman & Satterthwaite, 2009; Romero-Lankao, 2007; Sánchez-Rodríguez, 2009; Hardoy & Pandiella, 2009; Romero-Lankao & Dodman, 2011; Romero-Lankao & Gnatz, 2013). I incorporate the multiple benefits framework (presented by IEA, 2018) to analyze potential positive effects of this program. The multiple benefits framework aids the advancement of the analysis beyond a reduction in consumption of energy.

The results of this dissertation support a more comprehensive approach in the creation and improvement of energy efficiency policy in low-income households of developing countries, where basic needs are yet to be covered and where energy consumption might not be a priority.

My findings show that low-income households face challenges that should be prioritized over energy efficiency efforts, such as the quality of the construction of their homes, which show structural damage and roof leakages within the first five years of use. Additionally, the cost of the energy efficiency devices has been estimated to represent between 2 and 4 percent of the original cost of the dwelling unit (Davis et al., 2018). This is a low cost, but not necessarily negligible, especially since this additional cost has been imposed to homebuyers in the lowest-income sectors of society, and without giving them an opportunity to choose whether they want to participate in the Program or not. From a multiple benefits approach, energy efficiency programs can still promote the improvement in the living conditions of low-income households, but the additional cost of the GM cannot be justified by its null effects.

A clear understanding of residential energy consumption is a key necessity for effective energy policy and planning (Brounen, Kok & Quigley, 2012; Hirst, 1980). The evolution of the

GMP, and information on its effects, informs the future creation, implementation and support for these types of policies. For example, the GMP started as a blanket policy that did not take into consideration the climatic variations in the Mexican territory with climate being an important predictor of energy consumption. Also, the basic package of energy efficient devices (also known as ecotecnologias) did not include two of the appliances with the highest demand of energy in households: refrigerators and clothes washers. These two omissions were later corrected by the program. In terms of information, the GMP failed abruptly at providing information and education to both housing sellers and buyers regarding the energy efficiency devices, their maintenance and potential benefits to the household expenditures. Additionally, the GMP failed at incorporating reliable monitoring devices that could make a continuous evaluation of the program a more feasible and reliable endeavor.

Other developing countries and particularly those in Latin America, who are embarking on a similar quest for improving housing programs and energy efficiency through financing mechanisms, benefit from looking at the Mexican experience in more detail. The GMP provides many examples of the challenges in the implementation and evaluation processes as well as the missed opportunities that could be addressed in future programs.

This study also contributes to the interdisciplinary research on energy efficiency and housing policy by exploring the incorporation of a financing component specifically aimed at supporting a rapid introduction of energy efficiency devices by avoiding their upfront costs. Existing research argues that the conditions of developing countries, namely market imperfections and insufficient investment in technical innovation, represent a barrier for the proliferation of energy efficiency. Thus governmental intervention is needed to promote change toward energy efficiency (Joskow, 1995; Friedmann & Sheinbaum, 1998). I build a case to explore and analyze the effectiveness of a national-level, mandatory program in a low-income population who lacks access to information and efficiency markets in order to understand the role of governmental programs at facilitating the expansion and success of such policies. I also address a prominent gap in the literature: the analysis of the potential change on environmental knowledge, attitudes and behaviors after experiencing the benefits of energy efficiency, in a population with no clearly defined alignment to these attitudes.

Lastly, the results of this research contribute to current debates on the creation of adaptation and mitigation strategies that address the challenges of climate change in urban areas. Policies and programs that target energy consumption and GHG emissions are central to mitigation strategies, but again, little is known about the implications for such strategies in the context of the developing world. Scholars argue that the developing world presents four main challenges in addressing climate change: 1) climate change is not generally perceived as a priority, 2) existing frameworks of analysis are generally not applicable to the characteristics of the developing world, 3) most of the urban growth in developing countries is expected to happen in smaller urban areas (which are generally not studied as much as larger conglomerations are), and 4) adaptation efforts must be coupled with development strategies (Hardoy & Romero-Lankao, 2011; Dodman & Satterthwaite, 2009; Romero-Lankao, 2007; Sánchez-Rodríguez, 2009; Hardoy & Pandiella, 2009; Romero-Lankao & Dodman, 2011; Romero-Lankao & Gnatz, 2013). The findings of this dissertation confirm these findings, as the population studied did not perceive GHG emissions or climate change as a priority, a merely quantitative analysis would have been impossible or inadequate due to the lack of access to reliable data and a high degree of informality both in the tenure of housing as well as in the provision of electricity. Furthermore, smaller cities in Mexico have not received much attention in terms of research and planning and generally lack the technical capacity; and finally, the four neighborhoods studied presented many other problems (informality, safety and security, quality of construction of the dwellings, lacking and failing infrastructure, lack of municipal services) that should be prioritized over energy consumption. The analysis of this case study shows that the Green Mortgage Program is a well-intended policy that failed to deliver results. The GMP is a burden to lower-income families who are imposed a higher cost of their dwellings under the promise of lower utility bills and better living conditions. The null effects of the Program in this case study and the other one cited in this dissertation (Davis et al., 2018) call for an in-depth analysis of this policy at the national, regional and local levels.

Energy Use and Energy Efficiency at the Household Level

Residential buildings are one of the greatest consumers of energy in the world. In Mexico, commercial, residential and public sector buildings are responsible for 19% of total energy consumption (see Figure 1), out of which, residential buildings consume almost 70%.

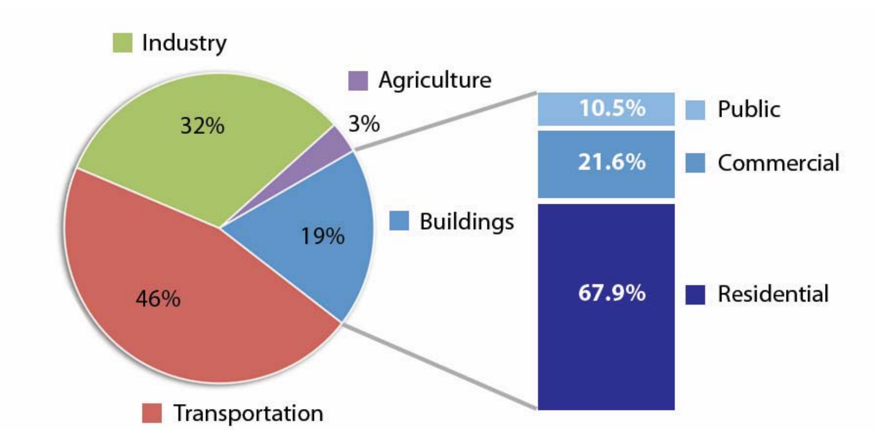

Figure 1. Final energy consumption by sector and building type, in Mexico, 2014.
NOTE: Data from the National Balance of Energy (Secretaría de Energía [SENER], 2015), chart by the author.

The environmental effects of energy consumption, in terms of greenhouse gas emissions, depend on the type of source of energy utilized. In Mexico the main sources of energy used in residential buildings are liquefied petroleum gas (35%), electricity (30%) and fire wood (28%) (see Figure 2). (SENER, 2015).

Furthermore, the generation of electricity in Mexico is not diversified. In 2015, 61.3% of the electricity generation depended on crude oil and only 7.9% depended on renewables, which makes the industry a heavy polluter (SENER, 2016a).

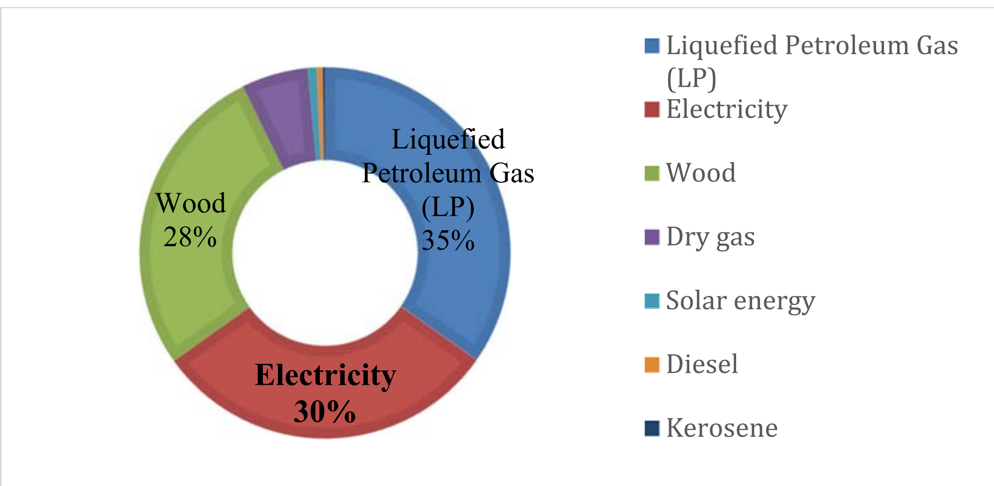

Figure 2. Final energy consumption in buildings, by source of energy, in 2014.
NOTE: Data from the National Balance of Energy (SENER, 2015), chart by the author.

Mexico’s electricity service coverage is high among developing countries, with a 98.7% of the country with electricity service by the end of 2015. Urban areas have a slightly higher coverage than smaller localities (see Figure 3), with a 99.7% coverage in localities larger than 100 thousand inhabitants, and a 96.1% coverage in the smaller localities of less than 2,500 inhabitants (INEGI, 2016a).

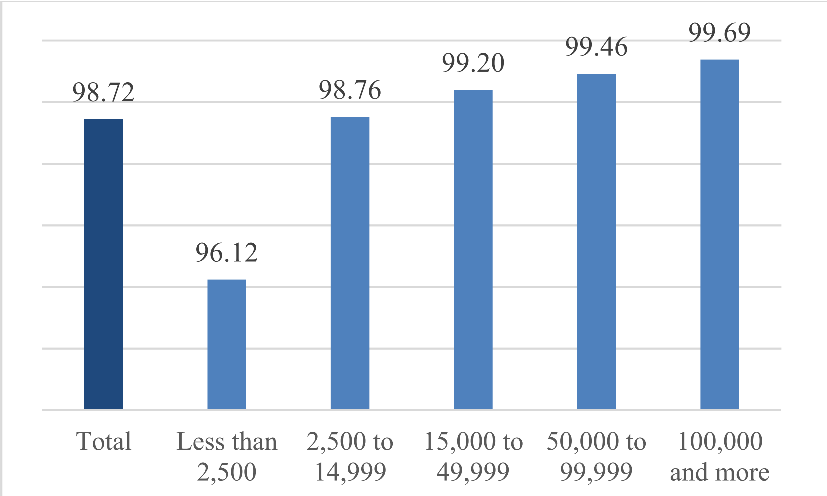

Figure 3. Percentage of households with electricity, by size of locality in 2015.
SOURCE: INEGI, 2016a

Electricity provision is controlled by the Federal Electricity Commission (Comisión Federal de Electricidad [CFE]), the dominant, State-owned electric utility in Mexico. CFE owns and operates 97.5% of the installed electrical capacity. Electricity is one of the basic services with better coverage at the national level, compared to other services such as water and sewage. The large coverage of electricity service in Mexico may be due to the fact that there is only one electric utility company in the country, while water and sewage are controlled by State and Municipal governments, and para-municipal entities. However, it is not the physical access to electricity but the financial access that is problematic. Electricity, as well as other resources such as gas and paraffin, have continuously increased prices in the last years. According to the IEA (2018) and after converting the data using purchasing power parity (PPP) adjusted exchange rates, the price of electricity in Mexico is slightly higher than in the United States and Canada, but lower than most other developing countries.

Changes in prices have a greater specific weight for the low-income sector. The additional burden that is imposed to a low-income family when energy prices rise has been conceptualized using the term ‘fuel poverty’, which refers to a situation where more than 10% of a family’s income is used toward utility bill payments, in order to maintain a minimum level of comfort indoors (Hills, 2012). Fuel poverty is a metric usually applied to heating systems of colder regions, but the same concept can be applied to cooling and ventilation systems (or air-conditioning). In Mexico, estimates show that almost 35% of the total energy consumed in residential buildings is used to achieve thermal comfort indoors, that is, more than one third of residential energy consumption goes into heating or cooling buildings (Comisión Nacional para el Uso Eficiente de la Energía [CONUEE], 2009). Hot and arid regions have the highest consumption of electricity dedicated to cooling buildings. These regions consume 72% of the energy in the country, but concentrate less than 45% of the Mexican population. In the period between 1998 and 2010, the consumption of energy used specifically for thermal comfort (air conditioning) increased in 10%, without including the residential high-users, also known as DAC tariff (De Buen, 2004; in Solis, 2008). The presence of subsidies in the summer months, supposedly intended to lower the economic burden of the inhabitants of this region, does not provide an economic incentive for efficiency or for a change in behavior. The dwellings of cities with hot and arid climate are the largest consumers of electricity of the residential sector in Mexico, especially considering that other climatic regions in the country do not require much heating.

Income and energy consumption are generally positively correlated (Cayla et al., 2011; Cramer et al., 1985; Kelly, 2011; Biesiot & Noorman, 1999; Filippini, 2011; O’Neill & Chen, 2002; Diaoglou, van Ruijven & van Vuuren, 2012). In Mexico, lower-income households are also low consumers of electricity and other resources, and consequently, low emitters of greenhouse gases. Their relevance in the energy efficiency discourse falls into two main issues: a) scale: low-income households are the largest and fastest growing sector of the societies of developing countries, and they represent an increasing potential to gain incremental efficiencies throughout the population; and b) equity: low-income households tend to pay a larger percentage of their incomes in utility bills. This situation is not unique to Mexico. In 2013, the US Bureau of Labor Statistics (BLS) explained the burdensome relationship between income and utility costs:

> Although the households in the top income quintile pay more than three times in shelter costs as the bottom quintile, they pay only 75 percent more in utility costs, suggesting that energy consumption is relatively income inelastic, and that a greater burden is placed on low-income households (BLS, 2013, as cited in Kaza, Quercia & Tian, 2014)

For the case of Mexico, low-income households face a greater burden than the higher income deciles when paying for electricity (see Figure 4). While electricity represents 3.4% of the total expenditures of households on the two lowest deciles, it represents less than 3% for the two highest deciles (García Soto, 2008).

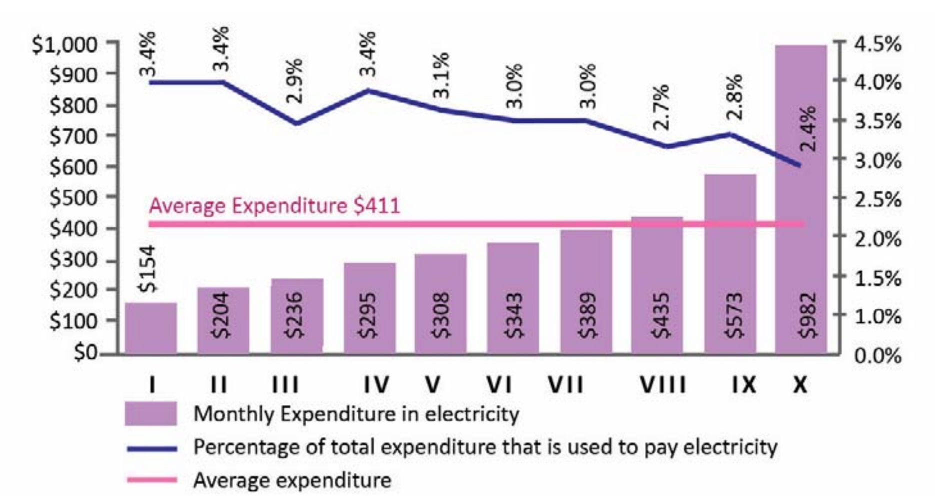

Figure 4. Monthly expenditure in electricity, average expenditure, and ratio by income decile in Mexico, 2006.
NOTE: Figure created by García Soto (2008), and re-drawn for clarity by the author.

The availability of subsidies and a tiered pricing system has been praised as a policy to help support the lowest-income sector of society, but in practice, it has benefitted mostly the higher-income sector.

Energy Efficiency Programs and Policies in Mexico

Mexico is recognized as a leader in the development and implementation of energy efficiency programs in Latin America. Mexico already had a long trajectory on the implementation of efficiency programs before the implementation of the GMP. In the early 1990's, CFE implemented *Programa Así* (Programa de Ahorro Sistemático Integral, or Integral Systematic Savings Program) as a way to encourage its customers to upgrade old appliances, such as refrigerators and air conditioning systems, and to phase out incandescent lightbulbs and trade them for Compact fluorescent lightbulbs (CFLs). This program also provided support regarding the finance and installation of insulation (walls and roof), and included a program to conduct energy audits by request (Friedmann & Sheinbaum, 1998, present a comprehensive review of this program).

Three more recent programs provide an example of the efforts of the Mexican government toward achieving energy efficiency: the Sustainable Lighting Program *(Programa Luz Sustentable*) distributed more than 47 million compact fluorescent lightbulbs (CFL's) in 2012 to phase out the use of incandescent lightbulbs, which were banned from the Mexican market in the same year. The savings promoted by this program were estimated at more than 2,000 giga-watt-hours (GWhr) and more than 14 million tons of carbon dioxide emissions avoided. Also in 2012, the National Program for the Replacement of Electrical Appliances

(*Programa Nacional de Sustitución de Equipos Electrodomésticos)* provided direct credits to low-income households so they could replace old and inefficient refrigerators and air conditioning systems for more efficient and newer versions, with the ultimate goal of reducing electricity consumption. While the specific outcomes in terms of kWh are yet to be proven, the program helped replace more than 1.7 million refrigerators and AC systems as of August of 2012. The ongoing program “Ahórrate una luz” (*Save a light*) is aimed at replacing 40 million incandescent lightbulbs for CFLs by the end of 2018.

The programs described here are just a few examples of the commitment of the Mexican government at improving residential energy efficiency at the national level, by replacing outdated and inefficient appliances, mainly lightbulbs, refrigerators and air-conditioners which are among the highest consumers of energy at home. However, there are known barriers to the acceptance of energy efficiency, which will be discussed in the next chapter, that could potentially diminish their effects. One of these barriers is the up-front cost of these appliances. The programs have addressed it by incorporating a financial component which facilitates the amortization of the costs of these upgrades, usually made possible by collaborative efforts between CFE and local NGOs. All other barriers, especially informational and behavioral ones, are still present, and while they could have an effect on these initiatives, are in general vastly unexplored and not well understood. Nevertheless, these programs and strategies are well aligned with national-level policies. The Secretariat of Energy (SENER), in its latest 2014-2028 National Energy Strategy, highlights energy efficiency as a priority task for the transformation of the country’s energy plan. According to SENER, ‘energy efficiency can help reduce the country’s vulnerability by reducing energy demand and consequently reducing greenhouse gas emissions in all sectors’ (SENER, 2014; translated by the author).

The Green Mortgage Program.

The Green Mortgage (*Hipoteca Verde*) is a housing finance program established by the Mexican Institute of the National Housing Fund for Workers (INFONAVIT) to support the incorporation of sustainability criteria in housing construction. The program started as a pilot project in 2007, and became mandatory for all credits granted by INFONAVIT in 2011. By the end of July of 2018, more than 3 million credits (equivalent to 3 million energy efficient dwellings) have been delivered under the GMP.

The program supports the incorporation of energy efficient systems and devices, also known as ecotechnologies[3], in low-income households through the incorporation of the cost of the equipment into the mortgage. The goals of the GMP according to INFONAVIT (2017) are:

- To facilitate savings in the payment of utilities by reducing water, electricity and gas consumption
- To contribute to a rational and efficient use of natural resources and environmental protection
- With the monthly savings, the mortgage payment is paid without affecting the family budget [sic]
- Transparency by providing flexibility in the selection of ecotechnologies and more saving opportunities for the home buyers, by choosing those that better fit their consumption savings requirements [sic]
- Increase in the equity value of the dwelling

[3] Ecotechnologies (ecotecnias): Refers to energy efficient devices or appliances that guarantee a reduction in the consumption of energy (gas and electricity) and water, and consequently a reduction in the emission of greenhouse gases (GHG), or as explained in the INFONAVIT website, that imply a significant reduction in the deterioration of the Ozone Layer (INFONAVIT, 2014)

By reducing energy consumption, the program aims to reduce energy demand and GHG emissions, while at the same time improving the quality of life of their inhabitants. The Program also aims to encourage housing developers to build homes with materials and technologies that facilitate energy savings. These savings are reflected in lower utility bills for the users, who can then improve their ability to pay their mortgages and improve their living conditions. Additionally, and although INFONAVIT declares this not to be the main objective of the program, the Institute expresses the intention to transform Mexican environmental awareness, stating that the GMP will become:

> an instrument of cultural change in respect of environmental awareness and the use of natural resources, to encourage people to adopt a more sustainable lifestyle and promote awareness of environmental issues [...] through capacity-building activities that include workshops and information materials, such as comic books and an informative CD handed to each holder of a Green Mortgage (World Habitat Awards [WHA], 2012).

From the supply side, housing developers are expected to promote capacity-building and provide information regarding environmental sustainability and technology maintenance to credit holders. INFONAVIT has also developed courses to improve the performance of its suppliers in accordance with its standards of customer satisfaction (WHA, 2012). However, none of these statements has been corroborated, documented or evaluated.

How does it work? The program is available to individual workers with a formal employment in the private sector, who become affiliated to INFONAVIT. Individuals purchasing homes with INFONAVIT are given an additional 'green' mortgage (a credit additional to the mortgage credit that they qualify for) of up to US$1,250, to cover the cost of additional eco-technologies (WHA, 2012). The additional credit, as well as the required monthly savings, is calculated using the creditor's monthly income (see Table 1), which is expressed through the legal monthly minimum wage (Veces el Salario Mínimo Mensual, or VSMM). In January 2014, 1VSMM was equivalent to $1,615 pesos, or $122 dollars. The additional cost of a GMP has been estimated at 2 to 4 percent of the original cost of the dwelling unit, so buyers pay slightly more for an efficient house.

Table 1.
Amount of the loans offered by INFONAVIT (in 2014 US Dollars), by monthly income tiers.

Monthly Income				Additional credit (max)	(Estimated) Monthly savings
From	1 VSMM $155.44	to	2 VSMM $248.71	$310.88	$7.60
From	2 VSMM $248.71	to	5 VSMM $621.77	$1,554.42	$16.34
From	5 VSMM $621.77	to	9 VSMM $1,088.09	$1,554.42	$19.00
From	9 VSMM $1,088.09	to	14 VSMM $1,709.86	$2,331.63	$22.04
From	14 VSMM $1,709.86	or	more	$3,108.84	$30.40

SOURCE: INFONAVIT, 2014
NOTES: 1USDollar = $13.16 MXN Pesos in January 2014. 1VSMM is equivalent to $1,615.00 MXN Pesos or US$122 in January 2014

Monthly mortgage payments are only US$6 or so more expensive than a conventional mortgage, yet low-income families are expected to save an average of US$17 per month on bills (WHA, 2012). In this way, the extra amount in the mortgage payment is arguably covered by the expected savings in monthly utility bills. The availability of the dwelling thus, depends on the current income (and the ability to pay) of the affiliated worker.

INFONAVIT has recently expanded its range of credit options, and now covers all housing categories as described by the National Code of Housing Construction (CONAVI, 2010). These categories range from the smallest and most affordable dwelling unit (*Económica*), with an average built area of 30 square meters (approx. 322 sq. ft.) and an average cost of up to 118 VSMM, to the highest end of the category (*Residencial Plus*), with an average built area of 225 square meters (approx. 2,420 sq. ft.) and an average price of more than 1,500 VSMM. Appendix A at the end of this document contains the complete categorization of dwelling units by the National Code of Housing Construction. Also, the credits provided by INFONAVIT can now be applied to the purchase of new homes, existing homes, land for construction, to cover construction costs not related to a private developer, and to renovations, as long as the ecotechnologies are incorporated into the projects.

In the case of new housing, the initiative encourages developers to build homes with simple energy-saving materials and technologies. For example, the GMP provides incentives and economic resources to cover the additional cost of incorporating thermal insulation and double glazed windows, which are usually easier to install during the construction process and for which developers can obtain better pricing. The specific package of eco-technologies varies according to the climate conditions of the cities where the dwellings are located. In general, the ecotechnologies are selected depending on certified quality and safety, water and energy consumption efficiency, manufacturer's warranty, useful life (WHA, 2012), but most importantly, their availability in regional markets (A. García de León, housing developer; personal communication, December 2013).

The eco-technologies. The program covers approximately 22 eco-technologies that include: water saving devices, such as water saving toilets (these can be low-flow or dual-flush toilets), water saving shower heads and faucets, isolating valves, and flow control valves for water supply pipes; electricity saving devices, such as energy-saving compact fluorescent lightbulbs [CFLs] or light emitting diode bulbs [LEDs], thermal insulation on roof and walls, reflective coating on roof, and voltage optimization systems. Also, systems to reduce gas consumption such as: gas and solar water heaters with or without vacuum pipes, and systems aimed to improve the health of the users, such as purified water filters, purified water supply and waste separation containers (WHA, 2012) (See Table 2).

Table 2.
Eco-technologies included in the Green Mortgage Progam

Energy	Water	Health
Compact Fluorescent Lighting (CFL)	Low-Flow Toilet (5lts and 6lts)	Water Filtering Devices
LED lamps	Dual Flow toilet	Complete Water Filtration System
Efficient Air Conditioning System*	Low-Flow Shower Head	Waste separation
Thermal Insulation - Roof and Walls	Water Saving Faucet (Bathroom and Kitchen)	
Reflective Coating - Roof	Faucet Aerators - Kitchen	
Double Pane PVC Windows	Faucet Aerators - Bathroom	
Voltage Regulator	Regulating Valve	
Energy Efficient Refrigerator*	Rainwater harvesting system	
Energy Efficient Clothes Washer*		
Solar Water Heater		
Photovoltaic panels		

NOTES: *These ecotechnologies were incorporated in 2015.
SOURCE: INFONAVIT, 2012.

In the case of new housing built by a developer, the selection of eco-technologies depends on the developer, who is in charge of purchasing and installing the devices. Developers make selections based on the availability of these technologies in regional markets and its expected efficiencies as proven by existing studies and national regulatory bodies. The basic guidelines and requirements respond to regional climatic conditions, as some devices provide greater savings depending on the climatic context. In the case of purchasing existing housing or applying the credit to the construction of the house by a private entity, the accredited worker can choose the ecotechnologies. The selection then depends on the requirements of the program and the consumer preferences.

In the preliminary stages of the program, the residents were allowed to select which eco-technologies were going to be incorporated in their homes based on their preferences, but also depending on the amount of their green mortgage and needs for savings in water consumption and energy. Users received a 'coupon', voucher or certificate that could be used to pay for energy-efficient devices at the local retailers. However, this option was later removed because users did not complete the purchase of devices, or they never installed them (A. García de León, housing developer, personal communication, December 2013). The certificate is currently available in some States and to those right-holders who buy an existing house that does not have the eco-technologies installed. With the certificate, the right-holder can purchase the eco-technologies and install them. The certificates have produced conflicting results, as some are traded or sold in the black market.

The selection of ecotechnologies is also guided by the minimum amount of monthly energy saving required for each income band, as determined by INFONAVIT. The Institute has developed an online simulator[4] to help residents choose the eco-technologies that will allow

[4] The online simulator (Simulador de Hipoteca Verde) is available online at INFONAVIT's webiste: http://201.134.132.145:82/simuladorHVWeb/home/simulador.jspx?entrada=T

them to meet the required monthly savings in their particular climatic zones (World Habitat Awards [WHA], 2012).

The Green Mortgage has been recognized as the first of its kind in addressing sustainability in the provision of low-income housing. In 2009, it received the “Star of Energy Efficiency award” by The Alliance to Save Energy, a non-profit based in Washington, D.C. (USA). It also received the Beyond Banking Award in 2010, by the InterAmerican Development Bank (IDB), under the category of Planet Banking ‘for its understanding of and response to global climate change” (INFONAVIT, 2012); and the World Habitat Awards in 2012.

According to the most recent estimates provided by the external consulting firm Enervalia, homes under the Green Mortgage have an average reduction of GHG emissions of 0.8 tons of CO_2 e (carbon dioxide equivalent) per dwelling per year, which in 2013 contributed to more than 2 million tons of CO_2 e (Enervalia, 2013). The incorporation of efficient eco-technologies into housing for low-income workers and the apparent success of the program has led to widespread interest from other countries such as Brazil, Chile, Colombia, Kenya and Canada. Government officials have requested support and information, and have manifested intentions to transferring the project to their countries. The Green Mortgage could soon be applied to different contexts. However, these estimates have been calculated internally by INFONAVIT (pre-occupancy simulations), and externally by Enervalia (post-occupancy evaluations), but present serious concerns and limitations. On the one hand, INFONAVIT only evaluates the performance of these dwellings pre-occupancy, and it uses estimates, not direct measurement. Pre-occupancy estimates have shown significant deviations from actual energy consumption in existing research (Stein & Meier, 2000). Additionally, INFONAVIT uses a deemed savings approach to evaluate the effectiveness of the program. This is a valid and widely used methodology to estimate energy and demand savings, and involves multiplying the number of installed measures by an estimated (or deemed) savings per measure, which is derived from historical evaluations (US EPA, n.d.). This approach is effective as long as the efficiency measures have well-documented and consistent performance characteristics. The market for energy-efficiency devices in Mexico is still in the development stage, and it has continuously evolved since the implementation of the Green Mortgage. This development process has required the Green Mortgage to rely on a wide variety of devices, usually depending on what is available by region. Because of this particular situation, where devices are not standardized and usage has been calculated through estimates and not direct measurement, there is not reliable quantitative data that can precisely corroborate the performance of the GMP post-occupancy.

On the other hand, the evaluations conducted by ENERVALIA have serious deficiencies, such as non-representative sample sizes of less than 2% of the population, and the reliance on self-reported information for electricity and water consumption. These semi-annual evaluations have been conducted since 2009 in an attempt to provide an assessment of the energy consumption, utility bill savings, current conditions of the eco-technologies (proof of installation and maintenance), and some aspects of user behavior and user satisfaction. As an example, the sample size in the last evaluation available (Enervalia, 2013) was of 192 households in 7 states of Mexico, which is not representative of the total population of houses under the Green Mortgage Program (currently around 1.6 million households in 32 states). Additionally, some of the questions of their survey rely on self-reported information or comparisons with their previous household conditions (especially in cases where metering systems are not available). The evaluations do not provide a robust evaluation of the effects of the GMP on energy consumption.

The external evaluation firm Enervalia highlighted the lack of information available both for providers and users. Knowledge dissemination amongst eco-technology users and providers is necessary to deliver proper instruction on the functioning of the equipment, information about benefits, use and maintenance; and to ensure the correct use and permanence of the technologies (Enervalia, 2013). Enervalia did not provide any information on changes in living conditions of the inhabitants of GMP dwellings in their evaluations.

Overall, the GMP is a complex program that incorporates financial mechanisms to attain environmental and social goals. Within its complexity it has been capable to adapt and evolve, and to transform itself and its context. With the 2012 change in administration, Mexico adopted a new National Housing Policy, and new version of the Special Program for Climate Change. With these changes and the Specific Program for the Development of Sustainable Housing before Climate Change, the housing sector in Mexico was expected to experience a significant transformation. These changes brought new priorities at the National level, and the Green Mortgage was able to subsist and confront them by transforming itself, especially by incorporating new technologies (such as refrigerators and clothes washers in 2015), widening its scope to the urban scale, and addressing aspects beyond technological solutions.

Chapter II. Literature Review

This dissertation brings together three mayor bodies of literature: first, the evolving research on energy consumption in the building sector, and more specifically on the determinants of energy consumption in residential buildings. This body of research includes methodologies for energy efficiency evaluation as well as theoretical models of energy efficiency that include environmental attitudes, knowledge, and other sociodemographic variables that explain how households use energy. Secondly, I review the theories on the economics of energy efficiency, including concepts such as the energy efficiency gap, rebound effects, and the multiple benefits approach which has been recently incorporated into energy efficiency evaluations. I conclude the literature review with existing research on the analysis of energy efficiency policy, in particular the analysis of these policies in the context of low-income housing and of developing countries. This review form the background and sustenance for the conceptual framework that guides this study. This chapter concludes with the description of the specific research questions and hypotheses to be tested.

The literature on determinants of energy efficiency in the building sector establishes the basis for analysis of energy consumption, and provide direction in the exploration of potential improvements at the household level. The analysis of theories on the economics of energy efficiency describe barriers to energy efficiency, and provides an argument to why and how societies are not able to achieve optimal levels of efficiency, even when most technologies are readily available in the market. The body of research related to the evaluation of energy policies provides the analytical tools and methodological considerations regarding measurement, monitoring and evaluation of policies and programs; and highlight the challenges and options available in this area of research that may guide improvements in energy efficiency.

A growing area of research explores more broadly the economic and social impacts of energy efficiency, going beyond the traditional focus on energy demand reduction. A common term used to describe this type of analysis is the "multiple benefits approach", and it aims to understand a broader range of positive impacts of energy efficiency across different sectors (IEA, 2014). Many aspects of this literature review have been selected for the specific focus of this research. Finally, considerations about equity, access and poverty alleviation, which are relevant to this type of policy and research in the context of developing countries, will be included in each of these sections.

Determinants of Electricity Consumption at the Household Level

There is an overall consensus among scholars that buildings are substantial consumers of energy in urban areas (Santamouris et al., 2007), and that energy consumption in buildings is one of the main contributors to the generation of GHG emissions, and therefore an important factor in addressing the challenges posed by climate change. Scholars also agree that current efficiency levels have not yet reached the lowest expectations of optimal levels of resource consumption (Hirst & Brown, 1990; Estache & Kaufmann, 2011).

The study of energy consumption in buildings is dispersed across several disciplines (Estiri, 2014). Architects tend to have a focus on the design of the building, and engineers on the technical determinants and possible solutions. The field of engineering provides most of the metrics for this area. The field of behavioral economics links energy consumption to the sociodemographic and economic characteristics of households, as well as lifestyle-related preferences (Lutzenhiser, 1992; Estiri, 2014).

This section explores the main determinants of direct energy consumption. Direct energy consumption refers to energy consumed within the household, that is, energy is used for cooling, heating, water heating, lighting, appliances and so on (Vringer & Blok, 1995). I do not explore indirect energy consumption, which comprises the energy required for the production and transportation of the products consumed by the household, as well as the energy required for the transportation of its inhabitants to places of work and leisure (O'Neill & Chen, 2002).

The determinants of energy consumption have been categorized extensively in the literature. Climate, geographic location, weather, and energy markets can be placed within the contextual domain; while building characteristics, household appliances and household lifestyles can be analyzed under behavioral domains. I organized this literature review using the four major categories of the determinants of direct energy consumption at the household level, as outlined by Kavousian, Rajagopal & Fischer (2013); and an additional sub-section for urban form:

a. **Weather and Location:** Climate zone, average daily outdoor temperature, cooling and heating degree days.
b. **Physical characteristics of the building**: Size, type, and construction materials.
c. Appliance and electronics stock: Number and type of appliances, appliances by intensity of energy consumed.

d. **Occupancy and occupants' behavior towards energy consumption**: Income, household size, household composition, age, and education, environmental knowledge and attitudes.

e. **Urban form.**

Weather and location. Human beings, and the households they create, have certain level of freedom of choice regarding the selection of a place to live. But once this decision is made, weather and other climate-related determinants of a geographical location are outside of the control of the user. In order to account for the effects of climate on energy consumption, different research models have identified specific variables with varying levels of effect, with the most commonly found in the literature being: climate zone, average daily outdoor temperature, and cooling and/or heating degree days (Kavousian et al., 2013). Climate zones worldwide are defined using different systems with the most widely used being the Köppen climate classification, developed by Wladimir Köppen in 1884. A region's climate is the result of the combination between air temperature, humidity, wind, precipitation, atmospheric pressure, and the amount of radiation it receives from the sun. Some regions and countries have revised the Köppen climate classification to adapt it to the specific conditions of those areas. In the case of Mexico, the classification was revised by Enriqueta García in 1964 in order to take into account the small-scale nuances of the geographical and climatic conditions. Since then, this version has been the official reference for the study of climatic conditions in Mexico (Leautaud, nd).

Average outdoor daily temperatures serve as a basis for the understanding of climatic conditions. In architecture, this concept it is used to establish a baseline for thermal design. In temperate climates, if a building is designed in a way that its temperature indoors can be maintained at a level near to average outdoor temperatures, then the building will require less energy to reach conditions of comfort. In a hot climate, the building should be designed so that interior temperature is near comfort levels, and the difference between average outdoor temperatures and the optimal comfort temperature indoor can be then translated into cooling degree days. If a building can achieve indoor comfort temperatures with the least use of HVAC systems, then it is considered an energy efficient building, since its design help reduce the amount of cooling degree days. Because average outdoor temperatures are difficult to operationalize in terms of building design, and also because they are closely interrelated to heating or cooling degree days, the latter are more commonly used in building design, specifically in the analysis of thermal performance. Heating degree days and/or Cooling degree days provide a more accurate way to measure heating or cooling requirements depending on outdoor temperatures and a calculation of the energy required to ensure indoor thermal comfort conditions. Ewing and Rong (2008) provide a very clear explanation of how these indices are conceptualized:

HDDs and CDDs are quantitative indices reflecting demand for energy to heat or cool houses and businesses. They are based on how far the daily average temperature departs from a human comfort level of 65°F. Simply put, each degree of temperature above 65°F counts as one CDD, and each degree below 65°F counts as one HDD. For example, a day with an average temperature of 80°F contributes 15 CDDs to the annual total. (Ewing & Rong, 2008, p. 14).

The calculation of HDD for cooler climatic regions, and of CDDs for regions with hot climates is a straight-forward process that provides a single figure to facilitate comparisons across households, neighborhoods, cities and larger regions. It is important to note that the baseline temperature needs to be adjusted to reflect local levels of adaptation of any given area of study. A baseline of 65°F (18.3°C) like the one in the example above, may be appropriate for colder-climate regions, but not for hotter climates. One of the few studies about thermal comfort in hot-arid climates was conducted in a city with very hot and dry climate located in northern Mexico. This study found that the comfort temperatures were of about 28.7°C (83.6°F) in the spring season, and 36.2°C (97.1°F) during the summer season (Ochoa & Marincic, 2005), which demonstrates differences in the levels of habituation and adaptation to the climatic characteristics between different regions. However, existing research has attempted to define a specific range of temperatures that can guarantee acceptable thermal comfort levels for the population of different climates (Fanger, 1970; Givoni, 1976; Mayer & Höppe, 1987; Höppe, 1993; Mayer, 1993; Pickup & de Dear, 1999) without any conclusive results. Nevertheless, CDD and HDD are relevant variables in the study of energy consumption. Kaza, Quercia and Tian (2014) found that CDDs and HDDs (along with other variables) were related to total energy use; and Kavousian et al. (2013) found that after removing the location variable, CDD explains 38% of the variability in household energy consumption during the summer season (p. 187).

Location encompasses the characteristics of the place where the dwelling unit is located. It can refer to the geographical location in relation to country political boundaries, to the climatic characteristics, or to the location within an urban or rural setting. In their study, Kavousian et al. (2013) used Zip Code as a proxy for locality, and found that location explains 46% of the variability in household energy consumption. The authors explain that zip code (or location) is correlated with other variables that also influence energy consumption, such as climate, building type, appliances, building materials and socioeconomic status of the household (p. 187). At a larger scale, location defined by country can also have an influence in energy consumption: for example, higher income countries generally have a more reliable energy grid, therefore a more constant energy supply, and also have more technological and financial resources, thus greater access to different types and qualities of appliances; while lower-income countries may present a lower dependence on appliances for regular household activities such as dish washing or clothes drying. These activities may align with the customs and habits of household members, which will be discuss later in this section, but are also a result of less reliable energy supply and lack of availability of technologies. It is important to note that some of these behaviors are partially determined by location.

Physical characteristics of the building. Scholars agree that the characteristics of buildings are the most accurate predictors of energy consumption. Energy demand of buildings is correlated with size of building (Kaza et al., 2014) and construction materials, including presence and type of insulation (Ewing & Rong, 2008; Kaza, 2010; Kelly, 2011; Shimoda et al., 2007); the type of housing: attached or detached, multi-family or single-family (Brounen et al., 2012; Kaza, 2010; Ewing & Rong, 2008, Hirst, Goeltz & Carney, 1982***;*** Santamouris et al., 2007), and the presence of appliances, which will be discussed in the following sub-section. Kavousian et al. (2013) found that size of the building is a key determinant of household energy consumption, but it is also correlated to other determinants such as affluence, socioeconomic status, household size and number and quality of appliances (p. 187).

The separation between the physical (or structural) characteristics of the buildings and occupant behavior is an important one. A study of energy consumption in Dutch households found that "building characteristics determine 42% of the variability in residential electricity consumption, whereas occupant behavior explains [only] 4.2%" (Guerra, Santin, Itard & Visscher, 2009; cited in Kavousian et al., 2013). The same study found that, within the physical characteristics of the building, the determinants that have more significant effects on energy consumption are: size of building (or floor area), the type of building (attached or detached), and the use of electric water heater. These findings are consistent with similar comparative research on energy consumption. The findings about energy consumption in relationship to occupant behavior will be explored later in this section.

One additional component that may have significant effects on the energy use in buildings is passive design. Passive design refers to a type of architectural design that takes into consideration the conditions of the region where buildings are to be located. In this way, availability of materials, water, energy, and more importantly, the characteristics of local climate are considered in the design process, in order to reduce or avoid the use of mechanical systems to ensure comfort indoors, in particular the use of heating or cooling systems which demand more energy. According to the categorization of this literature review, passive design would fall between the realms of 'weather and location' and 'physical characteristics of the building', since passive design requires using the information of the former in order to dictate the latter. In general, passive design considerations have not been taken into account in most energy-efficiency related studies. In the case of Mexico, Marincic et al. (2011) explored passive design parameters (or the lack of) in the production of Mexican social housing and its effects on energy demand, and found that overall, social housing produced in extreme climates does not incorporate enough principles of passive design that could improve the thermal comfort of its occupants and consequently reduce energy demand. While certain considerations on passive design exist in official reports and regulations at the national level (Comisión Nacional de

Fomento a la Vivienda [CONAFOVI], 2006), these remain as ‘suggestions for improvement’ and lack a regulatory strength that could have a real effect in the construction processes commonly used in Mexico.

Another component that is generally not taken into account in existing research is the interior height of the building. The interior height of a single-story dwelling unit has a direct effect on the thermal comfort indoor, more so if the roof slab is not well insulated. This effect is measured by the amount of radiative heat that a roof slab can transfer depending on its thermal transmittance. This type of heat gain can increase the indoor temperature and create conditions of discomfort for the users, especially if the interior height is too low. This situation also promotes an inefficient performance of mechanical ventilation and cooling systems, thus requiring more energy to reach comfort levels indoors. The role of interior height of the building has not been analyzed in the vast majority of existing research, which may be due to the fact that building codes generally regulate this aspect of construction.

Finally, a third aspect of energy efficiency that is generally unexplored in the literature is the relationship between construction process and energetic performance of buildings, and more specifically the difference in energy demand between formal and informal housing[5]. Because ‘formal’ construction schemes require compliance with the different rules and regulations of the industry, which may require the use of insulating materials and finishes, we can infer that structures built under a ‘formal construction process’ (i.e. through a developer or construction

[5] The Affordable Housing Institute (n.d.) defines informal housing as those structures lacking one or more of the following: tenure, residential zoning, utilities, and safe housing structures.

company), are more efficient, thus requiring less energy per square meter than informal, self-built structures. In contrast, self-built structures follow a longer and more organic construction process that may juxtapose different construction materials and construction methods, which may or may not be regulated. The ‘informality’ of self-built structures may compromise the energy performance of the final product. However, households in self-built structures may consume less energy due to the presence of less appliances, less access to constant and reliable energy sources, and lower income levels.

Appliances and electronics stock. The number and type of appliances or the electronics stock of households have a direct effect on the energy consumption of buildings (Sanquist, Orr, Shui, & Bittner, 2012). A large number of studies have focused on identifying which appliances demand the most energy within households. In Mexico, different organisms have studied the performance of different appliances and their effects on household energy consumption. In 2009, the National Commission for the Efficient Use of Energy (CONUEE) published general information about the electricity consumption of appliances at home. They identified air conditioning systems, lighting and the refrigerator as the most electricity-demanding appliances in Mexican households, followed by washing machines and clothes iron, computer and television, and other audio and video appliances (See Figure 5).

Since more than half of the Mexican territory has a temperate and mild climate, not all Mexican households need heating and air-conditioning systems. The 2016 ENIGH survey reports only 18.3% of Mexican households have an air conditioning system, and only 2.4% have a heating system.

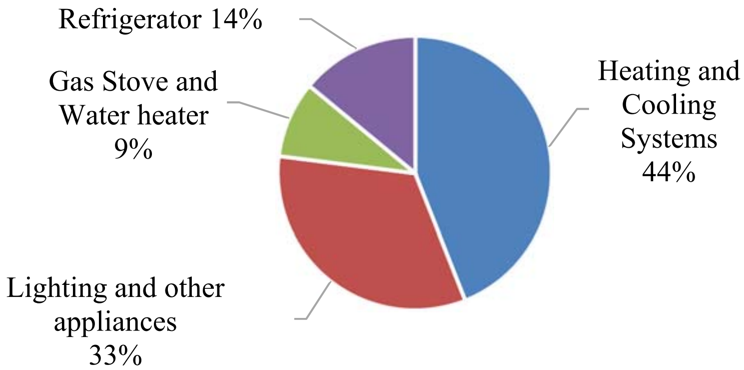

Figure 5. Average electricity and gas consumption by appliance in Mexican households with air conditioning, in 2009[6].
SOURCE: CONUEE (2009); graph by the author.

Around 50% of the Mexican territory has a dry or very dry climate, 23% is hot sub-humid, and the rest is temperate (Esquivel, 2000). Because of this climatic profile, heating systems are not as widely available as in other countries of northern latitudes. Additionally, the scarce presence of air conditioning systems in hotter regions is partially explained by cost and income constraints, due to the relatively high cost of these appliances and the high cost of operation (electricity). Because of this, CONUEE created the same chart for households without air conditioning systems. Once the load of the air conditioning system is removed, we can observe that a few ‘smaller’ appliances have significant electricity demands in the Mexican households (see Figure 6). The top three are lighting, refrigerators, and television, especially

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[6] Stove and water heater are included in this graph because the graph includes both electricity and gas usage. While electric stoves and electric water heaters are available in the Mexican market, these are not commonly found in Mexican households. The 2016 ENIGH survey reports that 76% of Mexican households had a gas stove, 1.1% had an electric stove, 35.5% had a gas water heater, and 4.9% had a solar water heater; while the rest cooked or heated water using firewood and other fuels. Electric stoves and electric water heaters were not included in this national survey.

since these three items have longer periods of electricity demand than other more intense appliances, such as washing machines and clothes irons.

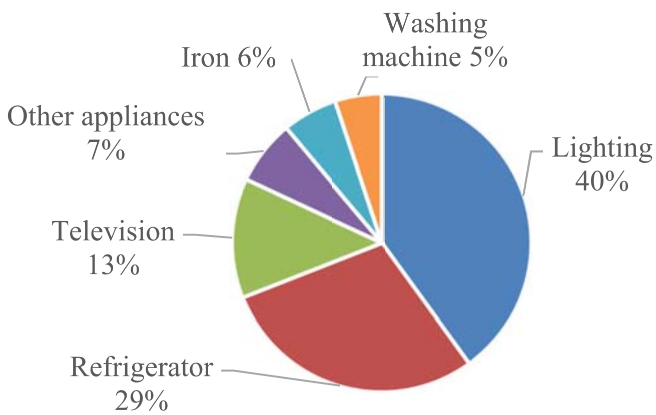

Figure 6. Average electricity consumption by appliance in Mexican households without air conditioning, in 2009.
SOURCE: Data from CONUEE (2009); graph by the author.

As a reference, I make the comparison with the electricity usage in the United States. As figure 7 shows, the distribution of electricity consumption in US households is quite different from the Mexican counterpart. In the US, the main uses for electricity are, in order of intensity: space heating, water heating, refrigerators, lighting, space cooling and others. The United States has more of its territory with cold climate thus requiring more energy both for space heating and water heating. Furthermore, it is more common in the US to use electricity to fuel space heaters, water heaters and kitchen stoves; while in Mexico these appliances are in general fueled by gas. These differences suggest that socio-cultural factors as well as climatic conditions determine the number and type of appliances in a household.

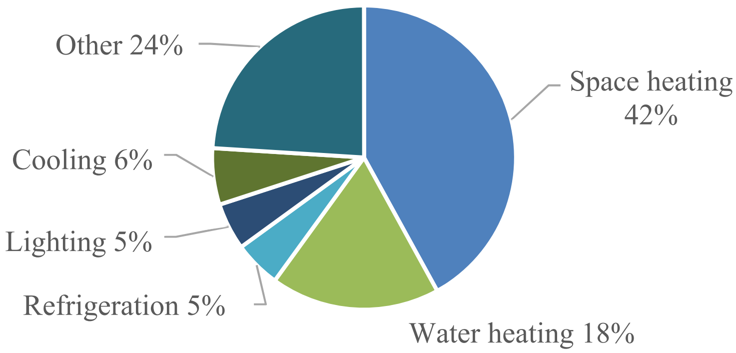

Figure 7. Average electricity consumption in US households.
SOURCE: Data from USEIA (2014); graph by the author.

It is also important to note that Mexican households, especially those in the lower-income levels, have less appliances overall than their counterparts in the US. For example, it is rare to find dishwashers, clothes dryers, and space heaters in Mexican households, so much that they are not even included in the census while other more common appliances (refrigerators, clothes washer, televisions and radios) are. In the case of clothes dryers, the gas-powered versions of clothes dryers are somewhat common in Mexico, but only in upper-income households. Another difference is the common presence of a second refrigerator in some US households. In the study by Kavousian et al. (2013), they identified 'number of refrigerators' as a key determinant of household energy consumption, most likely because having more than one refrigerator is in itself a duplicate of the demand of energy, but also because secondary refrigerators are usually older and placed in non-conditioned areas such as the garage, both factors that affect their efficiency (p. 189).

Figure 8 depicts the percentage of Mexican households according to the appliances they own. This graph shows that television sets have the largest coverage with more than 90% of households owning at least one TV; refrigerators and radios also have a large coverage (around

80%) among Mexican households, while other appliances, such as washing machines, are less common (66%). These comparisons are relevant at the moment from the point of comparability and applicability of the results of research conducted in countries with different socio-economical characteristics.

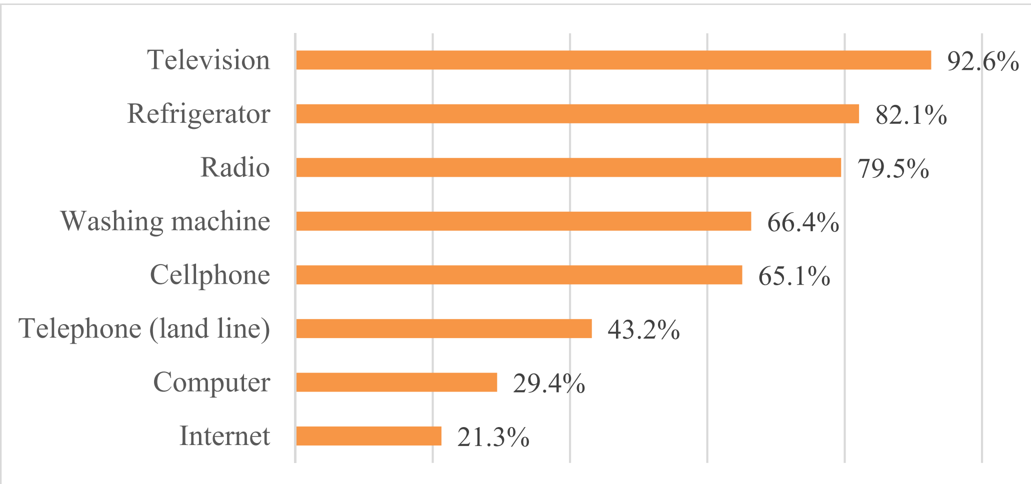

Figure 8. Percentage of households according to appliances owned.
SOURCE: Data from INEGI (2011), graph by the author.

Occupancy and occupants' behavior towards energy consumption. This last category of determinants of energy consumption is the least explored but the one with more emphasis in the last decade. Research shows that energy consumption is significantly correlated to income (Brandon & Lewis, 1999; Brounen et al., 2012; Hirst et al., 1982; Kahn, 2000; O'Neill & Chen, 2002; Santin, 2011; Van Raaij & Verhallen, 1983); positively correlated to household size (Kelly, 2011; O'Neill & Chen, 2002), education level of head of household, and other age-related variables, such as age of the head of the household (O'Neill & Chen, 2002), presence of children or the adult-to-children ratio (Hirst et al., 1982; Van Raaij & Verhallen, 1983; O'Neill & Chen, 2002). Income is also correlated to lifestyle preferences and choices (Sanquist et al., 2012). I describe these four factors separately below, but most studies use two or more of these factors together to explain energy usage at the household level.

Income. The relationship between household income and energy consumption has been subject of extensive research. Empirical research has been inconclusive: some studies show that energy consumption increases monotonically with income (Cayla et al., 2011; Cramer et al., 1985; Kelly, 2011; Biesiot & Noorman, 1999; Filippini, 2011; O'Neill & Chen, 2002; Diaoglou, van Ruijven & van Vuuren, 2012); while others report an inverted U-path relating energy consumption and household income (Foster, Tre & Wodon, 2000; Choi, Heshmati & Cho, 2010; Boopen & Vinesh, 2011).

The effect of income on household electricity consumption can be mediated by ownership of appliances; i.e. income of the household impacts the consumption through affecting the stock (quantity and quality) of appliances (Parti, M. & Parti, C., 1980; Dubin & McFadden, 1984; Sudarshan, 2011). This is especially true for populations where households have similar socioeconomic status and therefore the income effect is minimal (Reiss & White, 2005).

Estiri (2014) explores the potential for energy efficiency in low-income households. He states that while low-income households use less energy to conduct daily activities, they are also less able to reduce their energy use when compared to high-income households. Estiri (2014) and Santamouris et al. (2007) have explored the potential of low-income households to meet energy reduction estimates, and argue that the limited energy saving potential of low-income households may be caused by the building characteristics of their homes, which are generally characterized by older structures that are badly insulated, and which have operating systems that are not well maintained. An additional factor is the presence of older, less energy efficient appliances. While electricity bill payments of low-income families are generally small, they may represent a high proportion of their incomes, therefore the benefits of energy efficiency interventions are almost completely social benefits (Mendez & Proyecto, 2008).

Finally, in a cross country comparison of energy consumption, Lenzen et al. (2006) found that, even at equal income level, there are significant differences in average energy requirements by country, guided mainly by “geographical conditions and population density, but also energy conservation and technology, and consumer lifestyles” (p. 201). Similarly, Santamouris et. al. (2007) argue that, at a larger scale, household energy consumption “varies from country to country as a function of their economic and technical characteristics” (p. 893). In sum, the relationship between income and energy consumption needs to be better explored.

***Household size*.** Kavousian et al. (2013) found household size to be correlated with energy consumption in a concave relationship. That is, as household size doubles, energy consumption will increase but at a lower rate of 1.4 times according to their study (p. 191). This confirms results of similar research that conclude that larger households have higher overall electricity consumption but lower per capita consumption (Ironmonger, Aitken, & Erbas 1995; Vringer & Blok, 1995). O’Neill and Chen (2002) also describe the existence of household economies of scale, explaining that as: “a household size increases, the per capita cost of maintaining a given standard of living declines” (p. 61). In their study of the demographic determinants of residential and transportation energy consumption in the US, O’Neill and Chen (2002) found that “two-person households use about 17 percent less energy per person than do single-person households, and three-person households use more than a third less energy per person than do people living alone" (p. 68). They also found that, even after standardizing income, energy use per capita falls substantially with increasing household size which "suggests that the decline in per capita energy use with household size is unlikely to be mainly an income effect" (O'Neill & Chen, 2002).

Household composition. Household composition can refer to different measures: number of households within a dwelling unit, children-to-adult ratio, and other indicators of age composition such as the number of generations or the presence of extended families, as well as not-familiar households. The study by O'Neill and Chen (2002) found that households with children use 44 percent less residential energy than do adult-only households; and suggest that the number of adults is the main driver of energy consumption (p. 68). Conversely, in a study of 300,000 Dutch homes, Brounen, Kok and Quigley (2012) found that families with children consume almost one-fifth more electricity than families without children, and the difference increases in households with older children. However, per capita energy consumption is lower in families with children (p. 932).

Age of the householder. O'Neill and Chen (2002) found that residential energy use per capita increases consistently with the age of the head of the household. They explain some of the factors that may contribute to this linear relationship, including income as much as income is expected to increase with age, thus having an effect on comfort preferences and number and use of appliances. They also identify labor force status, assuming that older individuals work less hours or retire, then spend more time at home so occupancy rates along with electricity usage are higher. "Aging could also have direct impacts through an associated decline in household size and consequently a loss of economies of scale in energy use at the household level." (O'Neill & Chen, 2002, p. 53).

Education. Education plays a fundamental role in building an understanding of our relationship with nature. This understanding becomes the basis for our perceptions and attitudes toward the environment, and altogether education, perceptions and attitudes become evident in the efficient or inefficient use of resources. Education thus, can "play a pivotal role in instilling energy savings and efficient behavior and attitudes in society" (Zografakis, Menegaki & Tsagarakis, 2008, p. 3226). There is an expectation then, that education and energy conservation would be positively correlated (Semenik, Belk & Painter, 1982).

Ellis and Gaskell (1978; as cited in Zografakis et al., 2008) found a strong correlation between level of education and likelihood for an individual to adopt energy-saving measures and to accept government interventions that encourage more energy efficiency behavior. In general, higher level of education is related to lower energy use (Poortinga, Steg, & Vlek, 2004), but education is also correlated to income (Semenik, Belk & Painter, 1982).

A less explored aspect of the relationship between education and energy consumption is the fact that people in general, do not pay attention to energy consumption, as shown in a more recent study conducted by Brounen, Kok and Quigley (2013). In this study, the authors explored people's awareness of their monthly energy expenditures, and their ability to make rational decisions on energy efficiency investments, a combination that they refer to as 'energy literacy'. In their study of 1,721 Dutch households, they found that demographics and environmental attitudes have a more direct effect on energy consumption behavior than energy literacy and environmental awareness. For example, they found that older respondents with higher incomes tend to choose higher comfort levels, therefore demanding more energy, independently of their environmental knowledge and awareness. The authors challenge the widely accepted assumption that the market can rationally capitalize energy efficiency in investment decisions, as they found no evidence on the effect of energy literacy and awareness on actual energy consumption. In their sample, they found a large group of households (44%) that have no knowledge about their utility bill, and who do not consider changing their thermostat settings (therefore reducing their thermal comfort) to save energy. It is important to mention the context of this study, where Dutch households in the sample pay an average of 8% of their income on energy or utility bills, which suggests energy is regarded as a non-expensive resource, or in other words, the cost of electricity is not significant enough to motivate behavioral change.

Urban Form. The relationship between urban form and residential energy use has been vastly explored in the literature. However, most of this research refers to indirect energy consumption, that is, the energy required to conduct household's daily activities, including energy used for transportation. From this perspective, urban form, urban density and location are the main determinants of energy use and consequently greenhouse gas emissions in cities. (Owens, 1992; Steemers, 2003; Bulkeley & Betsill, 2005). Randolph (2008) addresses the seemingly obvious correlation between dispersed land use (or sprawl) and high per capita energy use, and also links longer travel distances to a greater transportation energy use, which comprises most of this higher energy usage of sprawling communities. However, he is careful to not assign causality only to sprawl. According to Randolph (2008), an urban average house can consume 30 percent more energy than a suburban green household and 100 percent more than an urban green household. In other words, while green measures can offset the impact of urban form on energy use, more compact urban form combined with green efficiency gives the lowest energy consumption of all. A smaller, urban multifamily, green household can consume one-fifth the energy of a larger, suburban average single-family household (p. 50).

The point that Randolph makes is that the potential energy savings from compact development and energy efficiency are not mutually exclusive (p. 50), so instead of confronting these two concepts against each other, he suggests to explore them together. While he advocates for a 'more compact urban form', he does not provide any guidance as to how achieve it, other than "better codes, zoning standards, and economic incentives" (p. 50).

It is also important to consider that the location and configuration of housing within the urban fabric has effects on urban form, travel patterns and overall connectivity, all of which have an effect on the opportunities to introduce alternative means of transportation. These factors contribute to maximize or minimize the potential of the city to reduce energy consumption and GHG emissions at a larger scale, but also affects the alternatives of the residents to improve their living conditions. The location of housing in relation to services and amenities can also determine access to different opportunities for the residents, and this accessibility or lack of thereof, determines the overall quality of life of the communities. From the perspective of a life-cycle assessment, the provision of housing must take in consideration the construction systems and materials and its energy demand and emissions during its service life; but it also must consider its location within the urban fabric and the effects that this location has on the transportation and connectivity options for its inhabitants.

Knowledge and environmental attitudes. Many studies in the psychology of energy use have focused on the effectiveness of informational strategies (Steg, 2008; and for a review, see Abrahamse et al., 2005). While informational strategies attain only modest behavioral change, information can be seen as a baseline to promote environmental behavior, or in other words, people will not change behaviors if they do not know they are expected to change. Steg (2008) states the informational strategies “are especially effective when pro-environmental behavior is relatively convenient, and when individuals do not face severe constraints on behavior.” (p. 4450). Parallel to knowledge is the understanding or perception of energy consumption. Climate change, energy consumption, and the role that a single household or individual has at addressing these issues are complex processes which can cause confusion. People tend to know little about their own energy use. Steg (2008) provides an example by stating that people tend to “think that energy use is related to the size of appliances. The larger the appliance, the more energy it is believed to use” (p. 4450). Understanding of energy usage, and common perceptions about self and others may also drive environmental attitudes and actions. Another factor to consider is the effectiveness of information and knowledge at changing energy consumption. Abrahamse et al. (2005) argue that mass media (information) campaigns tend to increase knowledge or attitudes, but there is no clear evidence that this increment results in reductions in energy use (p. 278). Gadenne, Sharma, Kerr and Smith (2011) conducted a study to explore the relationship between environmental beliefs and attitudes on energy saving behaviors. The authors found that, contrary to previous research (Abrahamse et al., 2005, Ozaki, 2011), certain environmental beliefs and attitudes directly influence environmental behavior (p.

7692). However, they caution that cost is still a barrier to adoption of environmental behaviors, particularly if the means to attain or change environmental behaviors are costly or not available.

Studies examining the effects of structural strategies[7] mostly examine intention to change behavior, not actual behavioral change (Steg, 2008, p. 4451). Another gap in the literature is the analysis of the effects of structural changes on peoples' knowledge, attitudes and behavior. In this study, I will incorporate these variables into the exploration of the effects of the GMP, instead of using them as determinants of energy consumption reductions.

Interactions among determinants of energy consumption. There are many interactions between demographics, socio-economic status, household composition, and in general, between most of the factors described here as determinants of energy consumption. Income and education, and income and rural/urban location are generally correlated (Semenik et al., 1982; Büchs & Schnepf, 2013; Sharygin, 2013). Higher income may be correlated to higher education, and education may be correlated to environmental awareness, but this does not necessarily imply that higher income is correlated to higher environmental awareness, and consequently with a lower energy consumption. In general, research shows that higher incomes are correlated to higher energy consumption, with a few exceptions. As Sharygin (2013) explains, this correlation is not constant:

> More educated individuals earn higher incomes, but they also spend their incomes in ways that reduce the carbon intensity of every marginal dollar relative to other wealthy but less educated households. Household heads with college or greater education spend

[7] In this context, structural changes refer to the introduction of new or better products and services, changes in infrastructure, pricing policies and legal measures (Steg, 2008).

> more on housing but less on energy utilities; more on airfare and mass transit but less on gasoline (p. 15).

In comparison, lower-income is generally correlated to lower energy consumption, but not necessarily higher energy efficiency. As Santamouris et al. (2007) noted, lower-income households may have higher energy consumption and lower potential to reduce it, due to the characteristics of the buildings they occupy, and the type and vintage of their appliances.

The existing literature on the relevance of different factors regarding energy consumption, or in some cases, greenhouse gas emissions, is inconclusive. Wier, Lenzen, Munksgaard and Smed (2001) argue that only income and household size are determinant factors; while the rest of the literature shows that at least one additional variable can produce different results. For example, studies like the one conducted by Baiocchi, Minx and Hubacek (2010) identify employment status, education, rural/urban location, household composition, and age to be relevant for household emissions, once income and household size are controlled for. Kaza et al. (2014) combine variables of contextual and structural type, using cooling degree-days, number of heating degree-days, electricity prices, area of the house to estimate energy consumption. Sanquist et al. (2012) combine geographic location, household equipment (number of appliances and usage), family structure, and income with additional contextual variables such as local electricity prices and access to natural gas.

The study by Kavousian et al. (2013), which provides the framework for this section of the literature review, combines structural and behavioral determinants of electricity consumption at the household level, and found weather, location, building size, and appliances, to be the most important determinants of energy consumption; followed by environmental beliefs (climate change), and age of occupants. Contrary to other studies, they found no significant correlation between energy consumption and income, home ownership or building age.

An important gap in the literature is the scarcity of studies addressing low-income households, and lower-income or developing countries. The majority of the studies reviewed here have been conducted in higher income societies and developed countries. This is an important gap in the literature, particularly because scholars estimate that the energy demand from developing countries is likely to increase at a higher than expected rate, due to economic development and poverty reduction (Wolfram, Shelef & Gertler, 2012).

One of the few cross-country analyses available is that of Lenzen et al. (2006), who found that the elasticity between energy requirements and household expenditure vary across countries, even after controlling for socioeconomic-demographic variables (p. 201). The authors also argue that there is "no one-fits-all recipe for planning for energy reductions" (p. 201). The results of this study confirm the uniqueness of the contextual factors that affect energy consumption at the household level in each country; and make a call for a more localized analysis that takes into account these differences.

Energy Efficiency Theory

We cannot identify a specific theory of energy efficiency per se, as theories from different disciplines (physics, engineering, economics, behavioral economics, psychology, anthropology, and social studies) have been applied to the understanding of the policy-oriented research field of energy use, as described more comprehensively in the review by Moezzi and Lutzenhiser (2004). The field has been fueled by different crises through time, for example the

1970’s energy crises and the 2000’s climate change debates. The field has evolved accordingly, from an early focus on improving technical energy efficiency as the main strategy to reduce energy consumption, to a behavioral approach that questions how and why people make conscious changes in order to reduce energy usage. With the rising of global concerns framed under the sustainability and climate change challenges, the energy efficiency field has been required to expand its boundaries and take a more holistic approach and broader scope (Moezzi & Lutzenhiser, 2004, p. 7-208).

I analyze three approaches of energy efficiency theory to create a framework for the understanding of the effects of the GMP: the energy efficiency gap, the rebound effect, and the multiple benefits approach to energy efficiency.

The energy efficiency gap. The energy efficiency gap is a concept that analyzes the discrepancies between the potential for energy efficiency that we, as a society, could accomplish with the existing technologies, and the actual energy efficiencies that we are currently achieving. The term was first coined by Eric Hirst and Marilyn Brown (1990) in an article called “Closing the energy efficiency gap: barriers to the efficient use of energy”. In this article, the authors emphasize that, while the technically feasible energy efficiency measures that could help us reduce energy consumption are currently available and are cost-effective, they are not being deployed at their full potential. According to Hirst and Brown, the energy efficiency gap exists because of market failures and barriers that stand in the way of achieving energy efficiency at its full potential. They categorized these barriers to energy efficiency in two: structural barriers, which are generally beyond the control of the individual end-user; and behavioral barriers, that are related to the personal choices that users make regarding efficiency. Structural barriers include the distortion in energy prices; limited access to capital (up-front costs); lack of fiscal and regulatory policies, codes and standards; and lack of availability of technologies; while behavioral barriers include attitudes toward energy efficiency, perceived risk, information asymmetries and misplaced incentives. There is some level of interdependency amongst them. Hirst and Brown (1990) also discuss the important role of policy interventions at overcoming some of these market barriers and reducing the gap in benefit of energy efficiency. Other authors have suggested ways to overcome the energy efficiency gap, or some of its barriers. For example, Fuller (2009) suggests financing systems as a way to overcome up-front costs, such as a mortgage plan that facilitates access to capital.

Rebound effect. The rebound effect is a term that has been applied to the "direct increase in demand for an energy service whose supply had increased as a result of improvements in technical efficiency in the use of energy" (Khazzoom, 1980, as cited in Greening, Greene & Difiglio, 2000, p. 390; Abrahamse et al, 2005). Goldstein and Cavanagh (2011) refute the existence of a rebound effect, arguing that the US economic production more than tripled between 1973 and 2009, while total US energy use increased by less than a third. This type of progress would not have been possible if the rebound effect was present. In contrast, Herring (2006) challenges the overtly accepted view that energy efficiency can reduce energy consumption, arguing that efficiency would lower the implicit price of energy, making it more affordable and causing people to use more, not less. The author argues that in order to reduce energy consumption and GHG emissions, policies should focus on *energy sufficiency* which he describes as the process of achieving the same rates of productivity with a lower demand of energy. The author also relates higher levels of efficiency with dynamic productive economies, which in turn are related with higher quality of life (p. 19).

Overall, the existing literature does not provide support for claims that energy efficiency gains will be reversed by the rebound effect. Gillingham, Rapson and Wagner (2014) attempted to quantify the magnitude of rebound effects in energy efficiency programs, and found that the rebound effect is only one component that factors into the equation; however, it is a factor that in most cases leads to welfare gains, most notoriously an induced innovation and productivity growth from an energy efficiency policy.

Multiple benefits of energy efficiency. The concept of multiple benefits is not entirely new. Other policies and programs have looked beyond the scope of the main issue they are addressing for possible alternative benefits, for example, improved health benefits from cookstove replacement (Ruiz Mercado, Masera, Zamora & Smith, 2011), and other welfare gains. The term is used by several important organizations such as the US Environmental Protection Agency (US EPA) and the International Energy Agency (IEA). Multiple benefits are also referred to as co-benefits, ancillary benefits, or non-energy benefits and other terms in existing literature.

The multiple benefits approach states that energy efficiency policies may have effects beyond energy usage, which may also contribute to an improvement in living conditions. Certain structural interventions aimed at improving energy efficiency, like insulation, heating or better glazing quality, can also have an effect on occupants' health. These positive, and sometimes negative, health effects can be caused by a more comfortable environment inside the houses, better sound insulation, or better quality of the construction (Maidment, Jones, Webb, Hathway & Gilbertson, 2014). In their meta-analysis of thirty-six studies, Maidment et al. (2014) found that on average, household energy efficiency interventions led to a small but significant improvement in the health of residents.

Ryan and Campbell (2012) of the Energy Efficiency Unit of the IEA, explore and categorize the multiple benefits of improved energy efficiency and suggest implications for policy design. The typology they propose (and adopted by IEA) categorizes multiple effects of energy efficiency by economic level:

- Individual level benefits: health and wellbeing; poverty alleviation through energy affordability and access to energy services; and increased disposable income.
- Sectoral level benefits: industrial productivity and competitiveness; energy provider and infrastructure benefits; and increased asset values.
- National level, they list the benefits of job creation; reduced energy-related public expenditures; energy security; and macroeconomic effects
- International level they highlight reductions in greenhouse gas emissions; moderating energy consumption prices; natural resource management; and development goals.

From this list, it is important to note that some of the benefits are not dependent on actual energy savings. For example, a household can improve their health by structural changes aimed at improving insulation or weatherization, even when such improvement does not reduce energy consumption. Furthermore, the benefits of improved energy access that can be facilitated by energy efficiency programs do not depend on energy savings. While Ryan and Campbell are inconclusive on which methodology is best to measure and evaluate the multiple benefits of energy efficiency improvements, they recommend a comprehensive approach that takes into account the three dimensions of sustainable development (social, economic and environmental) and moves beyond the net benefits approach of energy efficiency policy evaluation (p. 11). They argue that "many of the benefits [of energy efficiency] are non-market, diffuse, indirect and difficult to monetise" (p. 11). The concept of well-being would fall under this type of benefits.

Well-being. While various methods exist to assess the economic, social and environmental effects of policies, only a few of them consider social indicators, arguably because of lack of knowledge of valid methods, tools and techniques for assessing relevant social impacts (Steg & Gifford, 2005).

Several approaches have been developed to measure wellbeing or quality of life. For this study, I base the measurement of wellbeing on the OECD's Better life initiative's conceptual framework (Durand, 2015; OECD 2011). The OECD aims to measure present and future individual's well-being using variables in two main categories: material living conditions (i.e., income and wealth, jobs and earnings, housing conditions); and quality of life (health status, work–life balance, education and skills, social connections, civic engagement and governance, environmental quality, personal security and life satisfaction). Due to the scope of this research, and the limitations in data availability and collection, I focus on three variables related to quality of life which are more relevant for this study: work-life balance, education and skills, and life satisfaction.

a) Work-life balance determines the amount of time people devote to working (and procuring an income) and how much time they devote to leisure, personal care and other non-work activities that contribute to individual's well-being (Durand, 2015, p. 7). In this research and due to restrictions on the type of information I could collect, I operationalize work-life balance as the type and amount of participation in recreational activities, since recreational activities implicitly affect well-being, but sometimes require certain economic investment that can only be possible if people have additional expendable incomes.

b) Education and skills cover two aspirational efforts: education is a basic need and an aspiration for all humans, as well as an instrumental component for achieving many other economic and non-economic well-being outcomes (Durand, 2015). I explore educational opportunities for adult household members as well as extracurricular educational participation by younger household members. Additionally, I include participation in skill-building activities which can be interpreted as investment in future improvements of the individual's or household's economic capacity.

c) Life satisfaction or subjective well-being, also interpreted as happiness, refers to the way people feel about their own life and experience (Durand, 2015, p. 8).

Fuentes and Rojas (2001) explore the relationship between subjective and economic well-being in Mexico, arguing that the economic differences among the Mexican population provide a different context for understanding these terms, a context which deviates from the more homogenous economic distribution of the places where most research on these issues has been conducted. Traditional approaches find a linear and positive relationship between income and well-being; however, empirical studies have found only a weak relationship. The same occurs for the relationship between income and sense of basic need satisfaction. The sense of basic need satisfaction is based on Venhoveen (1988, as cited in Fuentes & Rojas, 2001) absolute theory, which assumes that the satisfaction of basic needs is associated to subjective well-being. Fuentes and Rojas found a positive relationship between subjective well-being and sense of basic need satisfaction, but not to income (p. 291).

Effectiveness of Energy Efficiency Policy and Programs.

Several studies analyze the effectiveness of energy-efficiency policies and programs, but there is still no consensus regarding a preferred approach. Two major approaches are present within the literature on energy efficiency: the economic and the engineering approach (Sanstad & Howarth, 1994), and they continuously try to cancel each other, even when the engineering approach is based upon firm economic foundations.

In a study conducted by Harmelink, Nilsson and Harmsen (2008), they analyze what factors characterize successful energy efficiency policies across different sectors and countries in Europe. In their analysis, they include 20 energy efficiency instruments, using a methodology called theory-based policy evaluation, which they determine is better than ex post evaluation, basically "because (1) the whole policy implementation process is evaluated and the focus is not just on the final impacts, (2) through the development of indicators for each step in the implementation process, the "successes and failures" can be determined to the greatest extent possible, and (3) by applying this approach, we not only learn whether policies are successful or not but also why they succeeded or failed and how they can be improved." (p. 131). The authors propose this method as an alternative to ex post evaluations, which do not receive a high priority among policy makers. The authors found a lack of quantifiable targets, clear timeframes, and monitoring components that could facilitate data collection ex post. The lack of ex post monitoring and evaluation is a concern, since deemed savings and simulations usually do not provide a clear picture of the performance of such technologies. They also identify as good practices the following components: (1) existence of clear goals and a mandate for the implementing organization, (2) the ability to balance and combine flexibility and continuity, (3) the involvement of stakeholders, and (4) the ability to adapt to and to integrate adjacent policies or develop consistent policy packages (Harmelink et al., 2008; p.131). However, due to its complexity, the theory-based policy evaluation as delineated by Harmelink et al. could be difficult to implement in areas where technical and economic resources are limited.

A major concern in the literature of energy efficiency is a generalized inconsistency between pre-occupancy estimates and the actual (i.e. post-occupancy) effects of these programs. In general, the literature shows that pre-occupancy models generally overestimate the actual energy savings. For example, a recent study by Davis, Fuchs and Gertler (2014) evaluates a large-scale appliance replacement program in Mexico that from 2009 to 2012 helped 1.9 million households replace old refrigerators and air conditioners with energy efficiency models, in a similar manner that Cash for Clunkers worked in the USA in 2009. This study found that the replacement of these appliances only reduced energy consumption by 8%, a small amount when compared to the estimated reduction in 35%. In a similar study by Fowlie, Greenstone and Wolfram (2015), which analyzes the Weatherization Assistance Program (WAP) in the USA, the authors found that the upfront investment costs of the program are about twice the actual energy savings, and also, that the preliminary model-based projections were about 2.5 times higher than the actual energy savings. However, this study has not been free from criticism. The main criticism against is the fact that the authors analyzed energy usage only from an economics perspective, and without including the standard and well-known analytical methods used in the field of energy efficiency. For example, the authors did not normalize for weather, there is no baseline energy usage for comparison (before weatherization), and there is no account for after-weatherization energy usage. Furthermore, there are certain elements that cannot be measured by cost-benefit analysis, such as the value of the improved quality of life and improved safety for the people who live in these houses. Weatherization, and the additional improvements that are usually required to weatherize a building can act together as a package that will have positive benefits in the daily lives of the inhabitants of these homes. Weatherizing a home can mean different things, in the case of leaking roofs, the repairs will most likely include fixing the roof, but also the attic and the ceiling inside the rooms. This type of work may also include asbestos abatement if asbestos is present in this home. It may also include repairs to faulty wiring. Both of these will certainly improve living conditions, even when these factors will most likely not appear in a cost-effectiveness analysis. Apart from these material improvements, once weatherized, these homes will be more comfortable to live in, will reduce their electricity consumption and bills, and in the case of the asbestos removal, will improve health expectations for these families. Finally, energy savings will not amount much if local energy prices are low. The benefits explained here are not necessarily part of the program, as the Weatherization clearly states that its goal is to improve energy efficiency. However, the additional benefits are of significant importance especially for the households in the lowest-income brackets. The analysis made by Fowlie et al. (2015) highlights the need to incorporate more aspects of the social benefits and welfare effects that these programs may have in order to have a better picture of the effects of such policies and programs.

In study conducted in a multifamily development in the city of Los Angeles, Chen, Delmas, Kaiser & Locke (2015) analyze the differences in energy consumption for similar households who inhabit housing units of practically the same size. They found that even when these households use the same major appliances, they exhibit substantial variation in appliance-level electricity consumption. For example, households in the 75th percentile of HVAC usage use over four times as much electricity as a user in the 25th percentile. Additionally, the authors show that behavior accounts for 25–58% of this variation, and argue that the behavioral element of energy use is often ignored by the engineering estimates provided by the manufacturers of these appliances.

A more recent study by Chuang, Delmas and Pincetl (2018), provides empirical evidence of the inconsistency between the estimates and the actual effectiveness of different residential energy efficiency incentive programs by analyzing more than 11 million households in Southern California. In this study, the authors find considerable variation in the outcomes of the different subsidy programs, ranging from an increase in energy usage or null improvements for those programs targeting appliance upgrades and building shell, HVAC and whole house retrofits. Other programs such as the replacement of old refrigerators and freezers show an average 6% reduction in electricity consumption, and the replacement of pool pumps yields the higher electricity consumption reduction at an average of 12% savings.

***Targeting*.** Another issue with some policies, is the fact that they may, deliberately or not, target some specific sectors of the population. In the case of energy efficiency, there is a clear need to assess how much energy efficiency policy can effectively reduce energy consumption, but there is also a great need to identify what types of consumers are induced to be more energy efficient. As I stated before in the introduction to this proposal, most of the well-known energy efficiency programs such as LEED in the USA and GEM (formerly BREEAM) in the UK are oriented at the higher-income sectors of society, which also have certain level of freedom at selecting their own participation and level of involvement. In the case of national policy, such as with the GMP, the issue of targeting becomes relevant. To this date it is difficult to understand why the Mexican government is targeting the lowest-income sector of its population, especially since it is evident that this is not the most energy-demanding nor polluting sector of the Mexican economy. Allcott, Mullainathan & Taubinsky (2014) explain:

Targeting is a fundamental problem in the design of public policy. For example, policymakers often want to target redistributive transfers but do not perfectly observe individual need. Alternatively, as in Diamond (1973), we may want to levy corrective taxes when agents impose heterogeneous externalities, but only uniform taxes may be feasible. In these examples, we think of a policy as "well-targeted" if it successfully allocates transfers to the neediest or preferentially affects the behavior of agents that impose large externalities. (Allcott et al., 2014, p. 76)

A different but similar debate is based on the nature of these policies and programs. Whether programs are mandatory or left to be regulated by free-market principles is an area of research that is still ongoing, but without conclusive results thus far. Supporters of mandatory or government enforced programs argue that certain countries face particularities and challenges that keep them from effectively implementing such policies at a voluntary level. Among these challenges is the presence of weak information and technological contexts, a technology market not sufficiently developed, and weak regulations. Joskow (as cited in Friedmann & Sheinbaum, 1998) states: “Market imperfections and insufficient technical innovation RD&D [Research, Development and Dissemination] in developing countries make government intervention in energy efficiency promotion more necessary in these countries than in the OECD context” (p.

227). Additionally, and according to Enervalia's evaluations (Enervalia, 2012, 2013 and 2014), in the early stages of the GMP, the Mexican market was not quite ready to supply the energy efficiency devices to the construction sector. The GMP has contributed in building a market for the devices where there was no clear interest for these products from the consumer perspective. With the demand of devices, there was also an increasing demand for regulations and guarantees to protect the consumers. This demand was reflected in the number of new regulations created since 2008 (See Appendix B for more information). An analysis of the effects of these changes on the market and regulatory context of the country will be part of the analysis conducted through this work.

Chapter III. Methodology

The goal of this research project is to understand the role of energy efficiency as an instrument to improve the living conditions and environmental awareness of low-income households. As a case study, I analyze the Mexican Green Mortgage Program (GMP), which facilitates access to energy efficiency devices by amortizing their costs through mortgage loans granted to low-income families. The GMP is relevant since it overcomes most of the known barriers to energy efficiency as described in the previous chapter[8], and also because it addresses most of the known determinants of energy consumption at the household level, also discussed in this literature review. While existing research looks for ways to promote the incorporation of energy efficiency devices and how to facilitate access to them through the use of incentives, subsidies and other finance mechanisms (see for example Sarkar & Singh, 2010), this study aims to go one step forward and analyze what happens when these devices have been delivered together with the dwelling unit, that is, when people do not have to make the rational decision to acquire and install them. Moving beyond the measurement of the expected reduction in energy consumption, this analysis is based on the multiple effects framework, and uses variables that try to measure alternative outcomes such as the possible effects on people's knowledge, perception and attitude toward the environment, and toward energy consumption, peoples' ability to invest in recreational and skill-building activities, and perceptions of their own wellbeing.

[8] Amongst the barriers are distortion in energy prices; limited access to capital (up-front costs); lack of fiscal and regulatory policies, codes and standards; and lack of availability of technologies; attitudes toward energy efficiency, perceived risk, information asymmetries and misplaced incentives.

The analysis is based on a comparison of traditional neighborhoods to neighborhoods financed through the GMP. All dwelling units within a GMP neighborhood have the same package of efficiency devices and similar structural characteristics. Using secondary data from the main utility company in Mexico (CFE), I first evaluate the effectiveness of the program at reducing electricity consumption. Later, I analyze data obtained through an original survey administered to a sample of the inhabitants of these neighborhoods, to analyze the effects of the program on their living conditions and environmental knowledge and attitudes.

Figure 9 shows the conceptual framework for this research. The variables of the determinants of energy consumption at home are grouped into five categories, and each category includes a specific sub-set of variables that have demonstrated to be strong predictors of energy consumption (see figure 10 for a detailed diagram). An additional variable which defines whether the household belongs to the GMP is included as part of this analysis. The variables that represent the outcomes are energy savings, and three categories created using the multiple benefits approach: knowledge, living conditions and environmental awareness. The operationalization of these categories is depicted in detail in figure 11.

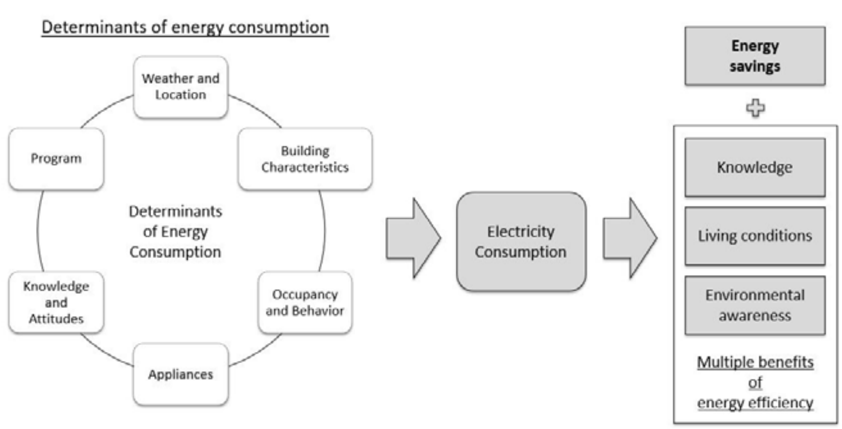

Figure 9. Conceptual framework

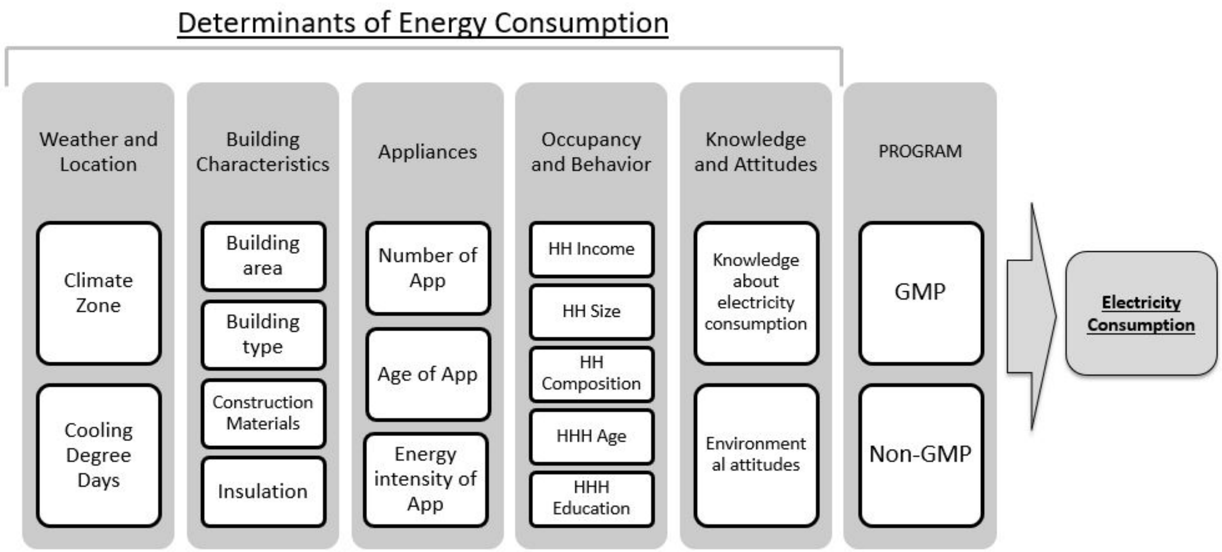

Figure 10. Detailed diagram of conceptual model depicting the variables included as determinants of energy consumption at the household level.

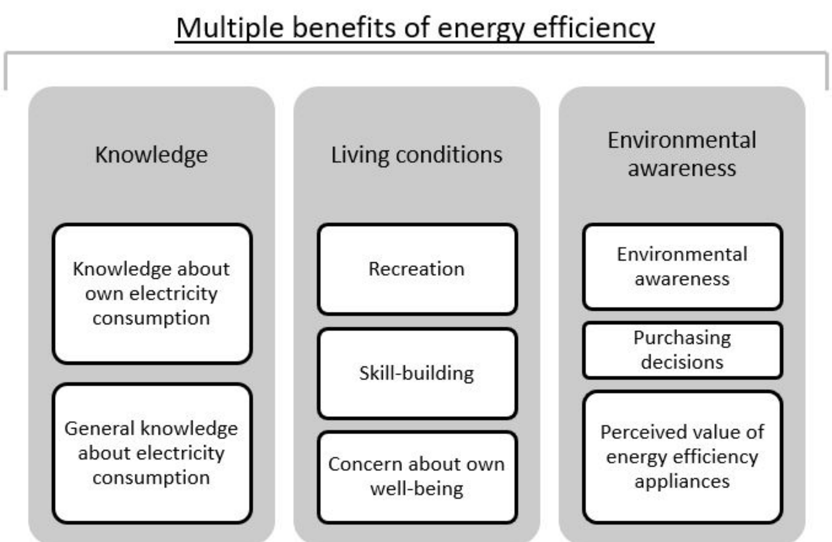

Figure 11. Detailed diagram of conceptual model depicting variables included as measures of the multiple benefits of energy efficiency for this study.

Research questions and hypotheses

The principal question that I am addressing with this research is whether energy efficiency can have an effect in living conditions of low-income households, an effect that goes beyond a reduction in energy consumption and utility bills. In other words, does energy efficiency can bring about multiple effects, and if so, what are these and how tangible are they? With the answer to this question I expect to have a more thorough understanding of other potential outcomes of energy efficiency programs and policies. This information can guide the formulation of new policies and programs, and help improve existing ones.

The main question of this research is broad, so three more detailed sets of questions help explore this issue. The first set of questions deals with the effects of the GMP on electricity consumption[9], and on living conditions, and includes the following questions: Does the GMP reduce energy consumption in low-income households? Is there a difference in participation in recreational activities between inhabitants of the GMP and those in the traditional neighborhoods? Is there a difference in participation in skill building activities between inhabitants of the GMP and those in the traditional neighborhoods? Is there a difference in the perception of their own wellbeing between inhabitants of the GMP and those in the traditional neighborhoods?

Hypothesis 1. Houses in GMP neighborhoods consume less energy than those in the traditional neighborhood group.

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[9] I only examine electricity consumption because of limitations in the access and quality of water and gas data, as will be described in the Section on Limitations in this Chapter.

Hypothesis 2. Households in GMP neighborhoods participate in more recreational activities than those in the traditional neighborhood group.

Hypothesis 3. Households in GMP neighborhoods invest in more skill-building activities than those in the traditional neighborhood group.

Hypothesis 4. Households in GMP neighborhoods show lower levels of concern about being able to satisfy basic needs than those in the traditional neighborhood group.

The second set of questions deals with the effects of the GMP on knowledge about electricity and efficiency. The questions are: Is there a difference between inhabitants of the GMP and those in the traditional neighborhoods on a) knowledge about their own electricity consumption; b) knowledge about the electricity consumption of common household appliances.

Hypothesis 5. Households in GMP neighborhoods have a better understanding of their own energy consumption than those in the traditional neighborhood group.

Hypothesis 6. Households in GMP neighborhoods have a better understanding of the energy consumption of common appliances than those in the traditional neighborhood group.

The third set of questions deals with the effects of the GMP on environmental attitudes, perceptions and behaviors. I explore three main topics: a) environmental attitudes; b) purchasing preferences for small and large appliances; and c) value assigned to energy efficiency appliances, and conduct a comparison between both groups to find possible differences between inhabitants of the GMP and those in the traditional neighborhoods.

Hypothesis 7. Households in GMP neighborhoods have a more environmentally-friendly attitude than those in the traditional neighborhood group.

Hypothesis 8. Households in GMP neighborhoods pay more attention to energy efficiency standards when purchasing small and large appliances, than those in the traditional neighborhood group.

Hypothesis 9. Households in GMP neighborhoods assign a higher value to energy efficiency appliances than those in the traditional neighborhood group.

Additional questions. The application of the survey also allowed me to answer many questions that have not been addressed by either the Program's internal evaluations conducted by Enervalia, or by INFONAVIT. As stated in the literature review, information and knowledge can act as prerequisites of attitudes and, sometimes, behavior (Steg, 2008; Abrahamse et al., 2005). There is currently no data available about the amount of information about the GMP that the homebuyers receive when they purchase their homes. INFONAVIT arguably distributes pamphlets, CDs and comics at the time of purchase, but the consistency of this process as well as its effects have not been recorded before. The questions that explore this issue and provide information to understand other effects of the GMP, are: How do the inhabitants of GMP households perceive their homes in terms of energy consumption and compared to other houses (of their neighborhood, of other neighborhoods, older houses, newer houses)? Are they aware they live in an energy-efficient building? Do they know that they are part of the GMP? Do they know that the GMP means? Is it important for them? Are they aware of any savings enabled by the GMP? What other benefits are they obtaining from purchasing an energy efficient home? The answers to these questions will illustrate additional conditions that can help improve the GMP and other energy efficiency and housing programs.

Study Area

I chose to select one city in the north of Mexico as a case study, mainly because of data limitations. Access to information and data in Mexico is still very limited, even with some recent progress in this area, such as the creation of the National Institute for the Access to Information[10] (INAI). Though the results of a national level analysis, or a comparative study between different states in Mexico would have been more informative, I focus on one region of Mexico because of these limitations.

The selection of one climatic region to choose households for analysis presented the reasonable compromise of working with a smaller sample, but controlling for climate, one major determinant of energy consumption at the household level. Notwithstanding this limitation, I foresee the use of the framework created for this research project on the analysis of other urban areas in all climate zones in Mexico. Therefore, the first focus of the selection was geographical. Using the Köppen climate classification for Mexico, I selected tentative cities within the Hot-Arid climate (BWh per the Köppen climate classification, shown in light yellow in Figure 12). Hot-arid climates are recognized as more energy-intensive due to their dependency on air-conditioning systems to achieve thermal comfort indoors (De Buen, 2004; in Solis, 2008), a fact considered relevant since the focus of this analysis is on electricity consumption. Cities in this

[10] See Appendix C for more information on the Institute (INAI) as well as the data request process.

climate zone include Hermosillo, Ciudad Obregón and San Luis Río Colorado, in Sonora; Mexicali, Baja California; La Paz and Guerrero Negro in Baja California Sur; Los Mochis, Sinaloa; Chihuahua and Ciudad Juárez in Chihuaha; Ciudad Acuña, Monclova and Torreón, in Coahuila.

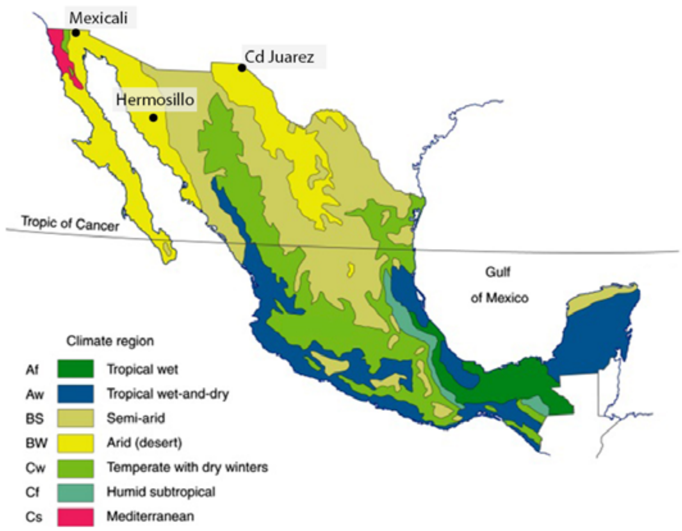

Figure 12. Map of climatic regions of Mexico with the location of the preliminary case studies[11].
SOURCE: Rhoda & Burton, 2009, modified by the author.

The second factor considered for the selection of the study area was the socio-economic characteristics of these cities. Cities located close to the border region such as Hermosillo, Ciudad Juárez and Mexicali share many similarities: they are young cities of approximately 150, 300 and 100 years old respectively, with rapidly growing populations, and they also share the characteristics of the Mexican North: these are cities with higher levels of education, higher

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[11] Figure 12 shows the climate map of Mexico, according to the Köppen climate classification system adapted by Enriqueta Garcia in 1964. This adapted version has been used in Mexico by official institutions such as INEGI. The adaptation consists of the addition of detailed characteristics specific to the Mexican geographical and climatic conditions, especially in terms of 'transitional climates' for which the traditional Köppen classification is insufficient (Leautaud Valenzuela, nd; Rhoda & Burton, 2009)

income, higher employment rates, a higher percentage of the population working in the formal sector, and in general perceived to have more and better economic opportunities than other parts of the country (Székely, 2005; OECD, 2015).

The third factor for the selection of the study area was the presence of GMP developments. Three of these cities have the most GMP housing developments: Hermosillo, Sonora and Mexicali, Baja California with five; and Ciudad Juárez, Chihuahua with four. Additionally, these three cities have similar size in population and geographical area (See Table 3). Other cities in this climatic region have either none, or no more than one GMP housing development.

Table 3.
List of cities and case studies selected

City	**Population (2010)**	**Area and Elevation**	**GMP housing developments (in 2014)**
Hermosillo, Sonora	784,342	168.2 Km^2 E 210 msnm	5 GMP (approx. 5,922 households)
Ciudad Juárez, Chihuahua	1,332,131	321.2 Km^2 E 1,137 msnm	4 GMP (approx. 3,600 households)
Mexicali, Baja California	936,826	113.7Km^2 E 8 msnm	4 GMP (approx. 4,200 households)

NOTE: Data edited by the author. Sources: INEGI, 2011; INFONAVIT, 2014; CFE, 2016.

Based on the number of GMP housing developments, the final selection included the cities of Hermosillo, Sonora; Mexicali, Baja California and Ciudad Juárez, Chihuahua. Due to limitations on the access to data for two of these three cities, the final analysis was limited to one city where CFE provided the electricity consumption by household, grouped by neighborhood. For a summary of the three year data request process and outcomes, see Appendix C.

Site Selection

I conducted an exploratory site selection before formulating the sample. At the time of the site selection (mid 2013), the city of study had five neighborhoods categorized as part of the Green Mortgage Program, either completed or in construction. Out of these five, only two of them were permitted and started construction before 2011, the year when the GMP became mandatory to all housing developments financed through INFONAVIT. After 2011 all developments financed through INFONAVIT were required to install energy efficiency devices. This was an important consideration for finding a comparison group that had a similar vintage than the GMP. The other three GMP developments had a large variation in the types of units offered (measured in construction area and reflected in number of levels, bathrooms and bedrooms). Additionally, two of these three developments had a large discrepancy between the number of units presented in the construction plans versus the dataset provided by CFE (one neighborhood had 188 permitted units, and CFE provided information for 348 units; the other neighborhood had 1288 units and CFE provided data for 3066 units). This discrepancy may be caused by different nomenclatures used by the housing developer when permitting the construction, by the separation of construction in phases, and by the lack of coordination between planning agencies and CFE. Furthermore, because of the lack of transparency and lack of access to the source of data, it was difficult to know what CFE was considering to be one neighborhood. Because there was no pragmatic way to solve these discrepancies, these three neighborhoods were removed from the study.

For the comparison group, I analyzed nine housing developments that matched the characteristics of the GMP dwellings: location within the city (near the comparable GMP development), size of dwelling, total number of rooms, construction materials, insulation specifications, appliances included with the house[12], household income, and household size. Because the neighborhoods are within the same city, I am naturally controlling for other intervening and constraint variables such as climate, urban effects, and sociocultural characteristics. The comparison group is referred to as ‘traditional households’ throughout this document. The descriptive statistics about the sample, the treatment and comparison groups are provided in Table 8.

Sample

I used a three-stage sampling method: For the first stage, I used stratified sampling, quota sampling for the second, and systematic (or interval) sampling for the third. The interest of this analysis is the comparison between two categories: inhabitants of GMP neighborhoods and traditional neighborhoods. Therefore, I needed to create a population from which I could draw participants in a semi-random way. A stratified sample consists of organizing potential participants into separate ‘strata’, each with specific categories. In this case, specific categories were the type of neighborhood (GMP or traditional) and the size of the dwelling unit. The assumption is that there will be little variance within strata, and large variation between strata.

The stratified sample consists of four different neighborhoods in a city in the North of Mexico. Two neighborhoods were built under the Green Mortgage Program (GMP), and two neighborhoods were not, and will be referred to as ‘traditional’ neighborhoods. The GMP

[12] In Mexico, some houses are delivered without appliances, kitchen, closets, flooring and other finishes.

neighborhoods conform the treatment group, and the two traditional neighborhoods conform the control group. The names of the neighborhoods have been omitted from this analysis, but their characteristics are listed in Table 4. The target population consists of 2,029 households distributed in these four neighborhoods: 791 belong to the GMP group and 1,238 belong to the control group.

Table 4.
Construction characteristics of the dwellings within the GMP and the traditional neighborhoods

	Green Mortgage 1	Traditional 1	Green Mortgage 2	Traditional 2
Total dwellings	506	453	285	785
Bedrooms	2	2	2	2
Bathrooms	1	1	1	1
Livable area	43 - 47 m^2	43 - 47 m^2	38 m^2	38 m^2
Lot size	130 m^2	100 m^2	100 m^2	100 m^2
Year of construction	2013	2007	2010	2004 - 2007
Wall materials	CMU block (12x20x40cm)	CMU block (12x20x40cm)	CMU block (12x20x40cm)	CMU block (12x20x40cm)
Wall insulation (1)	Yes, 21-30 m^2	No	Yes, 21-30 m^2	No
Roof materials	Pre-cast beam and polystyrene panels	Pre-cast beam and polystyrene panels	Pre-cast beam and polystyrene panels	Pre-cast beam and polystyrene panels
Roof insulation (2)	Yes, up to 45 m^2	Partial	Yes, up to 45 m^2	No
Reflective coating	Yes	No	No	No
Additional information about Energy Efficiency Devices (3)	Gas water heater, instant, 9.1-12 lts min 8 CFLs Polyurethane sealant in doors and windows	Gas water heater, instant, 6 lts min CFLs (does not specify quantity) Polyurethane sealant in doors	Gas water heater, instant, 9.1-12 lts min 8 CFLs Polyurethane sealant in doors and windows	Information not available (4)
Calculated savings	MXN$337 to $719 depending on income level	Not applicable	MXN$337 to $719 depending on income level	Not applicable

NOTES:
1 and 2: The specifications for wall and roof insulation will be included later in the analysis phase
3: Information about water efficient appliances was not included in this list
4: This information is not available because the construction company went out of business after the completion of this project and before the start of this research project.

Using this target population (2,029 households), I established the confidence level at 95%, with a margin of error of 5%. The resulting required sample size was of 324 households. Expecting a non-response rate of only 10%, I decided to conduct 360 surveys, 90 in each neighborhood. In this way, I established the quota for the second stage. “Quota sampling is a common modification of probability sampling that yields nonprobability samples” (Fowler, 2013).

The advantages of working with a sample of the population are generally accepted in the literature of survey data collection and in existing research: it saves money, time and personnel (Alreck & Settle, 1985; Klecka & Tuchfarber, 1978). Using only one part of the population (sample) versus the entirety of the population, also helps improve accuracy of response (Moser & Kalton, 2017). However, using a sample has some limitations: firstly, there is the issue of heterogeneity in the population and a chance for clustering. To address these issues, I used systematic sampling (or interval sampling) where interviewers were required to randomly select every third household from all households within the selected four neighborhoods, so responding households would not be geographically clustered together. The neighborhoods financed by INFONAVIT and FOVISSSTE (the two major financial institutions in Mexico) are generally homogeneous in terms of size, quality and cost of housing, therefore the chances to have a bias toward one particular type of house are reduced. Assuming that the households were not distributed in the dwellings in any particular order at the time of buying (and there is no particular reason to believe they were) this sampling technique is simple, more feasible and equally reliable than ‘pure’ random sampling. Secondly, there is the threat of a low- or non-response by those selected in the sample. We also experienced a low-response rate in one of the neighborhoods, and this issue will be discussed later under Survey Response.

Survey Design

The only way to explore a direct linkage to actual change in living conditions was the implementation of an original survey, as pre-existing data or secondary data on this matter were non-existent. I surveyed 351 households in four developments (2 GMP/treatment neighborhoods and 2 control neighborhoods) to test whether inhabitants of the GMP neighborhoods had different levels of awareness, knowledge and perceptions towards electricity consumption than the inhabitants of the control neighborhoods. I also created an index to estimate possible differences in living conditions between the two groups.

The survey was created with consideration of the contextual characteristics of the target population. The survey was also crafted to ensure confidentiality and anonymity, and no identifying information was asked or recorded. A pilot version of the survey included the option to request and photograph the household's most recent electricity bill. This question had two intentions: 1) to corroborate if people were keeping track of their electricity bills; and 2) to get reliable data about their electricity consumption. However, during our pilot phase of the survey, I realized that this question was providing identifying information that was not necessary for this analysis, and it was also adding time to the survey implementation process. Also, compensation would be recommended or required since I was asking respondents for an additional effort apart from just completing the survey. I removed this question to ensure confidentiality in responses and to protect respondent's identity and privacy. This consideration also contemplates another goal of the study, to keep the time to complete it short since these were personally applied on site. One of the most important goals, however, was to maintain measurement correspondence (Converse & Presser, 1986).

The original survey included questions in four main areas: knowledge and attitudes about energy efficiency or about energy efficiency and the GMP (for GMP households), knowledge and practices around their own electricity consumption, past and current living conditions, and knowledge and attitudes toward environmental issues in general. The survey also included questions regarding the characteristics of their current house and household, as well as general socio-demographic information (see Summary in Table 5 below). Some of the questions have been arranged at different positions in the actual survey implemented in order to improve the flow of the questionnaire. The original survey in Spanish, as it was implemented to the target population, is included in Appendix D, and the English version is available upon request.

Table 5.
Survey components

General housing and household characteristics	10 questions about home ownership, time living in this house, characteristics of previous house, and household members.
Perceptions and knowledge about energy efficiency	7 questions about perceptions and knowledge of energy efficiency devices.
Knowledge about Electricity Consumption	5 questions about their own electricity consumption and practices, and one question about general knowledge
Environmental attitudes, beliefs and practices	8 questions to explore their attitudes and beliefs toward environmental practices.
Living Conditions	4 questions about current living conditions.
Socio-demographic information	6 questions about the respondent and respondent's household income and level of education.
Knowledge and perceptions about the GMP (only for GMP Group)	5 questions about general knowledge and opinion of the GMP
Preference over energy efficient home	2 questions on people's preferences for an energy efficient home.

Questions about general housing and household characteristics. This set of ten questions explores the household's background information that could have an effect on electricity consumption, such as tenure, adaptation, novelty, and changes to the structure.

The first question asks how long the household has inhabited the house, Previous research has shown variation in electricity consumption depending on how long people have inhabited a house. These effects are corelated to the acquisition of appliances or the possible changes made to the house throughout its occupation (Reiss & White, 2008). The survey also includes a question about whether the house was brand new or second use in order to know if they are the first occupants of the dwelling. This information is important as previous owner/inhabitants may have changed the structure, appliances and furnishings of the house, thus affecting its energy consumption.

I also asked about their origins, assuming that if they are local, they may be better adapted to the climatic conditions and demands of a desert city, whereas if they recently moved to this area, they may be experiencing difficulties to adapt. This adaptation also affects how people deal with certain appliances, such as air conditioning. Very limited research has been conducted on these issues (Marincic, Ochoa & Río, 2012), so I considered relevant to include these variables.

Other factors that may have an effect on electricity consumption are type of ownership, as inhabitants may take better care of a house when its owned as compared to a rented property. I also included a question about their previous dwelling, to know if this is the first 'formal' house they have inhabited and if they are firs-time buyers.

The last two questions ask information about the household size and age composition. The age composition of household members (number of total household members, age of members, and whether they are related or not) is commonly used in energy efficiency research related to residential housing, and have strong correlations with energy consumption (Brounen et al., 2012; Kaza, 2010; O'Neill & Chen, 2002; Lucas, Hidalgo, Gomez & Rosés, 2001; Yohanis, Mondol, Wright & Norton, 2008).

Additional questions about renovations, extensions or any type of change made to the structure of the house were included in a different section of the survey to account for structural changes that may cause changes in electricity consumption. They were incorporated in a different section of the survey in order to improve the flow of the questionnaire.

Questions on perceptions and knowledge about energy efficiency. I did not find a standard set of questions that dealt with knowledge or perceptions about energy efficiency in the Mexican, Latin-American, or developing world contexts. Therefore, I created a set of 11 questions that explore perceptions toward their own electricity consumption, toward energy efficiency in general, and a few questions that explore how much people know about energy consumption and, thus, energy efficiency in their daily lives. I used a comparative scale in order to obtain the respondent's perception of their own energy consumption. Using their own house as the benchmark for comparison, I asked whether they thought their house consumes *more, less or the same* electricity than a) houses in the same neighborhood, b) houses in a different neighborhood, and whether they thought their house consumes *more, less* or *the same* electricity than c) newer houses, and d) older houses.

I also used a comparative scale to explore perceptions about common energy efficiency devices (EEDs), such as CFL and LED lighting, and central versus mini-split air conditioning systems, and old versus a new refrigerator, and tank versus tankless water heater. I asked if they believed these appliances used a) *much less*, b) *less*, c) *the same*, d) *more*, e) *much more*, or f) *don't know*.

To measure knowledge about energy efficiency, I started by asking if they knew their house had any energy efficiency devices (EEDs). The following question I used a comparative scale to determine which EEDs were included with the house, which ones were bought and installed by the inhabitants, and which ones they did not have. I will compare the standard set of appliances as described by the construction company to the ones that inhabitants declare not having, in order to find out if any of these appliances are missing. The last question in this set referred to the origin of these devices (who paid for them?) and was used as a way to gauge their knowledge about the GMP and the financial system through which they are paying their mortgage. I did this because the pilot survey showed that some people believed the EEDs were free, while in reality these households are paying for them in their mortgage.

Questions about electricity consumption. Four questions in this group explore inhabitants' knowledge of their own electricity consumption, and one explores knowledge of electricity consumption in general.

Knowledge about their own electricity consumption. Three questions in this set try to capture the degree with which people relate and pay attention to electricity consumption: do they remember how much they paid, do they know and remember how many kWh they consumed, do they remember what months the utility bill covers; and whether they keep their utility bills. The first two questions required respondents to provide an amount in pesos or kWh for the amount they remembered. I included the question "*What month or months did your utility bill cover?"* without an assigned value but used to reference the actual data (kWh and pesos) for the month they reported.

Knowledge about electricity consumption in general. In order to measure their overall knowledge of electricity consumption, I focused on their knowledge of the electricity required to power different appliances. I provided a list of six common household appliances (clothes washer, television, lighting, air conditioning, refrigerator and computer) and asked participants to rank them in order of electricity consumption. The correct ranking, according to information provided by the 2010 Mexican Census (INEGI, 2011) is as follows: 1) Air conditioning, 2) Lighting, 3) Refrigerator, 4) Television, 5) Washing machine, 6) Computer.

Questions about environmental attitudes. I used three sets of questions to try to capture environmental attitude: 1) general environmental awareness and attitudes toward global environmental issues; 2) whether respondents paid attention to energy efficiency while buying both large and small appliances, and 3) a measurement of the value given to energy efficiency devices.

The measurement of environmental attitudes resulted a complex task. Originally, the questions about environmental attitudes were crafted following the Revised New Ecological Paradigm (NEP) scale (Dunlap, van Liere, Mertig & Jones, 2000), a 15-item instrument for assessing pro-environmental attitudes widely used in research (Steg & Vlek, 2009; Abrahamse &

Steg, 2011; Attari, DeKay, Davidson & De Bruin, 2016). High scores on the NEP scale indicate strong beliefs that humans are able to disrupt the environment (Allen, Dietz & McCright, 2015). However, in the pilot survey, I found two relevant issues with this question. The five points of the Likert scale (1: *completely disagree to 5: completely agree*) seemed to disperse the respondents' opinions and did not provide enough reliability in their answers. More problematic was the fact that the respondents did not seem to completely relate to the issues presented in the questions, therefore seemed to not care about the accuracy of their response. Table 6 presents a list of the 15 questions generally used in the Revised NEP questionnaire.

Table 6.
Revised NEP questionnaire

1	We are approaching the limit number of people the planet can sustain
2	Human beings have the right to change the environment to suit their needs
3	When humans interfere with the processes of nature, the consequences are often disastrous
4	Human ingenuity and creativity will ensure that we do not make the planet uninhabitable
5	Humans are severely abusing the natural environment
6	The planet has abundant natural resources; it is only a matter of learning how to exploit them
7	Plants and animals have as much right as human beings to exist
8	The balance of nature is strong enough to cope with the impacts that industrialized countries cause
9	Despite our special skills, humans are still subject to the laws of nature
10	The idea that humanity will face a global ecological crisis has been greatly exaggerated
11	Planet earth is like a spacecraft that has limited space and resources
12	Human beings are destined to dominate the rest of the natural world
13	The balance of nature is very delicate and can be altered easily
14	Over time, humans will learn enough about how nature works in order to be able to control it
15	If things continue as they are, we will soon experience a major ecological catastrophe

SOURCE: Dunlap, van Liere, Mertig & Jones, 2000

To avoid random error from this measurement, the questions were simplified to represent more familiar terms and situations that the target population could refer to. If respondents can understand the question at hand, it is less likely that they randomly guess the answers, reducing the reliability of the data (Alreck & Settle, 1985, p. 64). An important factor of consideration was the level of education of the target population. In our case, the majority (86.9%) of the head of households in the target population only had a junior high or high school education.

To solve this issue, I provided four statements about personal beliefs regarding their contribution to environmental problems, with the option of answering yes or no. The first question addresses their perception of how their electricity-related behavior at home can have a negative effect on the environment. The second question captures their perception of effectiveness of current laws by asking if stricter laws could help mitigate the environmental issues. The third question asks whether they would agree to pay an annual fee to protect the natural environment. This question was crafted without a determined fee or sum of money, since it was oriented at exploring only the idea of paying to mitigate environmental damage. The fourth question asked whether they think it is necessary to change their own behavior in order to reduce environmental impact. One limitation for this question is that it only asks whether they think it is necessary or not, it does not ask if they are willing to change. However, since it is very unlikely that we will have the resources to verify if they actually will change, I decided that knowing the awareness and the relationship between behavior and environmental effects was present in the target population. I used these four questions to calculate an overall environmental-attitude score, where a higher score represents a more environmentally-conscious attitude.

To measure whether respondents paid attention to energy efficiency while buying both large and small appliances, I used a set of two questions to assess preferences toward energy efficiency, by asking how likely are they to consider electricity consumption when they buy either large or small appliances.

In order to measure perceptions of function and value (value given to EEDs or GMP), I started by asking if any EEDs had stopped working in their house. As a follow up question, I asked what they did about the malfunction, providing multiple options such as having the device repaired, changed or replaced. The assumption is that if people value the benefits of EEDs, they would repair or replace with another efficient device.

Questions about living conditions. The main intention of this set of questions was to get an approximation to the possible difference in well-being between the two groups. While I did not formally measure quality of life, I provide an assessment of differences in three living conditions that could potentially factor in this difference: participation by household members in recreational activities, participation by household members in education and skill-building workshops, and overall concerns over their own well-being and their own capacity to satisfy basic needs.

Current and future well-being are somewhat linked to the main assumption of the GMP, which states that because the Program helps reduce energy consumption, it thus reduces utility bills and therefore, GMP families have a larger part of their income available to invest in other expenses, such as education, recreation and skill building courses which eventually can contribute to improve their overall quality of life. Also, this set of questions needed to assess items that were comparable among the two groups.

I base these four questions on parts of the conceptual framework used by the OECD to define and measure well-being as part of its *Better Life Initiative*. This framework measures well-being from two perspectives: current well-being is measured by outcomes in material living conditions (income and wealth, jobs and earnings, housing conditions); and quality of life (health status, work–life balance, education and skills, social connections, civic engagement and governance, environmental quality, personal security and life satisfaction). Future well-being is assessed by the OECD by taking into account different types of capital (economic, natural, human, and social capital) which have the potential to improve well-being over time. Due to capacity concerns, mostly of not being able to incorporate a long list of questions to the survey, I focused on the human and social capital components of education and recreation. "Education and skills can be seen as both a basic need and an aspiration of all humans, as well as being instrumental to achieve many other economic and non-economic well-being outcomes." (Durand, 2015).

Based on this framework, the set of four questions included the perceived probability of being able to participate in (and pay for) different recreational activities selected from typical local activities such as an annual cattle exhibition or visits to popular local parks and plazas. A second question focused on the capacity to pay for additional educational activities for adults, such as skill-building workshops or continuing education. The third question was similar but focused on activities for children, such as after-school educational programs or summer camps. A fourth question required rating their current perceived concern about not being able to cover different basic living costs.**Questions about socio-demographic information**. The survey includes six questions with socio-demographic information such as sex, age and level of education of the head of the household, household income and number of recipients of income per household. The survey also includes one question regarding how typical is this income in comparison to the previous income received, which could help capture if the income reported is the usual income or an abnormality (due to additional sources of income or work) for that period of time.

Questions on knowledge and opinion about the GMP (only for GMP Group). Five specific questions addressed knowledge and perceptions about the GMP and were only asked to people in the GMP group. These questions explored whether the GMP inhabitants were aware of the fact that their household was part of the GMP and therefore equipped with energy efficiency devices. The five questions are whether they know what the GMP is, and if they answer yes they are required to describe it. Then they are asked whether they know that their house is part of the GMP, and if they answer yes they are asked how they know this. Lastly, I asked their overall perception of the program.

Questions on people's preferences for an energy efficient home. I included two questions to explore people's general perception of an energy efficient home. The first question asked if they were given the opportunity of selecting a house to buy again, would they select an energy efficient house (or a GMP house for the GMP group). In order to corroborate this response and to rule out social desirability bias, a follow-up question asked, if given the chance to choose, would they prefer the EEDs package, cash or a discount in their mortgage payment. These questions were intended to analyze the value that inhabitants give to the GMP in the GMP group, and to energy efficiency in the Control Group, and to the perceived value of energy efficiency devices in both groups.

Survey Implementation

The distribution and implementation of the survey was carefully organized to ensure a high response rate and be able to attain the established quota. A team of local interviewers conducted the field work. Personal interviewing has advantages over other methods of collecting data: it facilitates the most complete interaction with the respondents because of a face-to-face contact and it provides the opportunity to explain difficult or complex questions (Fowler, 2013). It also allows for interviewers to present different materials (pictures or cards with data to select, which can help make the information more understandable) (Alreck & Settle, 1985, p.42). In this particular case, personal survey collection played a role in facilitating meeting the sampling quota. I had to take additional considerations on safety and security based on recommendations of local inhabitants, local surveying companies and local members of the academic community. For example, due to concerns over the safety and security of the surveying team, the surveys were implemented during daytime hours (approximately from 9:00am to 4:00pm). For the same reasons, the surveys were presented printed in paper instead of using an electronic tablet, and no monetary incentives were offered for completing the survey. Surveys were crafted in Spanish and using language that could be easily understandable by the target population, and were completed in person by the interviewers. All 360 surveys were implemented in a period of six weeks between November 2016 and January of 2017.

Survey Response Rates

Interviewers were instructed to randomly select one household, and continue implementing the surveys every third house until they completed the quota of 90 households established per neighborhood. Because of this, we obtained a response rate of 100% in three of the four neighborhoods. Face-to-face survey interviews tend to get response rates that range between 67 to 70% (Goyder, 1987; Hox & de Leeus, 1994), and generally higher response rates than telephone or mail surveys (De Leeuw, 2008 in de Leeuw, Hox & Dillman, 2008; Groves, 1979; Klecka & Tuchfarber, 1978).

In one GMP neighborhood however, the response rate was extremely low. The team of interviewers were instructed to conduct a census instead, to capture as many responses as possible. In this neighborhood we were able to obtain a 88.9% response rate, and complete only 80 of the 90 surveys required to meet the quota. We are confident though that this non-response rate was not directly related to the survey content, so we conclude that there is minimal non-response bias. We assume that one of the causes for this non-response rate was the high rate of illegal squatting in the households of this neighborhood, and that the lack of response was driven by inhabitants being afraid of the potential consequences of identifying themselves to people they are not familiar with. This is an issue that will be discussed in Chapter VI, but for now we conclude that the selection of the respondents remains random for the stratified samples.

Data Entry and Completion

I developed a codebook at the same time that the survey was crafted and prior to data entry (see Appendix E). I created specific codes for missing or unclear responses, and a different one for irrelevant variables. I performed the data entry and coding myself in the months of January and February of 2017.

Secondary Data on Electricity Consumption

I used a secondary dataset of electricity consumption to measure neighborhood-level differences, particularly since a large number of the households surveyed did not answer the question on electricity consumption, and self-reported data is unreliable. I used this secondary and more reliable dataset to compare the self-reported data provided by the few respondents who answered this question.

This secondary dataset of electricity consumption data consists of electricity bills provided by CFE[13]. This dataset was created by CFE and obtained by the author through the recently created National Institute of Transparency, Access to Information and Protection of Personal Data (INAI). The dataset contains electricity consumption information for the three most recent years (2014, 2015 and 2016), for the four neighborhoods in this study. The data were collected in kWh and MXN$ pesos by dwelling unit. I will use the data in kWh to avoid normalizing the price data with the changes in the cost of electricity during these periods, the presence of subsidies and rates that vary by month and by region (for more information, see Appendix F), and the variation of currency exchange rates between the dollar and pesos in recent years.

In Mexico, each dwelling unit has a metering system that measures how much energy the household uses. As a standard procedure, an employee from CFE goes in person to read all meters of a sector of the city, and uploads the information to CFE's digital system. The

[13] CFE, or the Federal Electricity Commission, is the dominant, State-owned electric utility in Mexico

households receive their utility bill every month or every two months, depending on the region of the country. In the dataset used for this study, the readings for the utility bills in the city of study were taken monthly and bi-monthly, depending on the neighborhood, and only those accounts with 6 bimesters or 12 months were considered complete, thus included in the analysis.

Data from INFONAVIT and private developers

I was able to access internal data for all developments of study that were financed through INFONAVIT. These data consisted of site plans, construction drawings (including structural, architectural, and electrical plans) for all housing units. For those belonging to the GMP, I obtained specifications of the energy efficiency devices installed and the preliminary calculations of energy savings (pre-occupancy). I also interviewed the construction companies who built the developments in this study. They provided additional information regarding the type of information they provided to their homebuyers, if any specific training activities were conducted, and more details about the construction and permit process.

Data Limitations

Data availability and access. This study was originally designed to include electricity, water and gas consumption, which are the three parameters that the GMP is addressing as efficiency measures. However, in Mexico it is practically impossible to track water or gas consumption due to the lack of reliable metering systems. In the case of water, it is not uncommon, especially in low-income households and those of recent construction, to not have a metering system and pay only a standardized monthly tariff. Also, the pricing scheme of water has a wide range of variation between regions (some regions pay 20 times more than others). For our area of study, water service coverage is not as extensive as that of electricity, and water metering is not consistent. Around 60% of households have a meter, and due to lack of consistent readings, around 20% of those get charged a standard monthly rate. The other 40% may or may not pay for the service. Gas presents a similar challenge. Gas distribution services in Mexico are not consistent throughout the country, and the availability and type of distribution of gas varies by State. Furthermore, the vast majority of the country relies on the delivery of LP gas tanks, which are generally paid in cash and it is difficult to track consumption. In Sonora, only a few cities have a natural (piped) gas. In the city of study, there is no metering system, gas is sold in tanks, handwritten notes are delivered instead of tickets, payments are usually in cash, and consumers generally do not keep these notes or any other record of these transactions.

Access to data is also a limitation of this study. As presented in Appendix C, three years passed between the first data requests through INAI and the delivery of data. Each requests took an average of 4 months to be completed, and in some cases the data provided was not complete or was not useful because it had been aggregated. While the recent creation of INAI arguably facilitates this process, it is evident that there is much progress to be made in this realm.

Data quality. Poor quality of data is reflected in the lack of granularity and the lack of geographical references. There is no way to address lack of granularity, since that is the standardized way in which CFE collects its data. To this date, micro-level electric consumption data are not available to the public in Mexico. This is a limitation, since according to existing research "bi-monthly and monthly utility bills [are considered] low-resolution data, since residential electricity consumption has a strong temporal variation, which is not captured in monthly periods" (Kavousian et al., 2013). Additionally, utility bills are considered private information and are protected by Mexican laws. This is why data are available with very low-granularity and without any geo-reference that could identify the dwelling units and their inhabitants.

Deficient record of construction documents, and lack of continuity. It is difficult to track construction permits and construction documents. Cities like Hermosillo have limited institutional capacities, and recording changes during or after construction is not a regular activity. Access to this information is also considered private and developers are generally not easily convinced to share this information.

Probability of change at all levels: neighborhood, house structure and energy efficiency devices. A critical issue for the validity of the estimates from this study is the fact that some owners of GMP homes may have uninstalled or changed the energy efficiency devices, or did not know how to properly operate them to obtain the expected savings. These issues have been documented in the bi-annual evaluations provided by Enervalia (2011 to 2014). In this study, I assume that all households within the GMP group are using the energy efficiency devices that they were delivered with. Similarly, the households in the comparison group may have also installed energy efficiency devices as available in the market, due to their own interest in reducing consumption. I assume that because they were installed by the self-interest of the owners, these devices are maybe better understood and valued by its users, and thus, making them more effective at reducing energy consumption. This assumption is related to the following one, which is based on human behavior, meaning that within both groups, the GMP and the comparison group, there may be more ‘environmentally-conscious’ individuals who may have more energy-savings habits, even if their home does not have the energy efficiency devices that the GMP provides, or they may have purchased these devices with their own money, with the intention to reduce energy costs. A case-study that includes a survey or interviews of these households may provide a better understanding of what is actually happening inside these homes. In the Mexican context, houses acquired through INFONAVIT are relatively small and 'designed to grow'. This represents another challenge since a considerable number of dwellings will likely go through a remodeling process, where additional bedrooms, enclosed garages, or even a second floor will be added, all of which will affect energy consumption over time. This is particularly true for those cases where the renovations are made without any considerations for efficiency (selection of materials, use of insulation, location of openings, or orientation), and also for the cases where the renovation implies an increase in the number of members of the households (addition of a room for new members). However, I assume that the likelihood of these changes is similar in both the GMP and the control group. However, the survey results provide information about these changes, confirming that those will not have an effect on energy efficiency, as the vast majority of them consist of adding a perimeter wall or other safety features such as security bars in windows and doors.

Self-selection bias**.** One of the neighborhoods had a low response rate, and a high number of squatter settlers. The interviewing team tried to reach all inhabitants, but it was evident that those without an electric meter (and probably informal settlers) refused to answer the survey. Informal settlers were also present in other neighborhoods, but the number of houses was much larger so interviewers were able to simply skip those. This is an issue that may be partially resolved by selecting a sub-sample from the answers to the survey. This strategy will be discussed in detail in the next chapter, and the effects of informal settlement or illegal squatting on this project will be analyzed in the Conclusion chapter.

Chapter IV. Data Validity

In this Chapter, I begin with a description of the respondents to the survey, provide basic descriptive statistics of the population and original sample, and a full description of the final sub-sample. I also identify possible errors and bias, followed by explanations of the steps taken to correct them, such as non-response and post-stratification adjustments. I explain in detail the development and testing of scales for knowledge of electricity consumption and environmental attitudes, and explain their validity as components of this analysis. When applicable, I discuss certain threats to internal and external validity and provide corrections for violations of standard statistical assumptions. All statistical analyses in this study were conducted using IBM SPSS statistics software, version 24 for Windows. The texts used for reference in each statistical analysis are listed as references. Step-by-step statistical procedures are available in SPSS syntax form upon request.

Survey Response Rate and Sub-sample

The interviewing team was able to meet the quota of 90 surveys for three of the four neighborhoods selected. Only in one neighborhood they were limited to collect only 80 responses, even after conducting a census of all the households. The specific conditions of this neighborhood and the possible reasons why its inhabitants were reluctant to participate in this survey, will be discussed in the findings and discussion chapter. The author and surveying team were able to implement 350 surveys out of the 360 originally planned, thus the overall response rate was 98%.

I combined the responses to the surveys with the secondary dataset obtained from the electric utility company (CFE by its acronym in Spanish). This dataset included electricity consumption per household for the years 2014, 2015 and 2016. The combination of the survey responses to the electricity consumption as collected by CFE allowed me to have actual electricity consumption (as recorded by the metering system) per household. This allowed me to examine its correspondence with the self-reported information on electricity consumption in kWh and utility bill payment in pesos, which was collected with the survey. Because of the large disparities between the self-reported electricity consumption and the actual consumption, which entail a threat to construct validity, the analyses regarding electricity consumption in this study were conducted using only CFE data. However, not all data points provided by CFE corresponded to the surveyed dwellings, and not all households surveyed by the interviewers had a valid CFE metering number or metering account, so I was not able to match all the cases.

The surveying team was instructed to give preference to those households that had a metering system in place. In some cases, it is easy to determine which houses have a metering system. As an example, figure 13 shows the place where the metering systems are usually located. It is clear in that case that the house in the left does not have a metering system. However, in some other cases, it is not easy to discern if the metering system is valid, or working.

From the 350 households surveyed, 327 had a metering system installed, but only 208 of those were valid, or recognized by the CFE system (see Table 7). It is worth noting that all the missing metering systems correspond to the GMP2 neighborhood, which also has the lowest number of valid metering systems (56).

Figure 13. Common location of metering systems in low-income neighborhoods in Mexico. NOTE: The picture shows a metering system on the right, and a void in the place where the missing metering system would be for the house on the left. Photo by the author.

Table 7.
Completed surveys by neighborhood

	Green Mortgage 1	Traditional 1	Green Mortgage 2	Traditional 2	Totals
Survey quota	90	90	90	90	360
Survey response	90	90	80	90	350
Response rate	100%	100%	89%	100%	98%
Surveyed houses with electric meters	90	90	56	90	327
Valid electric meters (with some data)	38	67	30	73	208
Valid electric meters with complete data for 2016	33	63	22	70	188
Matching rate	36%	70%	28%	78%	54%
Total dwellings in neighborhood	506	453	285	785	2029

Lastly, not all cases had complete data. Incomplete annual electricity consumption information refers to those cases where information on electricity consumption is only available for 1, 2 or 3 months or bimesters per year. I decided to select only the cases where electricity information was complete for a full year (6 bimesters or 12 months). This selection resulted in 113 cases in 2014; 154 cases in 2015, and 188 cases in 2016. The control group resulted with more valid cases (*n*=133) and the GMP with less (*n*=55). Throughout this analysis I work only with data from 2016, which is the year with the most number of cases with valid information, and the most recent year at the time of this research.

Subsample. The use of subsamples is not atypical in research. There are two main reasons why a researcher may decide to use a subsample: one, when results are needed quickly, researchers can produce preliminary results using only one part of the sampled population; and two, when it is not clear in advance how complete the data will be, or it is difficult to establish their validity. A subsample can also be used when only certain variables are required in the analysis (Moser & Kalton, 1979; Alreck & Settle, 1985). In this dissertation, it was impossible to find out how many and which dwellings had a valid metering system with complete electricity consumption data available before the surveys were implemented and data analyzed. This task of finding dwellings with valid metering systems and with complete data for the three years of interest (2014, 2015, and 2016) would have probably require much more time and labor than feasible, and would have also increased the costs of the fieldwork data collection. Because of these limitations, this analysis is based on only a portion of the original sample, and represents only the specific subgroup of dwellings where survey responses were successfully matched with valid and reliable electricity consumption data obtained from CFE.

Description of the respondents and their households. I present basic descriptive statistics and frequencies of responses to three demographic questions for the head of the households (age, sex, education) and ten questions for the households as a unit. I compare the original sample (*n*=351) to the subsample (*n*=188), and I use data from the 2015 intercensal survey (the most recent data publicly available) to compare the sample populations to the population of the city[14]. The results are summarized in Table 8. On average, the households and head of households have the following characteristics:

- The head of the household was more likely to be female than male (83.8% women versus 11.7% men); while at the city level, the majority is male (67.7%). Female head of households are overrepresented in comparison to the city.
- Head of households tend to be younger than those of the city (38.3 years old versus 44.5).
- Approximately half of all head of households only completed basic education (53.3%); and one third completed high-school education (33.6%). Only 13.1% has a technical or college degree and none had a graduate degree. In comparison to the city level data, the sample is less educated overall, except for high school completion (33.6% in the sample, versus 16.2% at the city level).
- The average household size is slightly larger, with 3.77 persons per household for the sample and 3.4 for the city.

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[14] The census presents data at the municipal level, which in this case is quite larger than the urban area. To correct for this, I only used data from the AGEBs located within the urban area.

- The distribution of household members by age is similar in the original sample and the subsample. In both groups, a majority of households has a high number of individuals younger than 12 and aged between 25 and 44 while fewer households have individuals 55 years and older.
- Households are relatively poor: the majority (74.4%) of household incomes are below 3VSM or $6,075 pesos per month (US$360 dlls per month in 2018). Since these neighborhoods are financed and built based on the income level, a comparison to income levels to that of the city would be irrelevant. However, the comparison helps depict this sector of the population as a lower-income level in reference to the city as a whole, where only 25% of the population falls in this income category (under 3VSM).
- The majority of households (62.7%) depend on a single income, usually the father's.
- Similarly to the data for the city, the majority of inhabitants of these neighborhoods are homeowners (76.6% for the sample and 73% for the city)
- The majority of inhabitants are first-time home buyers (72.6%), they are also the original buyers of the house or first occupants (70.9%), and used to live in a formal house (70%) versus a self-built structure (30%) before moving to this dwelling. There are no data for these variables at the city level.
- A larger proportion of dwellers in the sample (96.1%) are originally from the same city or the same State, compared to those in the city (85.6%). Dwellers in the sample have resided in their current house between two to five years (45.6%) or between six to ten years (29.6%).

Table 8.

Sociodemographic characteristics of the original sample (N=351), and subsample (n=188)

Head of the Household characteristics

	Original sample (n=351)		*Subsample (n=188)*		*City(1)*
Sex	Total	%	Total	%	%
Mother (female)	294	83.8	153	81.4	30.5
Father (male)	41	11.7	25	13.3	69.5
Son / Brother	8	2.3	6	3.2	
Single person / Other	8	2.3	4	2.1	N/A
Didn't answer	0	0	0	0.0	
Age	Total	%	Total	%	%
Average	38.36		38.86		44.53
Standard Deviation	10.384		10.085		25.93
Education	Total	%	Total	%	%
Elementary (Primaria)	38	10.8	21	11.2	29.6
Junior high (Secundaria)	149	42.5	72	38.3	23.6
High school (Preparatoria)	118	33.6	66	35.1	16.2
Normal	7	2.0	6	3.2	1.2
Technical training	14	4.0	8	4.3	4.1
Bachelor degree	25	7.1	15	8.0	16.9
Graduate degree (master or doctorate)	0	0	0	0	2.3

Household characteristics

	Original sample (n=351)		*Subsample (n=188)*		*City(1)*
Number of HH members	Total		Total		Total
Average	3.77		3.94		3.39
Standard Deviation	1.465		1.54		1.63
Age of HH Members	Total	%	Total	%	%
Members younger than 12	220	62.7	120	66.7	24.6
Individuals between 13 and 17	103	29.3	58	32.2	8.6
Individuals between 18 and 24	103	29.3	54	30.0	13.0
Individuals between 25 and 34	181	51.6	89	49.4	17.9
Individuals between 35 and 44	153	43.6	96	53.3	14.4
Individuals between 45 and 54	72	20.5	44	24.4	10.18
Individuals between 55 and 64	32	9.1	12	6.7	6.4
Individuals older than 65	17	4.8	12	6.4	4.8
Household Income	Total	%	Total	%	%
Up to $2,200 pesos	13	3.7	8	4.3	2.3
From $2,201 to $4,250	81	23.1	41	21.8	8.8
From $4,251 to $6,500	167	47.6	89	47.3	13.9
From $6,501 to $10,750	71	20.2	42	22.3	21.3
From $10,751 to $21,300	9	2.6	2	1.1	25.6

More than $21,300 pesos	0	0	0	0.0	18.1
Did not specify / answer	10	2.8	6	3.2	10.2
Number of incomes per household	Total	%	Total	%	
Only the father's	220	62.7	113	60.1	N/A
Only the mother's	31	8.8	20	10.6	
Combined father's and mother's	56	16	28	14.9	
More than 2 incomes	40	11.4	25	13.3	
Did not answer	4	1.1	2	1.1	

Ownership characteristics

	Original sample (n=351)		*Subsample (n=188)*		*City(1)*
Ownership	Total	%	Total	%	%
Own	269	76.6	143	76.1	72.8
Rent	56	16	33	17.6	13.7
Borrowed	26	7.4	12	6.4	10.0
Other	0	0	0	0.0	0.03
First-time owners	255	72.6	134	71.3	N/A
Bought the house brand new	249	70.9	131	69.7	N/A
Previous dwelling	Total	%	Total	%	
Formal house	246	70.1	132	70.2	N/A
Self-built	105	29.9	56	29.8	

Length of residency and place of origin

	Original sample (n=351)		*Subsample (n=188)*		*City(1)*
Place of origin	Total	%	Total	%	%
Same city	288	82.1	154	81.9	85.6
Other city of the same State	49	14	26	13.8	
Other State	14	4	8	4.3	13.08
Other country	0	0	0	0.0	1.03
Residency	Total	%	Total	%	%
Less than 6 months	18	5.1	9	4.8	N/A
6 to 8 months	8	2.3	4	2.1	
One year	29	8.3	10	5.3	
Two to five years	160	45.6	76	40.4	
Six to ten years	104	29.6	67	35.6	
More than ten years	17	4.8	11	5.9	
Don’t know / Didn't answer	15	4.3	11	5.9	

NOTE (1): Data for the City based on data from INEGI *Encuesta Intercensal 2015*, and includes only urban AGEBs.
N/A refers to data that are not collected by the census.

Sampling-bias. The descriptive information listed above and included in Table 8 also help to compare the original sample (n=351) to the subsample (n=188), and analyze if the sub-sample is representative of the universe of potential respondents of the original sample. Overall, the sub-sample is demographically similar to the original sample with slight variations. For example:

- In the subsample for 2016, the presence of female head of households is slightly lower than in the original sample (81.4% versus 83.8%).
- Median age of head of households is practically the same in both samples (38 years).
- Education of head of households is similar in both groups (about 30% completed high-school, 7-8 % completed a bachelor's degree, and none have a graduate degree).
- Occupancy is slightly higher to that of the original sample, with 3.94 members per household in the sub-sample, versus 3.77 members per household in the original sample.
- The age composition of household members is similar in both samples.
- Incomes are slightly lower in the sub-sample. The sub-sample has a slightly lower percentage of households with incomes above 1VSM (92.5% versus 93.5%).
- Ownership rates, presence of first-time owner and occupants, and type of previous dwelling are similar for both samples, as well as place of origin and time of residency. For both groups, the majority of inhabitants (82.1% and 81.9% respectively) are originally from the same city, and have been living in their current residence between 2 and 5 years (45.6 and 40.4%) or 6 to 10 years (29.6% and 35.6%)

The rest of the analysis is conducted using the sub-sample of 188 households in four different neighborhoods. Survey responses were matched to their electricity consumption as recorded by the electric utility company.

Survey Data Validity

The selection of neighborhoods was conducted using a stratified sample based on two categories (belonging to the GMP and dwelling characteristics), and this process helped the internal validity of the analysis. Overall, houses financed by INFONAVIT and built by private developers are segregated by income levels. This is part of the reason why the houses within each neighborhood are very similar among them: developers are restricted to a specific cost of construction that allows them to sell the houses to a specific consumer with a specific income level, and also make a profit. Because of this, houses built under these conditions have many structural similarities (size, construction materials, type of building, number of rooms, design elements). These similarities allow for the control of several possible confounding variables in the two groups: dwellings of the Green Mortgage Program (GMP) and traditional neighborhoods. On the contrary, because the small size of the final subsample, it will be difficult to reach statistical significance and ensure external validity.

While the survey implementation obtained a high response rate, the fact that I could not match actual electricity consumption to almost half of the survey recipients reduced significantly the sample size. However, the similarities between the original sample and the sub-sample address the question of whether the sub-sample is representative of the original sample, and indicate a reduced probability of bias if any generalizations are to be produced from the analysis of the sub-sample.

Another concern is the low number of dwellings with a valid metering system in the two neighborhoods belonging to the GMP, which caused a very low matching rate (around 33%) with the electricity data. In the case of GMP2, one of the possible factors contributing to this is the novelty of the neighborhood (built around 2010). However, the units in GMP1 were built more recently (2013) and this problem is slightly less acute there. Both traditional neighborhoods that belong to the control group are around ten years old, which suggests that those are more consolidated in comparison to the two in the GMP group. Additionally, the surveying team as well as the author were able to identify a large number of homes without a metering system, but with electricity in their houses. The first picture on the left of Figure 14 shows a missing metering system in a house that has an air conditioner (note the pipe running from the external condensing unit to the interior of the house, right above the window). Situations like these were common in the GMP2 neighborhood, where the team also encountered a high number of households who decided not to answer the survey. We could not find a trend in households with or without a metering system and their probability of answering the survey, so I will not generalize that those who are using electricity illegally or squatting in these houses are more likely to not answer the survey.

Figure 14. Houses in the sample population without a working electricity metering system.

The internal validity of the study could also be compromised by two additional issues: the possibility that the owners of these dwellings had performed structural changes to the building that could result in a higher energy demand (such as the construction of a new room, a second level, or a garage); and the possibility that they had already incorporated other high-energy demanding appliances (such as air conditioning systems), which could also increase the electricity demand in comparison to other houses in the neighborhood and the comparison group. These two conditions are explored below.

Changes to the dwelling structure. A relevant factor in the amount of electricity consumed by a house, is the variation in the size of the structures (dwellings) used for this analysis. One question in the survey explored whether households had made any changes or improvements to their homes. A large majority responded that no changes had been performed (69.1% for the GMP group and 72.2% for the control group); and of those who responded affirmatively had made modifications that do not affect energy consumption, such as flooring, painting and other wall finishes, or construction of perimeter walls. From the list presented in Table 9, the only changes that can have an effect on energy consumption are extensions (the addition of one or more rooms), waterproofing and insulation. Very few houses in both groups had made any of these changes: 3.6% in the GMP and 3.8% in the control group had built an additional room (extension), and only one house in the GMP group had replaced or fixed the waterproofing of the home. None of the respondents expressed that they had added insulation to walls or roofs in their homes.

Table 9.
Changes made to the house (extensions and improvements)

	GMP (*n* = 55)		Control (*n* = 133)	
Nothing	38	69.1%	96	72.2%
Extension (addition of a room or more)	2	3.6%	5	3.8%
Waterproofing	1	1.8%	0	0.0%
Perimeter wall	4	7.3%	9	6.8%
Window safety bars	7	12.7%	14	10.5%
Paint	5	9.1%	12	9.0%
Flooring	2	3.6%	2	1.5%
Doors	0	0.0%	5	3.8%
Wall finishes	0	0.0%	2	1.5%

NOTE: Only the changes "Extension", "Waterproofing" and "Insulation" may have an effect on electricity consumption. None of the households had applied additional insulation to their structure.

Moreover, the majority of improvements or changes in these structures are related to the safety and security of the households. About 22% of households in the GMP group declared they had built a perimeter wall or installed protective bars in their windows, and slightly less than 20% of the control group households did so too. Along with painting the house, these are the three most common home improvements in both groups, which suggest that safety and security are priorities in these neighborhoods.

Differences in appliances between neighborhoods. A relevant factor in the comparisons made by this analysis, is the presence of appliances that demand a high amount of electricity to function. According to the estimates by CONUEE in 2009 (National Commission for the Efficient Use of Energy), air conditioning systems use about 44% of the energy consumed in Mexican homes, followed by lighting (33%), and refrigerators (14%). I inquired about the presence of air conditioning systems in the four neighborhoods surveyed based on the fact that the extreme climatic conditions of the region require some form of air conditioning system in order to accomplish thermal comfort indoor during the summer months, as proven by the high presence of air conditioning systems at the city level[15]; and also to explore the variation in type of air conditioning systems preferred in these neighborhoods. The preference for different types can be related to practical cost-benefit analysis conducted by the householders, who make decisions based on the effectiveness, cost and use of these units.

Figure 15 presents the results in type and total number of air conditioning systems per group. Overall, the presence of some of these appliances is extremely low, which can be explained by their high demand of electricity which represents a high cost of operation. For example, less than 5% of all households own a central air Conditioning system, and about 14% own a window-unit. Mini-split systems are more abundant, with 60% of all households stating they own this type of unit. Evaporative coolers (commonly known as *swamp-coolers* in the US) are common in the region because they demand less energy than any other air conditioning system with the exception of fans; however, they are not as effective in the summer months when air humidity levels are higher.

[15] The census data does not collect detailed information on the type of air conditioning system, but city-level data is available. In the case of the city where these neighborhoods are located, around 78% of households own an air conditioning system (which generally would fall into the first three types of air conditioning units described here: central, window or mini-split systems.

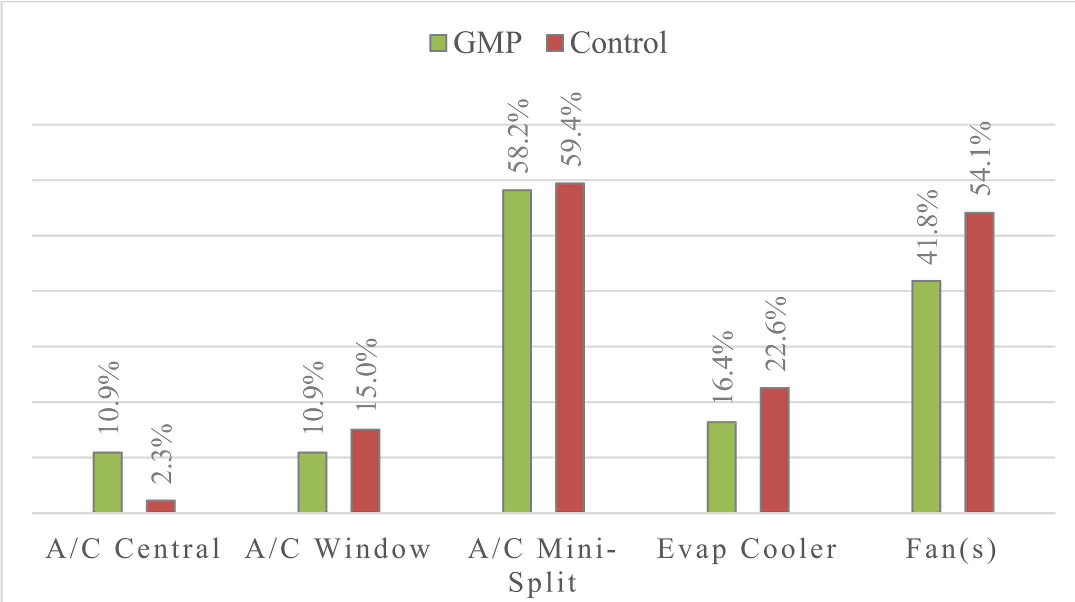


Figure 15. Number of households in each group that own appliances related to thermal comfort, in order or electricity demand.
NOTE: The bars are in order or electricity demand (higher to lower from left to right).

This may help explain the relatively low number (20%) of evaporative cooler units present in these neighborhoods. Fans, which are the least energy demanding but also least effective air conditioning system within this group of appliances is also largely present (half of the households), but surprisingly less than mini-split systems.

Data screening

All statistical analysis impose assumptions about the data, depending on the type of analysis to be conducted. Some of these assumptions include sample size, independence of observations, normal distributions, homoscedasticity, and that there are no extreme outliers. Some of the answers to the questions in the survey, thus some variables or sets of variables in the dataset do not meet all these assumptions. Overall, independence of observations and sample size were met, outliers were corrected or transformed when present.

The key outcome variable '*total electricity consumption in year 2016, measured in kWh*' had outliers and extreme outliers. When appropriate, I describe alternative steps to deal with these issues in each specific variable or set of variables along the definition of the problem depicted in the Findings and Discussion chapter.

Construction and validity of scales and indices

I constructed five different scales or indices to measure different latent variables. These scales were composed of a set of variables that were supposed to measure attitudes, knowledge and participation in certain activities.

I used an index to measure environmental attitudes using responses to four questions regarding people's views about the role that human activities have on the natural environment, their agreement or disagreement with the institution of more regulations or payment of fess in order to protect the environment, and the possibility of making changes to their own lifestyles in order to reduce negative effects on the environment. The scale was based on these four questions, therefore possible values ranged from 0 to 4. The results show a mean score of 2.32 for the control group (n=133, SD=.901), and 2.58 for the GMP group (n=55, SD=.937). However, the Cronbach's alpha for this index was extremely low (0.238), suggesting that the index has a low level of internal consistency (or reliability), therefore it does not effectively measure the latent construct of environmental attitude.

Given the poor reliability of this index, I decided to analyze each question using the single dichotomous variables. While none of the four questions used to measure environmental attitudes produced a significant p-value (suggesting no statistical difference in terms of environmental attitudes between the two groups), I decided to conduct the analysis using the generally used question of whether people prefer to change their behavior or to pay a fee to reduce their negative effect on the environment.

All other four indices were more reliable as they resulted in acceptable Cronbach alpha's: 0.768 for the index measuring knowledge about their own electricity consumption; 0.909 for the index measuring the likelihood to participate in recreational activities; and 0.843 for the index measuring how often people are concerned about covering certain common household expenses. The details of each one will be discussed in the next chapter as part of the discussion of the findings.

Chapter V. Findings

In this chapter, I present the main findings of the analysis of the two sources of data collected: electric utility bills and survey responses. The main goal of this research is to determine the effects of the Green Mortgage Program (GMP) on electricity consumption and living conditions of its inhabitants. I explored these effects in four neighborhoods in a city of Northern Mexico: two neighborhoods are part of the GMP and two are used as a comparison group. The four neighborhoods have similar and comparable dwelling characteristics. Additional research questions explored whether households in these two groups presented differences in their knowledge, attitudes and perceptions of electricity consumption and energy efficiency in general; and a subset of questions explored the perceptions over the GMP for the households in this group. During the fieldwork data collection, and through interviews with the construction companies, I found other valuable information that helps compose a more comprehensive case to understand the implementation, behavior and effects of this policy. This information will be discussed at the end of this chapter.

Summary of Findings

The main findings of this research are listed here and described in further detail later on: 1) there is no statistically significant difference between the energy consumption of GMP neighborhoods and that of traditional ones, 2) participation in recreational activities is similar and very low in inhabitants of both GMP and traditional neighborhoods, 3) inhabitants of both types of neighborhoods have an equally extremely low participation in skill-building activities (education and workshops), 4) inhabitants of both types of neighborhoods are practically equal in the type of concerns they have over their own wellbeing, or how often they manifest this concern. Furthermore, and consistently with previous research, inhabitants in both types of neighborhoods do not pay much attention to their own electricity consumption, and the vast majority cannot recall how much they pay or how many kWh they consumed recently. Also, the respondents only have partial knowledge about the energy consumption of common household appliances, mostly of those that they are familiar with.

Overall, all respondents of both groups have low environmental attitudes scores which suggests that participants would be less likely to opt in to participate in this kind of programs, if they had the option. However, households of both groups seem to assign a positive value to only one energy efficiency device: compact fluorescent lighting, which could be explained by their knowledge and familiarity with this specific item. Surprisingly, very few inhabitants of the GMP neighborhood are aware that they live in an energy efficient home. Lastly, when asked if they had the chance to buy a home again, a larger proportion of inhabitants of the control group manifested an interest for energy efficiency devices and a larger proportion of the GMP group preferred a discount in their mortgage payments. These findings are explained in detail in the rest of this chapter.

Electricity consumption. I conducted an independent samples t-test to examine the total electricity consumption in kWh per household in the year 2016, for the GMP neighborhoods and the traditional ones. The main objective of this question is to determine whether the GMP has been effective at reducing electricity consumption. The results show that the GMP group had an average consumption of 4,375.36 kWh (SD=1,907.9), while the control group had an average consumption of 4,503.25 kWh (SD=1,832.8). While the data used in this study shows that households in the GMP group are consuming an average of 128 kWh less than the control group, this difference is not statistically significant $t(186) = .430$, $p = .668$.

These findings align to the results of similar research which describes a discrepancy between the expected and the actual results of energy efficiency programs; that is, a discrepancy between the actual energy usage post-occupancy and the pre-occupancy engineering models and estimates (Chen et al., 2015; Chuang et al., 2018). While the null difference found in the two groups of analysis of this study can be partially caused by the illegality in the occupation of the housing as well as the illegality in their connection to the electric system, the studies mentioned above found similar discrepancies in programs implemented in more developed countries where the issues of corruption and illegal occupation are not as widespread as in the neighborhoods of this case study.

An Approximation to the Measurement of Living Conditions

In order to obtain information that allowed me to analyze a possible difference in living conditions between the two groups, I operationalized living conditions using three categories: recreation habits, investment in skill-building activities, and the householder's perceived concerns about their own capacity to cover the household's basic needs. Below is the analysis of the results in these three categories, and how I interpreted them as probable effects of the GMP on living conditions.

Recreation. I analyzed whether inhabitants of the GMP households were more likely, less likely or equal than the inhabitants of the control group to participate in common regional recreational activities. In order to do this, I created a Likert scale with six items about their likelihood to participate in different recreational activities. With the responses, I created a composite score (sum), and I used an independent samples t-test to compare the total score for both groups. While the households in the GMP group had a slightly lower likelihood to participate in recreational activities (M=13.98, SD = 2.92) than the control group (M=14.59, SD = 2.76), the difference between the two groups is not statistically significant, t(186) = 1.358, *p*=.176. I tested the validity of the index using Cronbach's alpha, which resulted in a score of 0.909**,** which suggests a high level of internal consistency or reliability of this scale. The low participation of households in both groups (less than 10% for GMP and less than 5% for the control group, see Figure 16) is disconcerting, but expected, due to the income level of the sample population.

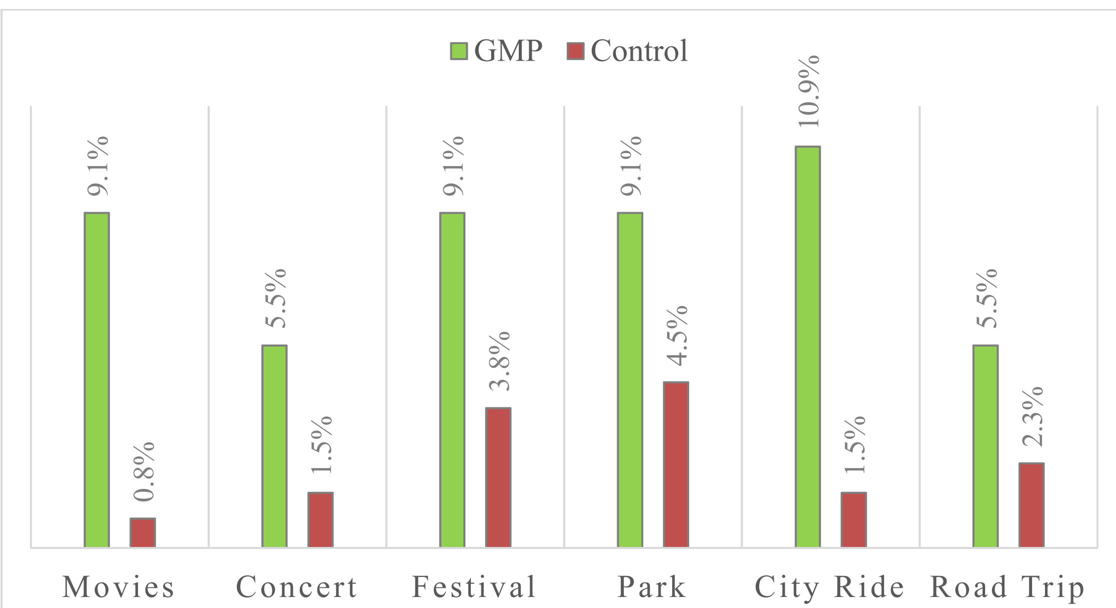


Figure 16. Percentage of households in each group who declared they are more likely to participate in six different recreational activities.

Investment in skill-building activities. I used three questions to compare the likelihood of households to pay for any of three different skill-building activities that have the potential to improve the livelihoods of these households in the short- or long-term. The activities were divided into a) art, dance or sports classes for adults or children in the household; b) skill-building workshops mainly for adults; and c) extra-curricular classes or summer camps for the children of school age.

Table 10 shows that a vast majority of the households in the subsample (95.2%) have not spent money on any of these activities (96.2% of the control group households, and 92.7% of the GMP households). Only one household in the GMP and one in the Control group participated in art, dance or sports classes; only one household in the GMP group participated in a workshop and none in the control group, while more households in the GMP (3.6%) and control group (3.01%) participated in extracurricular education or classes for their children.

Table 10.
Likelihood to invest in skill building and complementary educational activities

	None	Classes	Workshop	Education	Total
GMP	51 (93%)	1	1	2	55
Control	128 (96%)	1	0	4	133
Total	179 (95%)	2	1	6	188

Note: Number in parenthesis represent the percentage.

Pearson's chi-square requires each cell to have an expected frequency of five or more, and the extremely low participation in these activities did not meet this requirement, so I used instead a Fisher exact test to compare the two groups. The results of the analysis suggest that there is no statistically significant difference between groups for any of these activities (p=.501 for classes, p=.293 for workshops and p=1.000 for extracurricular education). Therefore I conclude that the likelihood of investing in these three types of skill-building activities aimed at improving livelihoods is not associated to the type of neighborhood. Figure 17 presents the results for those households who did participate in any of the skill-building activities. While the

GMP households appear to have a slightly higher -but not significantly different- participation in these activities, the magnitude of the participation (4.8% of the population in both groups) is not important in practical terms.

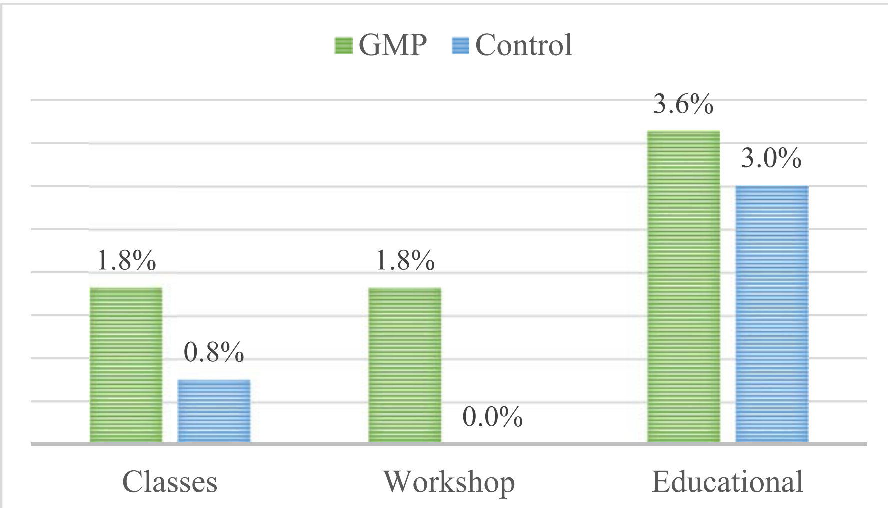


Figure 17. Percentage of inhabitants in each group who declared they have paid for skill building classes or workshops, or afterschool educational programs for their children.
NOTE: The figure does not show the percentages for those who stated that they do not pay for any of these classes.

Concerns about their own wellbeing. The last question in this group referring to the differences in living conditions between GMP and traditional households, asked about the inhabitants' concern over being capable to satisfy some basic needs such as paying for food, transportation, utilities, or being able to pay mortgage, debts, or to save money.

I analyzed how often the inhabitants of the GMP households were concerned over these basic needs in comparison to the inhabitants of the control group. In order to do this, I created a Likert scale with eight items and five answering options ranging from 1=*Worries every day,* to 5=*Never worries about this*. For the analysis, I created a composite score (sum) with all the responses, where a higher value represents better living conditions, or less concerns. I used an independent samples t-test to compare the scores for both groups. The concern mean scores are practically equal for the two groups. The mean for the GMP households is 23.29 (*SD*=6.68) and the mean for the Control group is 23.28 (*SD*=6.24). As expected, an independent samples t-test resulted in a p-value higher than the chosen significance level ($\alpha = 0.05$), suggesting that there is no statistically significant difference between the two groups $t(186) = -.005$, $p=.996$. I tested the validity of the index using Cronbach's alpha, which resulted in a score of 0.843**,** suggesting a high level of internal consistency or reliability of this scale. Figure 18 presents the issues that people identified as '*concerns that they worry about every day*'. The frequencies are similar in both groups.

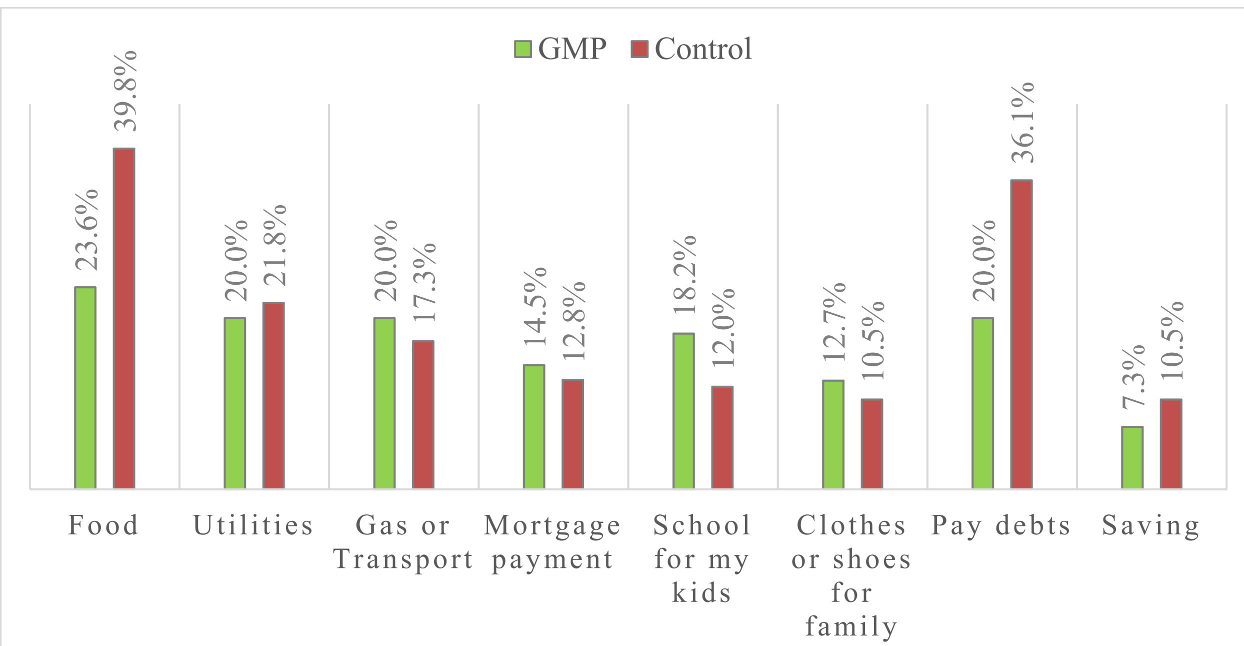


Figure 18. Percentage of respondents who identified what basic needs they worry about most (every day) in both groups.

Knowledge About Electricity Consumption in the Sub-sample Population

I measured knowledge about electricity consumption using two sets of questions: one measures knowledge about their own household's energy consumption, and the other measures knowledge about energy consumption of common household appliances.

Knowledge About their own Electricity Consumption. I examined how much attention people pay to their own electricity consumption with three questions about their most recent utility bill: how much they paid, how many kWh they consumed, and whether they save their bills.

In terms of payment, 164 households provided an answer to this question, and 24 (12.7%) responded that they do not know, do not remember, or do not pay. I used the data of these 164 households to conduct the rest of this analysis. I compared the amount of self-reported payment (in pesos) to the payment listed in the database provided by CFE. I operationalized the comparison as follows: a difference of ± 50 pesos or less is considered a perfect match, and the household would receive a score of 2; a difference between ± 51 and ± 100 pesos is considered a partial match, and the household would receive a score of 1; and a difference of more than ±100 pesos was considered a no match, and the household received a score of zero. These scores were tabulated in a new variable (*PAYmatch*). The correspondence between self-reported data and actual utility bill payment in pesos was extremely low for both groups: The control group has only four cases with a perfect match, and one case with a partial match. The GMP group had one perfect match and three partial matches. A large majority of households obtained a score of zero:

92.2% of respondents in the GMP group and 95.6% respondents in the control group had responses that did not match their actual consumption in pesos.

In a similar way, I compared the amount of self-reported consumption (in kWh) to the actual electricity consumption presented in the database from the electric utility company (CFE). If the two values had a difference between ± 100 kWh, they were considered a perfect match and received a score of 2; if the two values had a difference between ± 300 to ± 500kWh, they were considered a partial match and received a score of 1; and if the two values were different by more than ± 500kWh, they were considered a no match and received a score of zero. These values were tabulated in a new variable (*KWHmatch*). The results show that a vast majority (96.8%) of households in both groups combined pay less attention to their electricity consumption when it is expressed in kWh. From this majority, 67% answered that they do not pay attention to their consumption as expressed in kWh, and 29.8% answered that they do not remember the quantity of kWh in their utility bill. Table 11 summarizes the few respondents who tried to answer these questions, by group.

Table 11.
Knowledge about their own electricity consumption

Consumption in pesos						
Program	Perfect match	Partial match	No match	Subtotal	Don't remember	
GMP	1	3	47 (92%)	51	4	
Control	4	1	108 (96%)	113	20	
Total	5	4	155 (95%)	164	24	
Consumption in kWh						
Program	Perfect match	Partial match	No match	Subtotal	Don't pay attention to kWh	Don't remember
GMP	2	1	2	5	32 (58%)	18 (33%)
Control	0	1	0	1	94 (71%)	38 (29%)
Total	2	2	2	6	126	56

NOTE: Number in parenthesis represents percentage within their group.

The GMP group had two perfect matches, one partial match, and two non-matching responses in their comparison between self-reported and actual electricity bill data in kWh. The Control group had only one partial match.

The third question in this group asked whether people saved their utility bills. A majority of households stated that they did (74.5%). I was later informed that people tend to keep their utility bills along with their payment receipts so they can have proof of payment, in case the company erroneously shuts down their service. This is apparently considered a normal practice. Households who responded that they saved their utility bills obtained a value of one, and those who did not, a value of zero. These values were tabulated into a new variable (*ElecSaveBills).*

After analyzing the results to these responses, I created an index to compare households in the two groups on their knowledge about their own electricity consumption. The index is composed of the three variables: *PAYmatch* and *KWHmatch*, which reflect the correspondence between self-reported and actual data from the utility company; and *ElecSaveBills,* which represents whether households save their utility bills. The sum of these three values is tabulated in the new variable *KNOWown*. The range of possible scores goes from zero to five, zero represents those who have little knowledge about their energy consumption, and five those who have the best possible knowledge. A preliminary analysis of the data shows that the higher score in all households was three, which suggests a low level of knowledge about their own electricity consumption.

I used a Mann-Whitney U test to analyze these scores. The test showed that the GMP group had a higher mean rank in knowledge about their own electricity consumption (104.54) than the control group (90.35), and this difference was statistically significant (U=3105.5, *p*=.047). However, based on the overall results (see Figure 19) and the fact that none of the households achieved a score of four or five points, I conclude that respondents in the sub-sample, in general, were not very knowledgeable about their own electricity consumption.

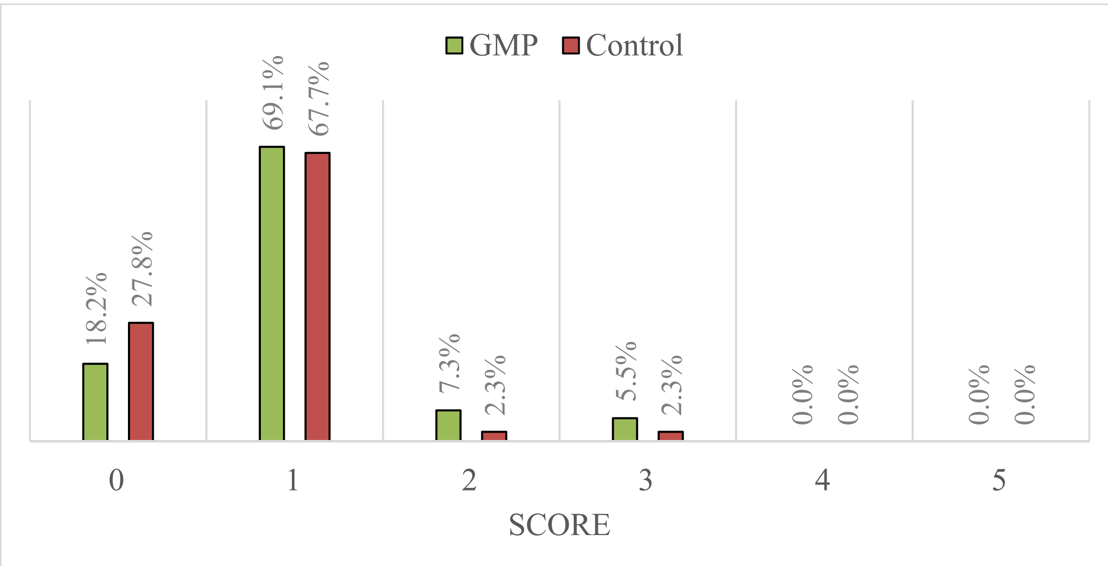


Figure 19. Distribution of scores for knowledge about their own electricity consumption. A higher score of three points represents better knowledge.
NOTE: Percentages represent proportion within their group.

Knowledge about the electricity consumption of commonly known household appliances. To measure knowledge about electricity consumption, I provided rating sale with six common household appliances in random order (clothes washer, television, lighting, air conditioning, refrigerator and computer) and asked participants to rank them from higher to lower electricity consumption. Figure 20 shows the percentage of correct answers by appliance and by group (GMP and Control), which also provide evidence on the disparities in the understanding of how much certain household appliances consume, particularly lighting and clothes washers.

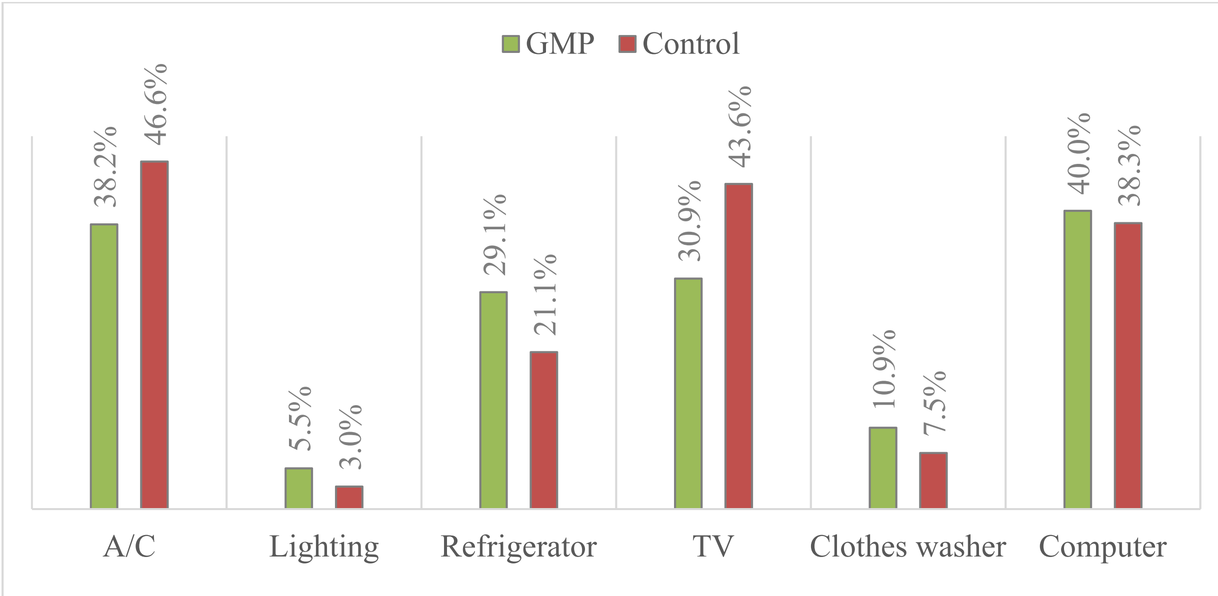
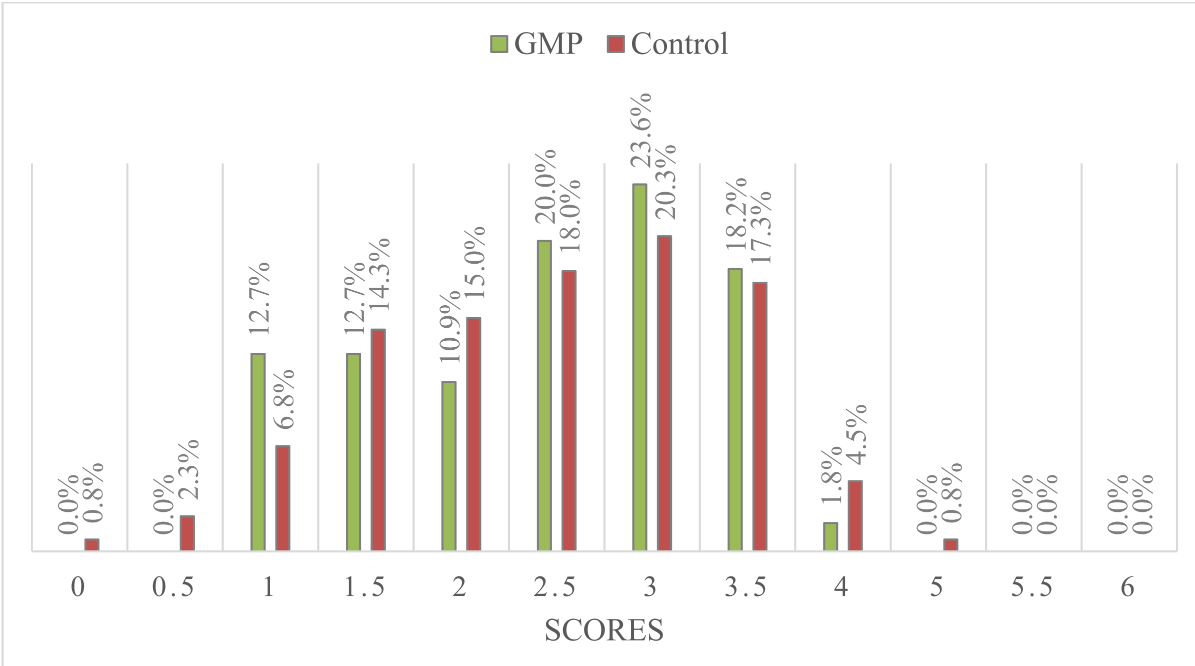


Figure 20. Percentage of households who answered correctly each of the ranking items, by neighborhood.
NOTE: The graph shows the appliances in order of consumption (rank) with highest in the left (Air Conditioning) and lowest on the far right (Computer).

To create an overall score to measure overall knowledge of energy consumption by household appliance, I gave a score of one to the correct answers, 0.5 to answers that missed the correct ranking by ±1 level, and zero to those that missed the correct ranking by more than one level. The sum of these values created an overall score ranging from zero (all rankings wrong) to six (all rankings correct). The majority of respondents for the GMP and control groups (23.6% and 20.3% respectively) had a score of three. The highest score achieved was five (by one household of the control group) and zero percent of respondents in both neighborhoods achieved a score of 5.5 or more correct answers (see figure 21).



GMP Group: *N*=55, Mean 2.45, SD .856.
Control Group: *N*=133, Mean 2.47, SD .920

Figure 21. Scores for the ranking scale on knowledge about electricity consumption of common household appliances. A higher score of six points represents better knowledge.

I conducted an independent samples t-test with a 95% confidence interval (C.I.) for the mean difference in overall scores between the two groups. The analysis resulted in a $t(186) = .158$, $p = .874$. The mean difference between the scores of the two groups is .023 points (houses in the Control group performed slightly better scoring roughly .023 points higher than those in the GMP group). The *p*-value is much higher than the chosen significance level ($\alpha = 0.05$), therefore I cannot reject the null hypothesis which states that there is a difference between the two groups. Also, the confidence interval 95% C.I. [-.262, .308] includes the zero value, therefore I conclude that there is no statistically significant difference between the two groups in knowledge about the electricity consumption of common household appliances, as measured by this ranking scale.

Attitudes towards Energy Efficiency

In Chapter 3, I explain why the use of the standard New Ecological Paradigm (NEP) scale to measure environmental attitudes resulted problematic for this population during the pilot study. I decided to create a simplified scale with only four simple questions that attempt to capture people's perspectives towards the environment and the potential effects of human actions over it. I created three different scales to measure this: firstly, an environmental attitudes scale formed by four questions; secondly, an analysis of the importance that households put on energy efficiency when purchasing household appliances; and thirdly, a scale that attempts to measure the value that people give to the potential benefits of energy efficiency devices. All three components are described below.

Measuring environmental attitudes. I included four questions to explore people's perceptions of the effects that their own behavior and decisions can have over the natural environment. The first question addresses the perception of how their own electricity-related behavior at home can have a negative effect on the environment. The second question captures their perception of effectiveness of current laws by asking if stricter laws could help mitigate the environmental issues. The third question asks whether they would agree to pay an annual fee to protect the natural environment. This question was created without a determined fee or sum of money, because the objective was to explore the idea of attaching a monetary cost to the mitigation of environmental damage, and the willingness to pay for that service. The fourth question asked whether they think it is necessary to change their own behavior in order to reduce environmental impact. They had the option to answer *Yes* or *No* to each of these questions.

The set of four questions could not be used as a scale due to a low Cronbach alpha value of .238, however, the analysis of the individual responses provide an overall understanding people's environmental attitudes. Table 12 shows the distribution of the positive responses by question and by group.

Table 12.
Percentage of households who agreed (responded Yes) to Environmental attitude questions, by group

		GMP	Control
Question 1.	Do you consider that your electricity consumption at home has negative effects on the natural environment?	47.3%	38.3%
Question 2.	Do you agree to the implementation of stricter laws to protect the environment?	94.5%	97.0%
Question 3.	Would you agree to pay an annual fee to help fund the protection of the environment?	34.5%	25.6%
Question 4.	Do you believe it is necessary to change your habits to reduce the negative impact on the environment?	81.8%	71.4%

The high positive responses for Questions 2 and 4, and in a lesser extent of Question 1, suggest the presence of social desirability bias; while question 3 depicts a different level of commitment with the environment once people have to make an economic contribution to protect it. However, a chi-square comparison between the two groups resulted in no statistically significant difference for any of the four questions (p=.328, p=.419, p=.218, p=.147, respectively).

Consideration of energy efficiency when purchasing appliances. As a strategy to explore if people in both groups pay attention at energy efficiency, or at the potential expenses on energy when purchasing small or large household appliances, I used the following two binary questions (respondents only had the option to answer Yes = 1 or No = 0)

Q1. When you buy large household appliances, do you take into consideration its electricity consumption before choosing which one to buy?

Q2. When you buy small household appliances, do you take into consideration its electricity consumption before choosing which one to buy?

The answers show that, when purchasing large appliances, the GMP households pay attention to the energy consumption 29.1% of the time, while the households in the control group only 24.8% of the time. I conducted a chi-square test and found no statistically significant difference between the two groups. $\chi^2(1, n=188) = .370, p=.543$. I obtained similar results for the purchasing of small appliances. The GMP households responded that they pay attention to the energy consumption of small appliances 29% of the time, while the Control households only 24% of the time. I conducted a chi-square test and found no statistically significant difference between the two groups, $\chi^2(1, n=188) = .518, p=.472$.

Overall, roughly only one third of the households in the subsample (both groups) pays attention to electricity consumption or efficiency when buying small or large appliances, with no statistically significant different between the two groups.

Value assigned to energy efficiency. As a way to measuring if households assigned a positive value to energy efficiency or to the potential savings facilitated by energy efficiency devices (EEDs), I asked what they did in the case that one EED had stopped working in their home. A preliminary question was whether any EED had stopped working. From the total households in both groups of the sub-sample (n=188), only 64 reported malfunctions with their energy efficiency devices. For the majority of households in the control group (74%) all energy efficiency devices were still working, and only 24% reported problems with their lighting (CFLs). In the GMP group, 47% of respondents have not had any device stopped working, while the same proportion (47%) expressed problems with their lighting (CFLs). In both groups, a very small percentage (2% and 5% for the control and GMP groups respectively) reported problems with other appliances such as air conditioning systems and refrigerators, which were not part of the GMP original EED package and were left out of the analysis. For the question about what they did about the appliances or devices that stopped working, I assigned a value of zero for actions that represented no interest in the efficiency benefits of the appliance, and a value of one for actions that represented some interest in benefiting from these devices. Below are the five possible answers to this questions and their values:

a) I changed it for a similar one (efficient), new or used (Value = 1)
b) I changed it for a non-efficient one, new or used (Value = 0)
c) I had it repaired (Value = 1)
d) I didn't do anything, I just stopped using it (Value = 0)
e) No device has stopped working (No value assigned and excluded from the analysis)

I added the frequencies for the two positive (energy efficient) actions, and the frequencies of the two negative (non-energy efficient) actions to construct a binary variable for '*value*'. I conducted a chi-square test and found no statistically significant difference between the two groups. $\chi^2(1, n=64) = .021, p = .885$.

The contingency table below (Table 13) shows the results of this comparison. Households in both groups assigned relatively high value to the use of energy efficiency devices, with 74% and 76% of households respectively deciding to change the non-working appliance with a similar one, or have it fixed.

Table 13.
Value assigned to Energy Efficiency Devices (EEDs)

Program	Valuable	Indifferent	Total
GMP	22	7	29
	75.9%	24.1%	100%
Control	26	9	35
	74.3%	25.7%	100%
Total	48	16	64
	75.0%	25.0%	100%

Considering that the previous two questions in this set show a low environmental awareness and also a low level of attention for energy efficiency when purchasing appliances, one possible explanation of this high level of value assigned to EEDs may be a result of the familiarity with the devices. In other words, I assume people replace a broken appliance with a similar one because they are familiar with that type of appliance, and to avoid the steps required to change to a different one. In this case, CFLs represent 90% of the appliances that were replaced. Since incandescent lightbulbs have been banned in Mexico and LED lightbulbs are three to four times more expensive than CFLs, it seems common sense to replace a nonworking CFL with a new CFL.

An Exploration of Perceptions toward Energy Efficiency and the GMP

Perceptions about their household's energy consumption. In order to understand how dwellers of both groups place themselves in terms of energy consumption in comparison with other dwellings and other neighborhoods, I used four questions where households used their own consumption as a benchmark for comparison. The question asked whether they considered that their house used *more energy* (value = 3), the *same* (value = 2) or *less energy* (value = 1) in comparison with a) houses in the same neighborhood; b) houses in a different neighborhood; c) newer houses; and d) older houses. Then I conducted independent analysis of the responses, comparing those of the GMP group with the control group. Table 14 shows the distribution of the answers for each question.

Table 14.
Perception about their house's electricity consumption

		Uses more	Uses the same	Uses less
In comparison to other houses in their neighborhood	Control	22.9%	64.4%	12.7%
	GMP	18.4%	51.0%	30.6%
In comparison to other houses in other neighborhood	Control	20.3%	61.9%	15.3%
	GMP	18.4%	63.3%	22.4%
In comparison to newer dwellings (in the city)	Control	16.9%	58.5%	22.0%
	GMP	16.3%	36.7%	32.7%
In comparison to older dwellings (in the city)	Control	16.1%	59.3%	19.5%
	GMP	20.4%	30.6%	32.7%

NOTE: Percentages are calculated within their own group (control or GMP)

About half of inhabitants of GMP households (51%) see themselves as consuming the same amount of energy than houses in their own neighborhood, compared to 64.4% of traditional houses. However, more households of the GMP group (30.6%) perceive they use less energy than houses of the same neighborhood, while about 23% of households in the control group perceive they use more. In comparison to houses in other neighborhoods, more than half households in both groups (63.3% in the GMP and 62% in the control group) perceive their consumption to be about the same.

Their opinions vary when they compare their consumption to older or newer houses. Around one third of GMP dwellers see themselves consuming the same or less (36.7% or 32.7% respectively) than newer houses in the city; and consuming the same or less (30.6% and 32.7% respectively) than older houses in the city. The respondents of the control group also perceive themselves to use about the same or less electricity than both newer and older dwellings in the city. By comparing them statistically using independent chi-square tests for each question, I found a statistically significant difference between the two groups in two cases: when compared to houses within their own neighborhood, slightly more inhabitants of the control group perceive themselves using more energy than their neighbors, and more GMP inhabitants perceive themselves using less energy than their neighbors, $\chi^2(2, n=167) = 7.529, p = .023$. Considering that houses within neighborhoods are supposedly similar, these perceptions are separated from what would be expected: a perception of similar consumption. When compared to older houses in the city, more inhabitants of the GMP group perceive themselves using less energy than older houses, while the inhabitants of the control group are more balanced in their perception, $\chi^2(2, n=153) = 8.526, p = .014$.

Perceptions about energy efficiency devices. I explored the perceptions about the energy consumption of common household appliances which are also listed as the highest consumers of electricity in Mexican households, namely air conditioning systems, lighting and refrigerators (CONUEE, 2009). I used Likert-type questions with five possible responses ranging from 1 (*Uses much less),* to 5 (*Uses much more).* Respondents were also given the choice to answer "*Do not know*".

Little is known about the perceptions or relevance that low-income households attach to energy efficiency devices. Previous research argues that due to lack of information, people may not have a positive perception of these devices, could consider them useless, or can also perceive that certain appliances use more when in fact, are more efficient (Steg, 2008). Table 15 presents the results of their perceptions over lighting devices.

Table 15.
Perception about the electricity consumption of common household appliances (lighting)

		Much less	Less	The same	More	Much more	I don't know
CFLs	Control	6.0%	56.4%	30.1%	4.5%	0.8%	2.3%
	GMP	18.2%	41.8%	20.0%	12.7%	1.8%	5.5%
LEDs	Control	0.0%	3.8%	20.3%	18.8%	4.5%	52.6%
	GMP	0.0%	9.1%	23.6%	14.5%	7.3%	45.5%

NOTE: Dark grey denotes the majority of first choice responses, Light gray denotes the second choice, and the box demarcates the correct response for each question.

Overall, inhabitants of both groups have a relatively well-grounded perception over the consumption of CFLs, which compared to the traditional incandescent bulb use less electricity, but slightly more than LEDs. This understanding may be caused by recent changes in Mexican legislation banning incandescent lightbulbs at the national level, and also several programs intended at exchanging or providing CFLs free of cost. Both initiatives increased the publicity and information about the electricity consumption of CFLs, particularly its efficiency in comparison to regular incandescent lightbulbs. In contrast, the overwhelming lack of understanding of the electricity consumption of LED lightbulbs (45.5% and 52.6% of respondents in the GMP and control groups respectively responded '*I don't know*'), raises concerns about the information that these households have received, particularly those belonging to the GMP, where the initial pack of eco-technologies includes a mix of LED and CFL lightbulbs.

Similarly, the responses for the perceived use of electricity of three commonly used air conditioning systems in the region denotes a lack of understanding of the energy demand of each of these systems (see Table 16). This lack of knowledge can be partially explained by the overall low presence of central and window A/C units as depicted in Figure 8. Mini-split systems are more commonly found in the two groups surveyed, but even so, most respondents in the Control group (30.7%) thought it uses more than the other two choices, or about the same (29.3%); while the majority of the GMP group perceives that these units use about the same amount of electricity (30.9%) or more (27.3%).

Table 16.
Perception about the electricity consumption of common household appliances (A/C)

		Much less	Less	The same	More	Much more	I don't know
A/C Central	Control	0.0%	0.8%	27.1%	20.3%	24.1%	27.8%
	GMP	1.8%	3.6%	16.4%	34.5%	12.7%	30.9%
A/C Window	Control	0.8%	3.0%	27.1%	27.8%	18.0%	23.3%
	GMP	3.6%	5.5%	18.2%	25.5%	16.4%	30.9%
A/C Mini-split	Control	2.3%	3.8%	29.3%	30.8%	23.3%	10.5%
	GMP	10.9%	5.5%	30.9%	27.3%	10.9%	14.5%

NOTE: Dark grey denotes the majority of first choice responses, Light gray denotes de second choice, and the box demarcates the correct response for each question.

Finally, in the comparison between newer and older refrigerators (10 or more years of usage), most respondents in both groups (63.2% in the control group and 61.8% in the GMP group) thought new refrigerators use about the same or more electricity than an older one, when in general, new refrigerators are more efficient, therefore use less electricity (see Table 17).

Table 17.
Perception about the electricity consumption of common household appliances (Refrigerators)

		Much less	Less	The same	More	Much more	I don't know
Refrigerator (new)	Control	3.0%	4.5%	37.6%	25.6%	16.5%	12.8%
	GMP	0.0%	14.5%	29.1%	32.7%	14.5%	9.1%
Refrigerator (used)	Control	0.0%	3.8%	32.3%	35.3%	17.3%	11.3%
	GMP	5.5%	1.8%	25.5%	36.4%	16.4%	14.5%

NOTE: Dark grey denotes the majority of first choice responses, Light gray denotes de second choice, and the box demarcates the correct response for each question.

These results show a lack of understanding of the electricity consumption of common household appliances, regardless of the group the respondents belong to. Furthermore, the high incidence of answering “the same” for the three appliances explored, can also be due to central tendency bias (a potential tendency to rate electricity consumption the same, or average, due to lack of understanding the question of not having the certainty in their responses).

Knowledge about the Green Mortgage Program (GMP*).* This set of questions was only included in the questionnaire for GMP inhabitants. I measured knowledge about the GMP using four questions. The first question asked whether the interviewee had ever heard about the GMP, and if the answer was positive, he/she was required to describe the Program. The next question asked whether their house was part of the GMP, and if the answer was positive, the respondent was required to explain how they were informed about this.

The sub-sample used for this analysis (n=188) only includes 55 GMP dwellers. Out of this sample, 47 (85.5%) responded they did not know what the GMP was, and only 8 (14.5%) responded that they knew about the GMP. However, when asked if they could describe it, three persons responded that they "did not know what it was, they had only heard about it", while the other four responded that the house "was saving water or electricity", and one person called it "ecologic". So overall, only four persons out of 55 had a relatively certain idea of what the program was about, even though their houses belong to the GMP. Furthermore, when asked if they knew if their house was part of the GMP, five respondents (9.1%) responded yes, two responded no (3.6%), and the vast majority (87.3%) responded they did not know. The five respondents who knew that their house was part of the program responded that they were informed at the time of purchase or delivery of the house, by INFONAVIT, by the construction company, or it was stated in their contract.

The lack of information among GMP dwellers is an issue of concern. While information by itself is not sufficient to promote change, it is one of the most basic components of any effort to motivate behavioral change. Providing information leads to knowledge acquisition and then to attitude change (Jones, 1996). According to INFONAVIT and to private developers, homebuyers are informed about the program and its functioning at the time of purchase. The answers to this question in this group suggest that this important component in the implementation of the Program is failing.

Furthermore, there is also lack of information of who is paying for the energy efficiency devices. When asked this question, the inhabitants of the GMP neighborhood had varying responses: 25 responded that INFONAVIT or FOVISSSTE[16] had paid for them, 10 responded that the construction company paid for them, one said the city, one said the federal government, and one responded "other"; while 17 responded that they did not know. None responded that the cost of the energy efficiency devices was, in fact, included in their mortgage payments. With no acknowledgement that they are paying for these energy efficiency devices and that are potentially benefitting their households, there is little interest in some households to use them appropriately.

Opinion about the Green Mortgage Program (GMP). I asked GMP dwellers (*n*=55) their overall perception about the GMP using a multiple-choice question with the following possible responses: 1: *It is very good and should be continued*; 2: *It is good but not necessary, people already figure out ways to reduce their consumption*; 3: *I do not have an opinion about the GMP*; 4: *It is an unnecessary expense*; 5: *It is bad, it does not work*; and 6: *Do not know / Did not answer.* Figure 22 tabulates the results of this question: almost half of the interviewed (27) expressed no opinion about the program, 21 said it was a "very good program and should continue" (40%). Two respondents (3.6%) expressed that the program is good, but not really

[16] FOVISSSTE (Fondo de la Vivienda del Instituto de Seguridad y Servicios Sociales de los Trabajadores del Estado) is the other major mortgage lender in Mexico, but it is only available for workers of the public sector.

necessary as 'people already find a way to save'. Two responded that the program is unnecessary and two others responded that the program is bad and does not work (3.6% each).

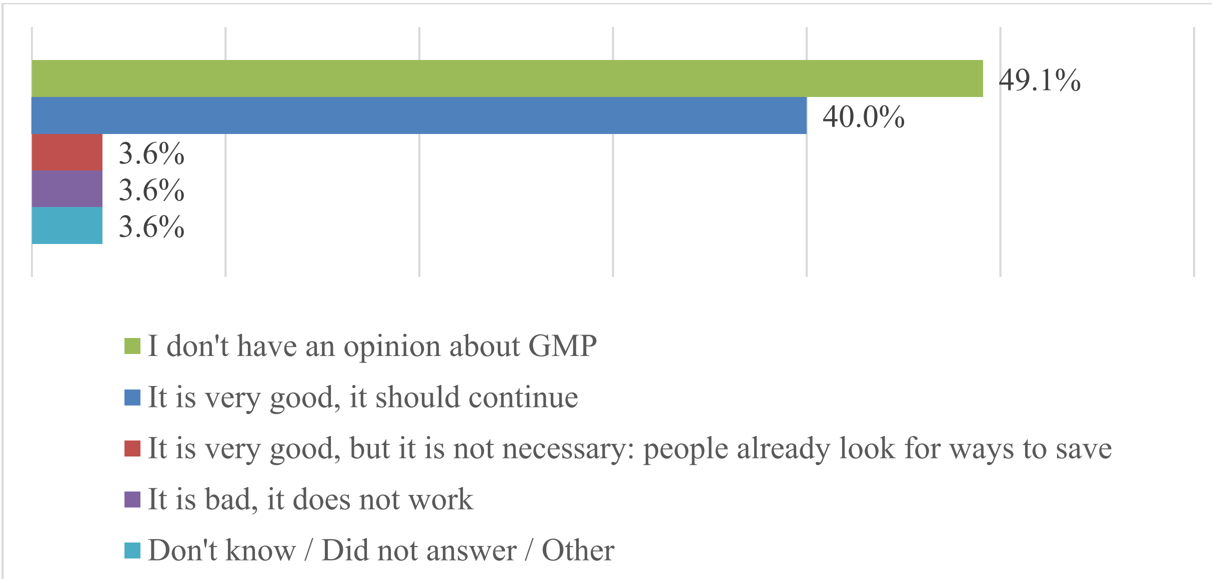


Figure 22. General opinion about the GMP among GMP dwellers (*n=55*)

Considering that out of the 55 GMP households, only 5 responded that they knew they were part of the GMP (2 responded that they did not belong, and the rest that they did not know), the probability of obtaining the most positive statement about the GMP (*It is very good, it should continue*), was most likely caused by social desirability bias. In order to address this issue, I included one set of exploratory questions regarding the perceived value that people assign to energy efficiency in general, and to the potential reductions in energy consumption that the efficiency devices could facilitate in their dwelling. In these follow-up questions, I asked them to think about the possibility to go back to the time when they were considering buying a new house, and think if they would consider buying an energy efficient home or not. The respondents in the control group seemed more likely to opt for an energy efficient home (63.2%) versus those of the GMP group (47.3%) (see Figure 23). However, a chi-square test found no statistically significant difference between the choices of the two groups. $\chi^2(2, n=188) = 4.292$, $p = .117$. It is also noteworthy the apparent indifference of GMP dwellers towards buying an energy efficient home (again, in their case). Almost 40% responded that they did not know if they would make that choice.

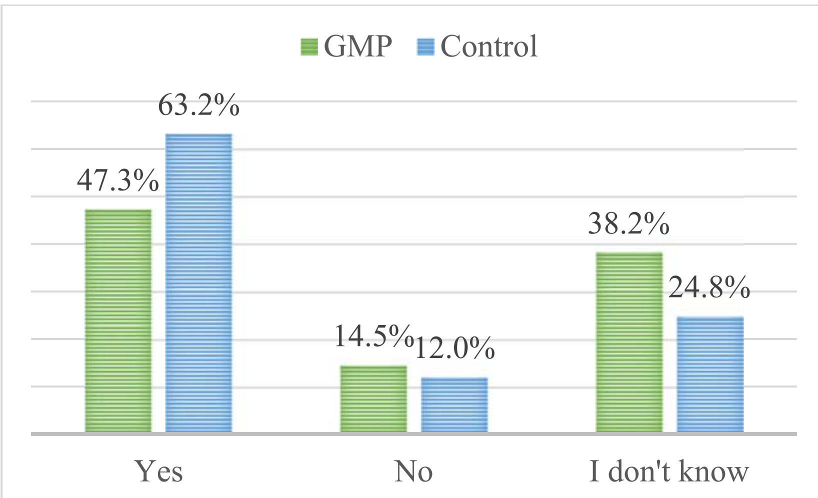


Figure 23. Percentage of respondents who would buy an energy efficient home if they were given the option to go back in time.

To further corroborate these responses, and explore social desirability and acquiescence biases, I asked them a second follow-up question: if when they were buying their home for the first time, they would have had the opportunity to choose, would they have preferred a) the energy efficiency devices (such as a house within the GMP), b) a discount in their mortgage payments or c) the equivalent amount of money? See figure 24 for the tabulated results. The first option for most GMP dwellers (43.6%) was a discount in their mortgage payment, followed by the equivalent amount in cash (25.5%), and lastly the energy efficiency devices (23.6%). For the control group, most respondents opted for the energy efficiency devices (45.1%), followed by a reduction in their mortgage payment (31.6%), and the cash equivalent (23.3%). A chi-square test found a statistically significant difference between the choices of the two groups. $\chi^2(2, n=184) = 6.299$, $p = .043$.

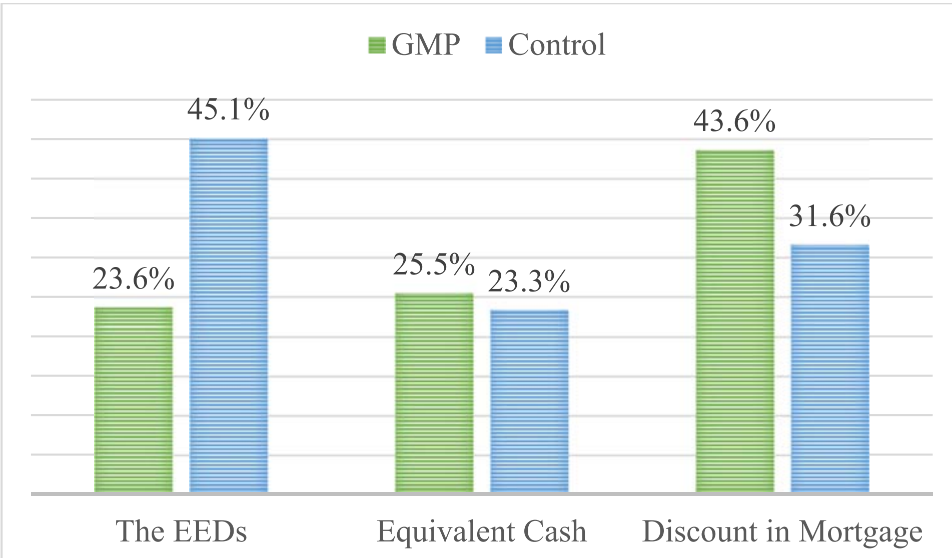


Figure 24. Stated preferences for three different options to buying an energy efficient home (*n=184*)

Chapter VI. Discussion and Conclusion

The objective of this dissertation is to evaluate the effects of the Green Mortgage Program (GMP) on electricity consumption at the household level, and the living conditions of its inhabitants. To do this, I analyzed electricity consumption at the household level, measured by electric utility bills, and applied an original survey to a sample of inhabitants of two neighborhoods belonging to the Green Mortgage Program (GMP) and two *traditional* neighborhoods, in a medium size city in the North of Mexico. The results of this analysis show no statistically significant difference in either electricity consumption or living conditions, between the neighborhoods of both groups.

In the comparison of household electricity consumption between neighborhoods, I find no statistically significant difference between neighborhoods, suggesting that the GMP is not delivering the expected results. The analysis of survey responses show no statistically significant difference between the living conditions of both groups, demonstrating that the GMP has had no effect on the living conditions of its inhabitants.

The results also show that knowledge on electricity consumption remains very low in all the households studied, and without a statistically significant difference between the GMP and control groups. Similarly, perceptions and attitudes toward the environment in general, and toward energy efficiency in particular, range from indifferent to negative in both groups. These results provide evidence to conclude that the GMP has not become an instrument of cultural change nor a relevant factor in the promotion of environmental awareness, as stated by INFONAVIT (WHA, 2012). Far from these objectives, its inhabitants remain unaware not only of their possibility to reduce energy consumption and transform their lifestyles into more sustainable ones, but of the existence of the program itself. I found that the vast majority (87%) of inhabitants of the GMP neighborhood are unaware that they live in an energy efficient home, or that their house belongs to the GMP. Consequently, they have no knowledge about the functioning or implications of the GMP nor about the energy efficiency devices and their potential benefits.

Furthermore, almost half of the inhabitants of the GMP stated that they would prefer a reduction in their mortgage payments, while the other half was almost equally divided between receiving the equivalent cash amount or the energy efficiency devices. These results merit questioning the mandatory character of the program, its targeting and its poor implementation. While the mandatory character of the GMP has guaranteed its rapid expansion and coverage, it has not guaranteed its effectiveness at reducing energy consumption, at least not at the levels expected by the Institute as corroborated by the results of this study.

In terms of targeting, the GMP targets the sector of society with the lowest electricity consumption rates and the lowest income levels, while at the same time imposes the burden of a price premium -estimated of around 4% to 10% of the value of the house- for an energy efficient home that does not reduce energy consumption or utility payments. If a well targeted policy affects the behavior of agents that significantly contribute to a given problem (Allcott et al., 2014, p. 76), I conclude that the GMP is not properly targeted.

Through the analysis of this information and with additional information collected during the field work, I also find that the implementation of the GMP failed at two important steps: a) the provision of information and b) the provision of training efforts by INFONAVIT and by the construction companies for both their sales personnel and for homebuyers at the time of purchase. All representatives of the construction companies interviewed considered that the GMP is an additional bureaucratic step, and none defined it as a positive initiative towards improving the environmental performance nor qualitative characteristics of these dwellings.

Considering these three aspects, the GMP needs a considerable review and transformation so it can deliver the expected results, or it must become optional, giving homebuyers the option to buy into the program if they decide to do so. Lastly, INFONAVIT and housing developers must improve the communication and training so that homebuyers can obtain optimal levels of efficiency and optimal benefits from their investment.

Another important and feasible area of improvement for the GMP is the incorporation of monitoring systems that can facilitate a robust evaluation of its performance. The difficult access to reliable data on electricity, water and gas consumption is a significant barrier for the monitoring, measuring and evaluation of the program. These and other policy recommendations are presented later in this Chapter.

Theoretical contributions of the results and research recommendations

The central contribution of this project to the existing literature is providing solid evidence of the multiple ways in which this kind of program fails to achieve its expected results, and the challenges of implementing something like a GMP in Mexico entail. Based on this, I recommend to expand of the focus of analysis for research in energy efficiency policy, to a broader consideration of additional benefits, as outlined in the multiple benefits framework.

This dissertation also provides new knowledge about the perceptions and attitudes toward energy consumption among low-income households in Mexico, a knowledge that could be contrasted to other communities and countries of the developing world. I also include recommendations for the analysis of the contributions of low-income households of developing countries at addressing climate change through smaller, cumulative effects facilitated by their large presence.

These topics are timely and relevant, particularly because energy efficiency is one of the preferred options to address the challenges of climate change. The results of this dissertation can inform the development of strategies for mitigation and adaptation to climate change in urban areas of the developing world.

Energy efficiency policy and a multiple benefits approach. The advancement of research on energy efficiency policy is relevant for two main reasons: energy efficiency has been used as one of the main strategies to mitigate the effects of climate change in urban areas; and because it has been generally created in and by developed countries, where technological solutions may have a higher probability to deliver successful outcomes, facilitated by a reliable regulatory context, sociocultural characteristics and sound markets. As researchers have suggested before (Romero Lankao, 2008), the global south cannot be understood with the same tools and from the same perspectives that we analyze and understand the global north. Research in the global north tends to be overtly focused on quantitative analysis, while data in the global south, when and if available, can present many limitations and can leave outside of the analysis many other factors that directly affect the issue at study and consequently its results. In this dissertation, a mere quantitative analysis of electricity consumption would have left out important considerations such as the informalities found in housing occupation and electricity usage.

I recommend further analysis and usage of the framework of multiple benefits approach, because it aligns with a pro-poor perspective for the development of adaptation and mitigation plans to address the challenge of climate change. As Hardoy and Romero-Lankao (2011) have suggested, the inclusion of development initiatives parallel to adaptation and mitigation efforts makes the most sense firstly, because a significant proportion of the region's population remains very poor; and secondly, because the risks of climate change fall disproportionately on low-income groups who have greater vulnerability and less adaptive capacity to cope (Hardoy and Romero-Lankao, 2011). In general, the low-income sector is not a high consumer of energy, therefore an energy reduction policy shall address other necessary considerations. While the framework of a multiple benefits approach is still evolving, it presents researchers with a structure to incorporate other effects beyond energy usage, particularly improvements in living conditions such as health, poverty alleviation, comfort, safety and security, all of which are relevant in the developing world.

Additionally, the developing world has already examples where climate change related issues have been included in existing policies, but have been reframed to highlight other perceived priorities. In the case of large Latin American cities, problems of air pollution, public health and poverty alleviation have traditionally been assigned a higher priority. For example, Mexico City developed a refined framing of the carbon domain and its relationship to air quality. By targeting a local concern such as air quality, authorities *localized* climate change by relating it to an existing local agenda (Romero-Lankao, 2007). Furthermore, pro-development and pro-poor policies can have a considerable influence on reducing emissions and increasing adaptive capacity[17] (Romero-Lankao and Dodman, 2011). In the context of developing countries where resources are limited and needs are multiple, the multiple benefits framework is a more appropriate tool to guide the creation of policies that address the underlying causes of vulnerability, by potentially providing solutions that address more than one problem at a time.

Knowledge about the perceptions and attitudes toward energy consumption among low-income households. This dissertation also contributes to the scant literature on the understanding, awareness, perceptions and attitudes toward electricity consumption in low-income households in Mexico. While other environmental issues such as perceptions over climate change (Zamora Saenz, 2018) or pro-sustainability actions at home (Arizpe Islas & Cervantes Vega, 2016) have been partially explored, research and information on people's understanding of electricity consumption at home, and specifically in low-income households, is practically non-existent. This dissertation provides a first review, albeit limited, on this issue.

I recommend to continue this analysis with a survey specifically designed to study knowledge, perceptions and attitudes toward the environment, and toward energy consumption. One way to accomplish this would be to conduct a national level survey, or the inclusion of relevant questions in the national census or any of the additional surveys conducted by INEGI.

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[17] Adaptive capacity "is the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." (IPCC, 2007).

Participation of the low-income sector and smaller urban areas in addressing climate change. This dissertation also contributes to the scarce literature on the analysis and effects of the participation of the low-income sector, and in this particular case study, of a smaller urban area, on energy efficiency policies and programs aimed at addressing the challenges of climate change in developing countries. Research on strategies for adaptation and mitigation to climate change in the global south are generally scarce, while most of the existing literature builds on examples applied to the developed world (Romero-Lankao, 2007; Sánchez-Rodríguez, 2009; Hardoy & Pandiella, 2009). Scientific data and predictions confirm that even if strict mitigation strategies were implemented today, the effects of a changing climate are inevitable, and these effects are expected to be more severe in developing countries. This type of analysis is relevant and necessary to urban planners of developing countries, who currently face the urgency of addressing these challenges. However, governments and urban planners of developing countries also deal with other pressing issues, such as providing new and maintaining existing infrastructure and services (Dodman & Satterthwaite, 2009; Hardoy & Romero-Lankao, 2011). They also face many limitations in the availability of economic resources, knowledge, technology and planning tools.

While Mexico's national emissions in 2015 represent only 1.4% of global emissions, and has relatively low net per capita emissions of about 5.9tCO_2e (Climate Watch, 2018), Mexico is currently listed as the tenth country with most emissions at a global scale. Its participation at mitigating the negative effects of climate change cannot be dismissed. Most of Mexico's GHG emissions are produced by transportation (26.2%) and electricity generation (19%), which are partially related to the location and maintenance of urban housing. While household-generated GHG are not the main source of its emissions, the GMP represents a worthy case study to understand in greater detail some of the challenges that developing countries face at implementing a national-level policy of this type.

The study of the GMP also provides an argument to support the consideration of the low-income sector as an active participant in climate change mitigation strategies. Until now, research on low-income dwellers of developing countries has mostly focused on how to address the negative consequences of climate change on them, and little attention has been given to the potential role that this sector has in addressing climate change. Nevertheless, the fact that low-income city dwellers comprise the majority of urban inhabitants in the developing world, suggests that it has a potential to contribute via cumulative effects. Therefore, low-cost, simple, and incremental solutions such as the GMP can be an appropriate way to partially address these challenges.

In the same way that the low-income sector has been practically invisible as an active participant in climate change mitigation, smaller urban areas are rarely the focus of academic and international research. This is an important and detrimental exclusion in research efforts, as it is estimated that places with fewer than 500,000 people will account for 45 percent of the expected increase in the world urban population (Romero-Lankao and Dodman, 2011). However, smaller cities in developing countries are often institutionally weak and lack the economic, technical and other resources that large urban areas have (Romero-Lankao and Gnatz, 2013). Because most of the development in these areas has yet to occur, smaller cities embody opportunities for strategic planning oriented towards sustainable development that would allow them to reduce vulnerability and risk, and to enhance their adaptive capacity to confront climate change. A strategic decentralization of economic and technical resources will be necessary to attain this goal.

Implementation. The role of effective implementation, as part of governance practices, is one of the greatest challenges for developing countries. Ensuring that adaptation assessment and planning move on to the implementation of concrete actions is key for the success of these strategies, but it is also a difficult process (Mata & Nobre, 2006; Hardoy & Pandiella, 2009). Ineffective implementation of climate change strategies is commonly linked to a lack of understanding of possible local impacts, lack of resources and institutional capacities, lack of national policies that address climate change, and lack of training and access to information at different scales (Hardoy & Pandiella, 2009). However, the presence of large and centrally controlled state-owned industries (such as oil and electricity in Mexico) or institutions (such as INFONAVIT) could represent an opportunity to overcome these barriers and facilitate the implementation and monitoring of large-scale initiatives which can have quick and significant effects at the national level, such as the Green Mortgage Program. In this study, I found that the implementation of the GMP has been weak at different levels, but most importantly at communicating between different scales and different stakeholders. I also found a lack of commitment to the goals of the GMP. In a telephone interview with a former INFONAVIT employee, he asserted that the Institute was never interested in measuring the program's outcomes, as the probable reductions in GHG were 'not expected to be significant at the national level, or at least not significant for a potential incorporation of the GMP in future carbon markets' (personal communication, November 2016). The majority of private developers deprecate the program and perceive it more as a cumbersome step and unnecessary procedure that they have to surpass in order to continue producing housing for INFONAVIT. Former members of Enervalia's evaluation staff who visited GMP dwellings stated their concern over the substandard conditions of the GMP dwellings, and they found that some of the energy efficiency devices were never installed by the construction companies. In other cases, the devices were not correctly installed, so inhabitants would complain about their functioning, and in the worse cases, the inhabitants had already sold them in the black market and purchased non-efficient appliances. Misinformation about the program goals and benefits especially at the implementation levels could be a significant cause for the GMP failure to achieve its expected results.

Policy Recommendations

The findings of this research support five important policy recommendations for the improvement of the GMP:

1. Communication. Increase and improve the communication of program goals and functioning at all levels. INFONAVIT must improve its communication within *delegaciones* (State representatives), and with local government officials as well as private housing developers.

2. Monitoring. INFONAVIT must incorporate monitoring systems that can facilitate a robust and continuous evaluation of the GMP performance. The current conditions of data availability in Mexico make this an important and necessary step toward a reliable monitoring system that can improve the monitoring, measuring and evaluation of the program.

3. Information and education. INFONAVIT, as well as other governmental entities, must create educational programs to increase knowledge of electricity consumption of common

household appliances, with particular attention to those included in the GMP. While existing research is still inconclusive on how well information is disseminated, understood and most importantly, how information can motivate behavioral change, information is still a basic building block for the creation of an educational program. Environmental knowledge and awareness is significantly associated with pro-environmental behavior, this analysis shows an opportunity for public education and social marketing campaigns to increase the quantity and accuracy of the information people have in regards to energy efficiency appliances. An increment in people's knowledge and awareness has the potential to promote greater demand and acceptance of energy efficiency appliances that could facilitate reductions in energy consumption as well as GHG emissions.

4. Focus on higher-energy demanding households. Urban planners and policy makers who seek to reduce energy demand by encouraging usage of energy efficiency devices, as well as changes in behavior (such as turning off lights or adjusting air conditioning thermostats), will have a larger impact if they target information and strategies to activate energy reduction behaviors at the majority of people who are determined to save on energy costs and who value protection of the natural environment.

5. Incorporate choice in the participation of the Green Mortgage Program. The analysis of the response to open ended questions regarding opinions toward the GMP provide evidence that demonstrates that GMP inhabitants are not familiar with the Program, or with its potential benefits, therefore prefer other options instead. Households may have other priorities and may not perceive expenses in utility bills as significant in their household budgets. On the other hand, a large proportion of non-GMP households are supportive of energy efficiency devices, even when they do not have information about their functioning or benefits. Supporting policies that allow environmentally conscious or cost-reduction driven households to access energy efficiency products could help expand the energy demand reduction goals of the country.

Apart from these recommendations, which are specific to the GMP and that are guided by the results of this research, Mexico has other issues in terms of policy generation and implementation, which are pertinent to address

Caution for policy transfer. Policy transfer is defined as the process in which knowledge about policies, administrative arrangements, institutions and ideas in one political setting (past or present) is used in the development of policies, administrative arrangements, institutions and ideas in another political setting (Dolowitz & Marsh, 2000). This case study presents evidence against the practice of simplistic policy transfers, in this case from developed to developing countries. To this date, there is not a generally accepted, transferable framework for the design, development, implementation and evaluation of adaptation strategies. The complexity of these issues requires professional, context-based, and flexible enough solutions that can facilitate expected effects but also incorporate change as stresses fluctuate. I emphasize that adaptation and mitigation strategies require a high level of contextualization, and that a direct transfer of these emerging concepts without taking into account the particular characteristics of such a different context would be an erroneous strategy. As a matter of fact, a simplistic transference of adaptation strategies is probably unfeasible within countries of the developed world.

Substandard housing, with or without energy efficiency devices. While initiatives like the GMP are necessary to improve the quality and energy efficiency of new buildings in Mexico, and to advance the country's commitment and participation in addressing the global challenges of climate change, it is also important to bring attention to the vast amount of existing substandard housing, which in 2006 was estimated to represent 16% of the population (World Bank, 2006). If the basic structural quality of housing is not satisfied, the implementation of programs such as the GMP will continue to fail, or have limited effects on the living conditions of their inhabitants. There are many guarantees that could involve the commitment of private developers and public institutions to provide better quality housing, and to address the vast amount of existing substandard housing which was formally or informally created decades ago.

***The urgent need to address the informal sector*.** As important as addressing the quality of housing, it is also urgent to generate viable housing solutions for the large percentage of the population still not served by formal sector institutions. In 2015, the informal sector represented 46% of the work force in urban areas, and according to the latest Technical Note on Housing Finance for Mexico (prepared by the World Bank and IMF), self-construction and self-production of housing remain the main sources of affordable housing supply for this sector (Garcia Mora & Shabsigh, 2016).

Limitations of the study

This is a study with many limitations, mainly of scale and data access. Despite its exponential growth, the GMP is relatively new and small compared with existing non-GMP neighborhoods. The number of GMP neighborhoods is not enough yet to conduct a city-, state- or national-level analysis of changes in residential electricity consumption trends caused by the Program, or to be compared to the totality of traditional households. Access to data is also a limitation of this study. While electricity consumption data are recorded by the main utility company (CFE), data in Mexico are generally not easily accessible. The formal requirement processes to access data demand a long, convoluted process managed by the newly created institute for access to information. But this process does not allow for a direct communication to the data sources, so the provided data can be of poor quality or irrelevant to the goals of the study. Also, data are generally delivered with an intentional lack of granularity, lack of resolution and lack of geographical references. This issue is described in the methodology chapter and supported by information presented in Appendix C.

However, the greatest limitation to this and other possible future studies, is the issue of informality in terms of squatting or illegal occupation of housing units, as well as the illegal connections to electricity. One of the neighborhoods analyzed here (identified as GMP2) presented the majority of challenges to this study. The GMP2 neighborhood was completed in 2012, and has a total of 285 dwelling units. Being one of the first GMP neighborhoods built in the city, I selected it to be an exemplar representation of the GMP in a desert city. During the first visits to the development and through direct observation and unstructured interviews of its residents during the pilot phases of the survey, I noticed the large amount of houses without a metering system. While I expected to find a certain level of illegality, informal occupation or squatting, I did not expect it to surpass a 20% of all dwelling units within each neighborhood. Social housing in Mexico, and particularly INFONAVIT, have faced a serious problem of abandonment in recent years. The rate of abandonment for INFONAVIT financed houses has been estimated at 14% in Mexico, a much higher rate than any other OECD country. This rate varies by region and state. In the northern states, and usually in border cities, the rates are higher (Ciudad Juárez, Tijuana). In the city of this study, relatively close to the border, the overall abandonment rate has been estimated at around 18% (including other neighborhoods that do not belong to INFONAVIT). Because of this precedent, I expected some level of abandonment mixed with illegal occupation, but not at the magnitude found in this neighborhood. The GMP2 only has 56 dwellings with valid metering systems. It is valid to assume that only legal homeowners have a valid and functioning metering system, since only those with a property title can legally contract the electricity service. If this is the case, then less than 20% of the total households in GMP2 are legally occupied. Furthermore, there were other incidents that suggested more concerning legal and safety problems for the population.

Beyond the concerns over the safety and security of the legal residents of this neighborhood, the high rate of illegal squatting intensify threats to internal validity in terms of selection (as described in Shadish et al., 2002). The interviewing team collected responses from all 56 dwellings with electric meters, but also interviewed 25 households without electric meter, which we assume are illegally occupying the unit. The average respondent in this case, is basically different to the ones in all other three neighborhoods. Roughly one third of the respondents in GMP2 could be squatting, and consequently they would have no information about the GMP at all. They could also be using electricity through their neighbor, therefore have practically no knowledge about the cost of their electricity consumption, and at the same time are inflating the electricity bill readings of those dwellings to which they are connected.

I requested the members of the interviewing team to not ask directly if people were squatting in their homes, or stealing or sharing electricity from their neighbors, even though a few respondents were open about it. All three other neighborhoods showed signs of abandonment, squatting and electricity sharing, however, at a lower percentage than this one. Also, the larger number of dwelling units of the other neighborhoods allowed for the interviewing team to skip the households without a metering system and only interview those who we identified as 'legally connected to electricity'. Therefore, the results presented here must be taken with the pertinent consideration to the contextual characteristics of the neighborhoods where this study took place.

Future research

Because of the negligible effects of the GMP on electricity consumption in the neighborhoods analyzed here, two of the research questions of this study were only partially answered. Do people's knowledge and perceptions towards energy consumption and energy efficiency change after being exposed to energy efficiency devices? And does this exposure and the potential enjoyment of the benefits of energy consumption reduction have a positive effect on general environmental attitudes, perceptions and behaviors? Future research can be conducted in neighborhoods that have obtained positive and significant effects from the GMP. A better research design must include a survey to GMP homebuyers before they inhabit their efficient homes in order to establish a baseline and be able to measure potential change. This research requires a longer timeline, and the involvement and support of INFONAVIT or private developers.

Depending on availability of data, smaller research projects must look into the economic effects of the GMP: do energy efficient homes experience a different appreciation in the value of the house over time? Are energy efficient households more or less likely to default on their mortgages? Is there a difference in the rate of abandonment between GMP and non-GMP homes?

Another opportunity for future research is to observe the difference among the salesforce of different development companies. Do they know they are selling energy efficient homes, and are they trained to explain the program to homebuyers? I could not address this question in this research, as both GMP neighborhoods had passed the selling period at the moment of the survey implementation. The few interviews conducted with personnel from the developers' offices reflected a lack of interest and a lack of understanding for the Program.

Conclusion

The negligible effect of the GMP at improving the energy efficiency of its households did not provide the necessary information to analyze in detail of whether energy efficiency can be an instrument to improve the living conditions of low-income households. However, and based in the review of the existing literature, case studies, and reports, I argue that energy efficiency programs and policies have the potential to have multiple benefits beyond a mere reduction in energy consumption, and their evaluation should include a more comprehensive measurement. Furthermore, this effectiveness depends on the quality of the program and the effectiveness of its implementation, both of which should be based on a careful analysis of contextual factors such as environmental culture (composed by knowledge, perceptions and attitudes toward the environment) and regulatory context; the existing markets for energy efficiency, defined by the availability and accessibility of good quality and affordable energy efficient devices; and lastly, how programs and policies address the determinants of residential energy consumption. While all these factors are required for the design and implementation of these policies, they can also become barriers for the success of any environmental policy that relates to energy efficiency, and should be given a serious consideration before creating and implementing energy policies in developing countries.

I hope this dissertation promotes the further analysis of environmental culture -environmental knowledge, attitudes and perceptions- in the Mexican population in general, and specifically in low-income households. This is an analysis that is required as the basic foundation for any other study, program or policy relevant to natural resources, but that has been bypassed by scholars and stakeholders in search for a quick solution to rapidly growing problems. As shown in this dissertation, the GMP missed the opportunity to increase knowledge, awareness and acceptance of energy efficiency devices, which would potentially improve attitudes toward the environment and pave the path to a more sustainable future.

Appendix A

Categorization of Housing Types by Average Cost in VSM.

Table A1.

Housing Categorization by Average Cost in VSM.

	Interés Social					
	Económica	Popular	Tradicional	Media	Residencial	Residencial Plus
Avg. Built Area (sq. m.)	30	42.5	62.5	97.5	145	225
sq. feet	322.92	457.47	672.74	1,049.48	1,560.77	2,421.88
Average Cost in VSMMDF	Up to 118	118.1 to 200	200.1 to 350	350.1 to 750	750.1 to 1500	More than 1500
Interior Areas	Multi-purpose area	1-2 Bedrooms	2-3 Bedrooms	2-3 Bedrooms	3-4 Bedrooms	3+ Bedrooms
	Bathroom	Bathroom	Bathroom	1.5 Bathrooms	3-5 Bathrooms	3-5 Bathrooms
	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen	Kitchen
		Living / Dining	Living / Dining	Living	Living	Living
				Dining	Dining	Dining
				Service room	Service Room	1-2 Service Rooms
					Family Room	Family Room

Source: National Code of Housing Construction. CONAVI, 2010.

Appendix B

Regulations related to the Green Mortgage Program (GMP)

Table B1.
Environmental Regulatory Bodies in Mexico, and Regulations related to the GMP

CONAE	Official Mexican Standard for Energy Efficiency	NOM-008-ENER-2001	Building Energy Efficiency. Non-residential Building Envelope
		NOM-007-ENER	Efficiency in Interior Lighting
		NOM-013-ENER	Efficiency in Exterior Lighting
		NOM-020-ENER-2011	Building Energy Efficiency. Residential Building Envelope
ANES	Mexican Standards	NMX-ES-001	Certification for Solar Collectors
		NMX-ES-004	Efficiency in Solar Water Heaters
		NMX-460-ONNCCE	Thermal Resistance of Construction Materials
CONUEE		DTESTV	Technical Report of Solar Thermal Energy in Housing
		NOM-003-ENER-2011	Thermal Efficiency of Domestic Water Heaters
		NOM-005-ENER-2012	Energy Efficiency of Domestic Clothes Washing Machines
		NOM-011-ENER-2006	Energy Efficiency for Residential Air Conditioning Systems
		NOM-015-ENER-2012	Energy Efficiency for Domestic Refrigerators and Freezers
		NOM-018-ENER-2011	Thermal Insulation for Buildings
		NOM-024-ENER-2012	Thermal and Optical standards for Glazing systems in Buildings
		NOM-025-ENER-2013	Thermal Efficiency for Cooking Appliances. Gas
		NOM-030-ENER-2012	Lighting Efficiency for LED lamps
Gob. DF		NOM Solar Water Heaters	
SEMARNAT		NOM Wind Power	
		NOM Photovoltaic Power	
CONAGUA		NOM-009-CNA-2001	Specifications and testing methodology - Toilets
		NOM-008-CAN-1998	Specifications and testing methodology - Showers
ONNCCE		NMX-C-415-ONNCCE-1999	Faucets

SOURCE: Compilation by the Author.

Appendix C

Data Request Process through INAI

The data collection process is complex and time-consuming, as it requires filing an official request through a third-party entity, the National Institute for Transparency, Access to Information, and Protection of Personal Data (Instituto Nacional de Transparencia, Acceso a la Información y Protección de Datos Personales, [INAI]). The first request I received data on the five GMP developments for the city of study. The second request consisted of the five GMP developments for the city number two, and the four GMP developments for city number three. A third request consisted of all the housing developments that comprise the comparison groups for the three cities. The process for each request takes about three months in total, if no delays or additional data is required.

Table C1.
Data request process through INAI

INAI Request ID #	Data requested	Data years requested	Date requested	1st response	Required re-submittal	Final data delivered	Notes
1816400 211117	Electricity consumption for all households in city of study (by neighborhood)	2010	8/21/2017	10/4/2017	YES	10/10/2017	Data was received aggregated by neighborhood
1816400 161216	Electricity consumption for 5 control group developments in city of study	2005 - 2016	8/5/2015	8/31/2016	NO	9/2/2016	Incomplete
1816400 093816	Electricity consumption for 12 housing developments in city no 2	2008 - 2015	5/6/2016	6/3/2016	YES	6/14/2016	DENIED
1816400 224515	Electricity consumption for 5 GMP developments in other city and 5	2010 - 2015	10/30/2015	12/1/2015	YES	4/29/2016	Incomplete Data (aggregated by

	GMP developments in city of study						urban area for Mexicali)
1816400 224615	Electricity consumption for 4 GMP developments in city no 3	2008, 2010, 2012, 2014, 2015	10/30/2015	12/1/2015	YES	4/6/2016	DENIED
1816400 141115	Electricity consumption for 5 GMP developments in city of study and 2 GMP developments in city no. 4	2005 - 2015	8/3/2015	9/18/2015	YES	10/1/2015	Incomplete
	Electricity consumption for 5 GMP developments in city of study		1/18/2015	3/25/2015	NO	4/20/2015	

After several failed attempts to obtain electricity consumption data from CFE through INAI and personal communication with local officials, it was clear that obtaining data for the cities number two and three would be impossible. The requests to CFE through INAI resulted in incomplete and low-quality datasets for the city number two, and no data for the city number three.

Appendix D

Surveys

1. Survey for control group (neighborhoods without GMP). Version of Nov 4, 2016

Introducción:
Presentación del proyecto y Formato de declaración de consentimiento para responder la encuesta

UNIVERSIDAD DE CALIFORNIA LOS ANGELES
HOJA DE INFORMACIÓN SOBRE ESTA ENCUESTA
Encuesta sobre el consumo de electricidad en viviendas en México

La Maestra Paloma Giottonini, estudiante de doctorado, y el Profesor Leobardo Estrada, miembros del Departamento de Planificación Urbana en la Escuela Luskin de Asuntos Públicos de la Universidad de California en Los Ángeles (UCLA), están desarrollando una investigación sobre el consumo de electricidad en las viviendas de esta ciudad.

Usted ha sido seleccionado al azar como un posible participante en este estudio. Su participación es completamente voluntaria. Si usted acepta contestar nuestras preguntas, tiene el derecho de pedir al encuestador que explique alguna pregunta o concepto que no haya entendido, así como de pedirle detener esta encuesta en cualquier momento y sin ninguna repercusión hacia su persona.

El objetivo principal de nuestro estudio es evaluar el conocimiento que tienen las personas sobre el consumo de electricidad en el hogar.

Si usted acepta participar en este estudio, se le pedirá que responda 45 preguntas, algunas son de opción múltiple y algunas son preguntas abiertas, acerca de su conocimiento sobre el consumo de electricidad en la vivienda, y sobre las formas en que podemos consumir más o menos energía en nuestros hogares. La encuesta incluye también preguntas sobre las características físicas de su vivienda y sobre la eficiencia energética. Finalmente, se le pedirá que nos proporcione una breve información demográfica respecto a las personas que habitan esta vivienda. La encuesta tiene una duración aproximada de 30 minutos.

Toda la información que obtengamos con sus respuestas será guardada de manera confidencial y sus datos personales serán protegidos y no serán distribuidos de ninguna manera. Una vez terminada la encuesta, no lo volveremos a contactar para hacerle más preguntas ni para pedirle más información.

Si tiene alguna pregunta, comentario o inquietud acerca de esta investigación, acerca de la encuesta o sobre alguna pregunta en particular, por favor contacte directamente a:
Miriam Paloma Giottonini Badilla
Teléfono (USA): 602-284-9751
Teléfono (Mexico)
Email: kicteric@gmail.com

Si tiene preguntas acerca de sus derechos al participar en este estudio, o si tiene alguna inquietud o sugerencia y quisiera hablar con alguien que no sea parte del equipo de investigación, por favor llame a la Oficina del Programa de Protección de la Investigación con Humanos (OHRPP) al número (310) 825-7122 (en Estados Unidos), o escriba a:
UCLA Office of the Human Research Protection Program
11000 Kinross Avenue, Suite 211, Box 951694
Los Angeles, CA 90095-1694
USA

¿Está de acuerdo en participar en nuestra encuesta?
- ❍ Si
- ❍ No (Pase a la sección de “Agradecimientos” al final de la encuesta)

COLONIA_________________________ Encuestador__________________________Fecha_____/______/______
Calle y Número de casa ____Hora _____/_____ COD. Co__

Sección 1. Características generales del hogar y de la vivienda

1.1 Cuánto tiempo tiene viviendo en esta casa? _______________ (Si recuerda cuándo se mudó, incluir mes y año)

1.2 Antes de vivir en esta casa, usted vivía: ❍ En Hermosillo, pero en otra colonia ❍ En otra ciudad del Estado de Sonora ❍ En otro Estado ❍ En otro país	1.3 La casa donde usted vivía antes era: ❍ Propia ❍ Rentada ❍ Prestada ❍ Vivía con familiares ❍ Otro: ______________________________
1.4 Su casa anterior era: ❍ Construida por una compañía constructora (Ir a preg. 1.6) ❍ Construida por usted mismo (Ir a preg. 1.5)	1.5 Si su casa anterior era construida por usted mismo, ¿cuál casa le gusta más? ❍ Mi casa anterior ❍ Esta casa
1.6 Esta casa es: ❍ Propia (comprada) ❍ Rentada ❍ Prestada ❍ Otro: __________________	1.7 Cuando Usted y su familia se mudaron por primera vez a esta casa, la casa ❍ Nunca había sido habitada por otra familia ❍ Otra u otras familias habían habitado esta casa

1.8 De las personas que viven en esta casa, cuántos tienen:

	1	2	3	4	5	6
Menos de 12 años	❍	❍	❍	❍	❍	❍
De 12 a 18 años	❍	❍	❍	❍	❍	❍
De 18 a 24 años	❍	❍	❍	❍	❍	❍
De 25 a 34 años	❍	❍	❍	❍	❍	❍
De 35 a 44 años	❍	❍	❍	❍	❍	❍
De 45 a 54 años	❍	❍	❍	❍	❍	❍
De 55 a 64 años	❍	❍	❍	❍	❍	❍
Más de 65 años	❍	❍	❍	❍	❍	❍

1.9 De las personas que viven en esta casa, ¿todos son familiares?
❍ Si ❍ No. Explique cómo están relacionados:________________________________

Sección 2. Conocimiento sobre la eficiencia energética

2.1 Ahora vamos a comparar el consumo de electricidad de su casa con el consumo de otras casas de tamaño y características parecidas a la suya. Usted cree que en comparación con:

	Mi casa usa más	Mi casa usa la misma cantidad	Mi casa usa menos	No sabe / No contestó
Casas de mi colonia o fraccionamiento	O	O	O	O
Casas de otra colonia o fraccionamiento	O	O	O	O
Casas más nuevas	O	O	O	O
Casas más antiguas	O	O	O	O

2.2 En los últimos años ha habido en el mercado más promoción a dispositivos como focos ahorradores, llaves ahorradoras de agua, sanitarios que usan menos agua, y otros aparatos que usan menos electricidad, agua o gas.
¿Sabe Usted si su casa tiene alguno de estos dispositivos de eficiencia energética?
❍ **Si tiene** ❍ **No tiene** ❍ **No sabe**

2.3 De la lista de aditamentos o aparatos que se muestran aquí, señale si ya venían con la casa o si usted o su familia los instalaron. Sólo marque respuestas para los aditamentos que tiene en su casa.

	Ya venía con la casa	Ya venía, pero no lo instalamos	Nosotros lo compramos	No tenemos	No sé
Focos ahorradores o fluorescentes	❍	❍	❍	❍	❍
Focos LED	❍	❍	❍	❍	❍
Aire Acondicionado central	❍	❍	❍	❍	❍
Aire Acondicionado de ventana	❍	❍	❍	❍	❍
Aire Acondicionado mini split	❍	❍	❍	❍	❍
Cooler	❍	❍	❍	❍	❍
Abanico (s)	❍	❍	❍	❍	❍
Aislante térmico en Muros	❍	❍	❍	❍	❍
Aislante térmico en Techos	❍	❍	❍	❍	❍
Calentador de agua de paso	❍	❍	❍	❍	❍
Calentador de agua de gas (tanque)	❍	❍	❍	❍	❍

NOTA: Aislante térmico es un material que se usa en la construcción para evitar que las viviendas se calienten más en el verano, o se enfríen más en invierno (esto es para el caso de Hermosillo). Generalmente se pone encima del muro o del techo durante la construcción de la vivienda y no es visible

2.4 Sabe quién pagó por los dispositivos que ya estaban instalados en su casa? (Omitir si no seleccionó ninguno como "Ya venía con la casa" en la pregunta anterior, y pasar a la pregunta 2.10)

❑ La compañía que construyó las casas	❑ El gobierno federal
❑ El INFONAVIT o FOVISSSTE	❑ Están incluidos en el precio o en la hipoteca de la casa
❑ El municipio	❑ Otro ______________________________

2.5 ¿Qué piensa usted de los siguientes equipos ahorradores y su consumo de electricidad?

	Usa mucho menos	Usa menos	Usa lo mismo	Usa más	Usa mucho más	No sé
Focos ahorradores	❍	❍	❍	❍	❍	❍
Focos LED	❍	❍	❍	❍	❍	❍
Aire Acondicionado Central	❍	❍	❍	❍	❍	❍
AC de ventana	❍	❍	❍	❍	❍	❍
AC mini split	❍	❍	❍	❍	❍	❍
Refrigerador nuevo	❍	❍	❍	❍	❍	❍
Refrigerador usado	❍	❍	❍	❍	❍	❍
Calentador de agua de paso	❍	❍	❍	❍	❍	❍
Calentador de agua de tanque	❍	❍	❍	❍	❍	❍

2.10 De la siguiente lista, ¿qué aparatos o dispositivos se han descompuesto o dejado de funcionar en su casa?

❑ Focos ahorradores	❑ Aire Acondicionado	❑ Calentador de agua de paso	❑ Otro:
❑ Focos LED	❑ Refrigerador	❑ Calentador de agua de gas	____________________

2.11 Si se le ha descompuesto alguno de los dispositivos ahorradores en su casa, ¿qué hizo al respecto?

❍ Lo cambié por uno igual, nuevo o usado. Dé un ejemplo:______________________________

❍ Lo cambié por uno no ahorrador, nuevo o usado. Dé un ejemplo:______________________________

❍ Lo mandé arreglar

❍ No hice nada o lo dejé de usar (todavía está descompuesto)

❍ No se me ha descompuesto ninguno de estos aparatos

2.12 Desde que vive en esta casa, ¿le ha hecho alguna mejora o cambio?

❍ Si

❍ No (Pase a la pregunta 3.1)

❍ No es mi casa, no le puedo hacer cambios (Pase a la pregunta 3.1)

2.13 Qué mejoras le ha hecho y cuánto le costó (aproximadamente)? ____________________

Sección 3. Consumo de electricidad

3.1 Cuánto pagó de electricidad en su último recibo? (Puede redondear la cantidad o darnos un aproximado) $__________ ❍ No recuerdo	3.2 Cuántos kWh consumió según su último recibo? ❍ No me fijo en la cantidad de kWh ❍ No recuerdo (Pase a la pregunta 3.2) ❍ Si recuerdo, el consumo fue de _______________
3.3 Qué meses cubrió su recibo anterior? ________________________________	3.4 Conserva sus recibos de electricidad? ❍ Si ❍ No

Sección 4. Ingreso disponible y condiciones de subsistencia

4.1 Piense por un momento en su situación económica de hoy en comparación con su situación económica de cuando vivía en otra casa. ¿Considera usted que ahora es más o menos probable hacer alguna de las siguientes actividades recreativas?

	Más probable	Igual	Menos probable
Ir al cine	❍	❍	❍
Ir a un concierto u obra	❍	❍	❍
Ir a la ExpoGAN o Fiestas del Pltic	❍	❍	❍
Ir a un parque de diversiones (como el Parque Infantil o el Centro Ecológico)	❍	❍	❍
Dar un paseo dentro de la ciudad	❍	❍	❍
Salir de la ciudad	❍	❍	❍
Otra actividad: _______________	❍	❍	❍

NOTA: Si para alguna actividad contesta nunca, preguntar por qué. Puede ser falta de dinero o distancia

4.2 De la siguiente lista, marque las actividades por las que ha pagado en los últimos 6 meses:

- ❑ Cualquier tipo de clases (arte, pintura, baile, deporte, música) para usted o sus hijos
- ❑ Talleres de capacitación para aprender un nuevo oficio o una nueva habilidad que le permitiera mejorar su ingreso (costura, mecánica, carpintería, etc)
- ❑ Cursos educativos o campamentos de verano para los hijos
- ❑ Otra actividad: ____________________

4.3 De la siguiente lista, marque qué tan seguido ha sentido que el dinero no le va a alcanzar para:

	Todos los días	Al menos una vez por semana	Una vez al mes	Rara vez pienso en eso	Nunca
Comprar comida	❍	❍	❍	❍	❍
Pagar los servicios	❍	❍	❍	❍	❍
Pagar gasolina o transporte	❍	❍	❍	❍	❍
Hacer el pago de la casa (hipoteca)	❍	❍	❍	❍	❍
Pagar por los gastos de la escuela de mis hijos (útiles, uniforme)	❍	❍	❍	❍	❍
Comprar ropa y zapatos para la familia	❍	❍	❍	❍	❍
Pagar deudas	❍	❍	❍	❍	❍
Ahorrar	❍	❍	❍	❍	❍

4.4 Si tuviera la oportunidad de volver a elegir una casa para comprar ¿buscaría una casa que le garantizara usar menos recursos (agua, electricidad, gas)? ❍ Si ❍ No ❍ No sé	4.5 Si tuviera la opción entre comprar una casa con aditamentos para ahorrar agua, gas y electricidad; o recibir un monto de dinero equivalente al costo de los aditamentos ecológicos, ¿qué escogería? ❍ Los aditamentos ecológicos ❍ Que me dieran el dinero equivalente ❍ Un descuento en mis pagos mensuales de hipoteca

Sección 5. Conocimiento y Actitudes Ambientales

5.1 De los siguientes aparatos, ¿cuál cree usted que consume más electricidad en una casa? Enumere del 1 al 6, 1 es el que más consume electricidad, 6 es el que menos consume.

___ Lavadora (de ropa) ___ Televisión ___ Iluminación (focos)	___ Aire Acondicionado ___ Refrigerador ___ Computadora
5.2 Cuando compra aparatos eléctricos grandes (como lavadora, refrigerador, aire acondicionado), ¿considera su consumo eléctrico al decidir cuál comprar? (sello FIDE) ❍ Si ❍ No	5.3 Cuando compra aparatos eléctricos chicos (como cafetera, licuadora, plancha), ¿considera su consumo eléctrico al decidir cuál comprar? (sello FIDE) ❍ Si ❍ No
5.4 Usted considera que el consumo eléctrico en la casa tenga efectos negativos en el medio ambiente natural? ❍ Si ❍ No	5.5 Usted está de acuerdo en que haya leyes más estrictas para proteger el medio ambiente? ❍ Si ❍ No
5.6 Usted estaría de acuerdo en pagar una cuota anual en la protección del medio ambiente? ❍ Si ❍ No	5.6 Usted cree que es necesario cambiar sus hábitos para reducir el impacto negativo en el medio ambiente? ❍ Si ❍ No

Sección 6. Información Sociodemográfica

A continuación, le haremos algunas preguntas acerca del jefe o jefa de este hogar. *El jefe o jefa de un hogar es aquella persona que toma la mayoría de las decisiones que tienen que ver con el gasto familiar o la manera en que se usa el ingreso de la familia. Estos gastos incluyen las reparaciones a la casa, la educación de los hijos, las actividades recreativas, y otros aspectos generales del funcionamiento normal de una familia. El jefe o jefa puede o no ser también el propietario de la casa.*

6.1 Quién es el jefe de este hogar? ❍ Padre ❍ Madre ❍ Otro. Describa quién: ____________________ ❍	6.2 Edad del jefe del hogar __________________años
6.3 Grado de escolaridad del jefe del hogar? ❍ Primaria ❍ Secundaria ❍ Preparatoria ❍ Escuela Normal ❍ Estudios técnicos o comerciales ❍ Licenciatura o profesional ❍ Maestría ❍ Doctorado	6.4 Con cuántos ingresos cuenta este hogar? ❍ Sólo los del padre ❍ Sólo los de la madre ❍ Ingresos combinados del padre y madre ❍ Ingresos combinados de más miembros del hogar (padre, madre, hijos, tíos). Describa quienes aportan: ____
6.5 En esta tarjeta vienen diferentes rangos de ingresos en pesos identificados con una letra. Identifique cuál fue el ingreso total de este hogar el mes anterior (puede ser un aproximado) y dígame a qué letra corresponde. [Nota para los encuestadores: Entregue la tarjeta que tiene las opciones de ingreso por categoría] ❍ A. Hasta $2,200 pesos ❍ B. Entre $2,200 y $4,250 pesos ❍ C. Entre $4,250 y $6,500 pesos ❍ D. Entre $6,500 y $10,750 pesos ❍ E. Entre $10,750 y $21,300 pesos ❍ F. Más de $21,300 pesos	6.6 El ingreso del mes anterior fue ❍ Lo normal ❍ Más de lo normal ❍ Menos de lo normal

Agradecimientos

Agradecemos su participación en nuestra investigación, “La eficiencia energética como mecanismo para mejorar las condiciones de vida en la vivienda de interés social: Un análisis del Programa Hipoteca Verde en México”. Si tiene alguna duda, pregunta o comentario respecto a este estudio, a la encuesta o sobre alguna pregunta en particular, no dude en contactarme directamente ya sea mediante correo electrónico a kicteric@gmail.com o al teléfono en Estados Unidos (602) 284-9751.

2. Survey for treatment group (neighborhoods with GMP). Version of Nov 4, 2016

Introducción:
Presentación del proyecto y Formato de declaración de consentimiento para responder la encuesta

UNIVERSIDAD DE CALIFORNIA LOS ANGELES
HOJA DE INFORMACIÓN SOBRE ESTA ENCUESTA
Encuesta sobre el consumo de electricidad en viviendas en México

La Maestra Paloma Giottonini, estudiante de doctorado, y el Profesor Leobardo Estrada, miembros del Departamento de Planificación Urbana en la Escuela Luskin de Asuntos Públicos de la Universidad de California en Los Ángeles (UCLA), están desarrollando una investigación sobre el consumo de electricidad en las viviendas de esta ciudad.

Usted ha sido seleccionado al azar como un posible participante en este estudio. Su participación es completamente voluntaria. Si usted acepta contestar nuestras preguntas, tiene el derecho de pedir al encuestador que explique alguna pregunta o concepto que no haya entendido, así como de pedirle detener esta encuesta en cualquier momento y sin ninguna repercusión hacia su persona.

El objetivo principal de nuestro estudio es evaluar el conocimiento que tienen las personas sobre el consumo de electricidad en el hogar.

Si usted acepta participar en este estudio, se le pedirá que responda 45 preguntas, algunas son de opción múltiple y algunas son preguntas abiertas, acerca de su conocimiento sobre el consumo de electricidad en la vivienda, y sobre las formas en que podemos consumir más o menos energía en nuestros hogares. La encuesta incluye también preguntas sobre las características físicas de su vivienda y sobre la eficiencia energética. Finalmente, se le pedirá que nos proporcione una breve información demográfica respecto a las personas que habitan esta vivienda. La encuesta tiene una duración aproximada de 30 minutos.

Toda la información que obtengamos con sus respuestas será guardada de manera confidencial y sus datos personales serán protegidos y no serán distribuidos de ninguna manera. Una vez terminada la encuesta, no lo volveremos a contactar para hacerle más preguntas ni para pedirle más información.

Si tiene alguna pregunta, comentario o inquietud acerca de esta investigación, acerca de la encuesta o sobre alguna pregunta en particular, por favor contacte directamente a:
Miriam Paloma Giottonini Badilla
Teléfono (USA): 602-284-9751
Teléfono (Mexico)
Email: kicteric@gmail.com

Si tiene preguntas acerca de sus derechos al participar en este estudio, o si tiene alguna inquietud o sugerencia y quisiera hablar con alguien que no sea parte del equipo de investigación, por favor llame a la Oficina del Programa de Protección de la Investigación con Humanos (OHRPP) al número (310) 825-7122 (en Estados Unidos), o escriba a:
UCLA Office of the Human Research Protection Program
11000 Kinross Avenue, Suite 211, Box 951694
Los Angeles, CA 90095-1694
USA

¿Está de acuerdo en participar en nuestra encuesta?
- ❍ Si
- ❍ No (Pase a la sección de "Agradecimientos" al final de la encuesta)

COLONIA___________________________ Encuestador___________________________Fecha______/_______/_______
Calle y Número de casa ____Hora _____/______ COD. HV__

Sección 1. Características generales del hogar y de la vivienda

1.1 Cuánto tiempo tiene viviendo en esta casa? _______________ (Si recuerda cuándo se mudó, incluir mes y año)

1.2 Antes de vivir en esta casa, usted vivía: ❍ En Hermosillo, pero en otra colonia ❍ En otra ciudad del Estado de Sonora ❍ En otro Estado ❍ En otro país	1.3 La casa donde usted vivía antes era: ❍ Propia ❍ Rentada ❍ Prestada ❍ Vivía con familiares ❍ Otro: ___________________________________
1.4 Su casa anterior era: ❍ Construida por una compañía constructora (Ir a preg. 1.6) ❍ Construida por usted mismo (Ir a preg. 1.5)	1.5 Si su casa anterior era construida por usted mismo, ¿cuál casa le gusta más? ❍ Mi casa anterior ❍ Esta casa
1.6 Esta casa es: ❍ Propia (comprada) ❍ Rentada ❍ Prestada ❍ Otro: ____________________	1.7 Cuando Usted y su familia se mudaron por primera vez a esta casa, la casa ❍ Nunca había sido habitada por otra familia ❍ Otra u otras familias habían habitado esta casa

1.8 De las personas que viven en esta casa, cuántos tienen:

	1	**2**	**3**	**4**	**5**	**6**
Menos de 12 años	❍	❍	❍	❍	❍	❍
De 12 a 18 años	❍	❍	❍	❍	❍	❍
De 18 a 24 años	❍	❍	❍	❍	❍	❍
De 25 a 34 años	❍	❍	❍	❍	❍	❍
De 35 a 44 años	❍	❍	❍	❍	❍	❍
De 45 a 54 años	❍	❍	❍	❍	❍	❍
De 55 a 64 años	❍	❍	❍	❍	❍	❍
Más de 65 años	❍	❍	❍	❍	❍	❍

1.9 De las personas que viven en esta casa, ¿todos son familiares?

❍ Si	❍ No. Explique cómo están relacionados:___________________________________

Sección 2. Conocimiento sobre la eficiencia energética y sobre el programa Hipoteca Verde

2.1 Conoce o ha oído hablar del Programa Hipoteca Verde de INFONAVIT? ❍ Si ❍ No (Pase a la pregunta 2.3)	2.2 Me puede describir brevemente en qué consiste? _______________________________________
2.3 Sabe si su casa es parte del Programa Hipoteca Verde? ❍ Si es parte del programa ❍ No es parte del programa ❍ No sé (Pase a la pregunta 2.5)	2.4 Cómo lo sabe? ____

2.5 Ahora vamos a comparar el consumo de electricidad de su casa con el consumo de otras casas de tamaño y características parecidas a la suya. Usted cree que en comparación con:

	Mi casa usa más	Mi casa usa la misma cantidad	Mi casa usa menos	No sabe / No contestó
Casas de mi colonia o fraccionamiento	O	O	O	O
Casas de otra colonia o fraccionamiento	O	O	O	O
Casas más nuevas	O	O	O	O
Casas más antiguas	O	O	O	O

2.6 En los últimos años ha habido en el mercado más promoción a dispositivos como focos ahorradores, llaves ahorradoras de agua, sanitarios que usan menos agua, y otros aparatos que usan menos electricidad, agua o gas.
¿Sabe Usted si su casa tiene alguno de estos dispositivos de eficiencia energética?
❍ **Si tiene** ❍ **No tiene** ❍ **No sabe**

2.7 De la lista de aditamentos o aparatos que se muestran aquí, señale si ya venían con la casa o si usted o su familia los instalaron. Sólo marque respuestas para los aditamentos que tiene en su casa.

	Ya venía con la casa	Ya venía, pero no lo instalamos	Nosotros lo compramos	No tenemos	No sé
Focos ahorradores o fluorescentes	❍	❍	❍	❍	❍
Focos LED	❍	❍	❍	❍	❍
Aire Acondicionado central	❍	❍	❍	❍	❍
Aire Acondicionado de ventana	❍	❍	❍	❍	❍
Aire Acondicionado mini split	❍	❍	❍	❍	❍
Cooler	❍	❍	❍	❍	❍
Abanico(s)	❍	❍	❍	❍	❍
Aislante térmico en Muros	❍	❍	❍	❍	❍
Aislante térmico en Techos	❍	❍	❍	❍	❍
Calentador de agua de paso	❍	❍	❍	❍	❍
Calentador de agua de gas (tanque)	❍	❍	❍	❍	❍

NOTA: Aislante térmico es un material que se usa en la construcción para evitar que las viviendas se calienten más en el verano, o se enfríen más en invierno (esto es para el caso de Hermosillo). Generalmente se pone encima del muro o del techo durante la construcción de la vivienda y no es visible.

2.8 Sabe quién pagó por los dispositivos que ya estaban instalados en su casa? (Omitir si no seleccionó ninguno como "Ya venía con la casa" en la pregunta anterior, y pasar a la pregunta 2.10)

❑ La compañía que construyó las casas	❑ El gobierno federal
❑ El INFONAVIT	❑ Están incluidos en el precio o en la hipoteca de la casa
❑ El municipio	❑ Otro ____________________________

2.9 ¿Qué piensa usted de los siguientes equipos ahorradores y su consumo de electricidad?

	Usa mucho menos	Usa menos	Usa lo mismo	Usa más	Usa mucho más	No sé
Focos ahorradores	❍	❍	❍	❍	❍	❍
Focos LED	❍	❍	❍	❍	❍	❍
Aire Acondicionado Central	❍	❍	❍	❍	❍	❍
AC de ventana	❍	❍	❍	❍	❍	❍
AC mini split	❍	❍	❍	❍	❍	❍
Refrigerador nuevo	❍	❍	❍	❍	❍	❍
Refrigerador usado	❍	❍	❍	❍	❍	❍
Calentador de agua de paso	❍	❍	❍	❍	❍	❍
Calentador de agua de tanque	❍	❍	❍	❍	❍	❍

2.10 De la siguiente lista, ¿qué aparatos o dispositivos se han descompuesto o dejado de funcionar en su casa?

❑ Focos ahorradores	❑ Aire Acondicionado	❑ Calentador de agua de paso	❑ Otro: ___________________
❑ Focos LED	❑ Refrigerador	❑ Calentador de agua de gas	

2.11 Si se le ha descompuesto alguno de los dispositivos ahorradores en su casa, ¿qué hizo al respecto?
❍ Lo cambié por uno igual, nuevo o usado. Dé un ejemplo:____________________________
❍ Lo cambié por uno no ahorrador, nuevo o usado. Dé un ejemplo:____________________________
❍ Lo mandé arreglar
❍ No hice nada o lo dejé de usar (todavía está descompuesto)
❍ No se me ha descompuesto ninguno de estos aparatos

2.12 Desde que vive en esta casa, ¿le ha hecho alguna mejora o cambio?
❍ Si
❍ No (Pase a la pregunta 3.1)
❍ No es mi casa, no le puedo hacer cambios (Pase a la pregunta 3.1)

2.13 Qué mejoras le ha hecho y cuánto le costó (aproximadamente)? ____________________

Sección 3. Consumo de electricidad

3.1 Cuánto pagó de electricidad en su último recibo? (Puede redondear la cantidad o darnos un aproximado) $__________ ❍ No recuerdo	3.2 Cuántos kWh consumió según su último recibo? ❍ No me fijo en la cantidad de kWh ❍ No recuerdo (Pase a la pregunta 3.2) ❍ Si recuerdo, el consumo fue de _______________
3.3 Qué meses cubrió su recibo anterior? ________________________________	3.4 Conserva sus recibos de electricidad? ❍ Si ❍ No

Sección 4. Ingreso disponible y condiciones de subsistencia

4.1 Piense por un momento en su situación económica de hoy en comparación con su situación económica de cuando vivía en otra casa. ¿Considera usted que ahora es más o menos probable hacer alguna de las siguientes actividades recreativas?

	Más probable	Igual	Menos probable
Ir al cine	❍	❍	❍
Ir a un concierto u obra	❍	❍	❍
Ir a la ExpoGAN o Fiestas del PItic	❍	❍	❍
Ir a un parque de diversiones (como el Parque Infantil o el Centro Ecológico)	❍	❍	❍
Dar un paseo dentro de la ciudad	❍	❍	❍
Salir de la ciudad	❍	❍	❍
Otra actividad: _______________	❍	❍	❍

NOTA: Si para alguna actividad contesta nunca, preguntar por qué. Puede ser falta de dinero o distancia

4.2 De la siguiente lista, marque las actividades por las que ha pagado en los últimos 6 meses:
- ❑ Cualquier tipo de clases (arte, pintura, baile, deporte, música) para usted o sus hijos
- ❑ Talleres de capacitación para aprender un nuevo oficio o una nueva habilidad que le permitiera mejorar su ingreso (costura, mecánica, carpintería, etc)
- ❑ Cursos educativos o campamentos de verano para los hijos
- ❑ Otra actividad: ____________________

4.3 De la siguiente lista, marque qué tan seguido ha sentido que el dinero no le va a alcanzar para:

	Todos los días	Al menos una vez por semana	Una vez al mes	Rara vez pienso en eso	Nunca
Comprar comida	❍	❍	❍	❍	❍
Pagar los servicios	❍	❍	❍	❍	❍
Pagar gasolina o transporte	❍	❍	❍	❍	❍
Hacer el pago de la casa (hipoteca)	❍	❍	❍	❍	❍
Pagar por los gastos de la escuela de mis hijos (útiles, uniforme)	❍	❍	❍	❍	❍
Comprar ropa y zapatos para la familia	❍	❍	❍	❍	❍
Pagar deudas	❍	❍	❍	❍	❍
Ahorrar	❍	❍	❍	❍	❍

4.4 En general, ¿cuál es su opinión sobre el programa Hipoteca Verde? ❍ Es muy bueno y debería continuar ❍ Es muy bueno, pero ya no es necesario, la gente ya busca cómo ahorrar ❍ No tengo ninguna opinión del programa ❍ Es un gasto innecesario ❍ Es malo o no sirve para nada ❍ Otro ______________________________	4.5 Si tuviera la oportunidad de volver a elegir una casa para comprar con su ahorro INFONAVIT, ¿buscaría una casa con Hipoteca Verde? ❍ Si ❍ No ❍ No sé

4.6. Si tuviera la opción entre comprar una casa con Hipoteca Verde, o recibir un monto de dinero equivalente al costo de los aditamentos ecológicos, ¿qué escogería?

- ❍ Los aditamentos ecológicos
- ❍ Que me dieran el dinero equivalente
- ❍ Un descuento en mis pagos mensuales de hipoteca

Sección 5. Conocimiento y Actitudes Ambientales

5.1 De los siguientes aparatos, ¿cuál cree usted que consume más electricidad en una casa? Enumere del 1 al 6, 1 es el que más consume electricidad, 6 es el que menos consume.

___ Lavadora (de ropa) ___ Televisión ___ Iluminación (focos)	___ Aire Acondicionado ___ Refrigerador ___ Computadora
5.2 Cuando compra aparatos eléctricos grandes (como lavadora, refrigerador, aire acondicionado), ¿considera su consumo eléctrico al decidir cuál comprar? (sello FIDE) ❍ Si ❍ No	5.3 Cuando compra aparatos eléctricos chicos (como cafetera, licuadora, plancha), ¿considera su consumo eléctrico al decidir cuál comprar? (sello FIDE) ❍ Si ❍ No
5.4 Usted considera que el consumo eléctrico en la casa tenga efectos negativos en el medio ambiente natural? ❍ Si ❍ No	5.5 Usted está de acuerdo en que haya leyes más estrictas para proteger el medio ambiente? ❍ Si ❍ No
5.6 Usted estaría de acuerdo en pagar una cuota anual en la protección del medio ambiente? ❍ Si ❍ No	5.6 Usted cree que es necesario cambiar sus hábitos para reducir el impacto negativo en el medio ambiente? ❍ Si ❍ No

Sección 6. Información Sociodemográfica

A continuación, le haremos algunas preguntas acerca del jefe o jefa de este hogar. *El jefe o jefa de un hogar es aquella persona que toma la mayoría de las decisiones que tienen que ver con el gasto familiar o la manera en que se usa el ingreso de la familia. Estos gastos incluyen las reparaciones a la casa, la educación de los hijos, las actividades recreativas, y otros aspectos generales del funcionamiento normal de una familia. El jefe o jefa puede o no ser también el propietario de la casa.*

6.1 Quién es el jefe de este hogar? ❍ Padre ❍ Madre ❍ Otro. Describa quién: ____________________	6.2 Edad del jefe del hogar __________________años
6.3 Grado de escolaridad del jefe del hogar? ❍ Primaria ❍ Secundaria ❍ Preparatoria ❍ Escuela Normal ❍ Estudios técnicos o comerciales ❍ Licenciatura o profesional ❍ Maestría ❍ Doctorado	6.4 Con cuántos ingresos cuenta este hogar? ❍ Sólo los del padre ❍ Sólo los de la madre ❍ Ingresos combinados del padre y madre ❍ Ingresos combinados de más miembros del hogar (padre, madre, hijos, tíos). Describa quienes aportan: ___________________
6.5 En esta tarjeta vienen diferentes rangos de ingresos en pesos identificados con una letra. Identifique cuál fue el ingreso total de este hogar el mes anterior (puede ser un aproximado) y dígame a qué letra corresponde. [Nota para los encuestadores: Entregue la tarjeta que tiene las opciones de ingreso por categoría] ❍ A. Hasta $2,200 pesos ❍ B. Entre $2,200 y $4,250 pesos ❍ C. Entre $4,250 y $6,500 pesos ❍ D. Entre $6,500 y $10,750 pesos ❍ E. Entre $10,750 y $21,300 pesos ❍ F. Más de $21,300 pesos	6.6 El ingreso del mes anterior fue ❍ Lo normal ❍ Más de lo normal ❍ Menos de lo normal

Agradecimientos

Agradecemos su participación en nuestra investigación, “La eficiencia energética como mecanismo para mejorar las condiciones de vida en la vivienda de interés social: Un análisis del Programa Hipoteca Verde en México”. Si tiene alguna duda, pregunta o comentario respecto a este estudio, a la encuesta o sobre alguna pregunta en particular, no dude en contactarme directamente ya sea mediante correo electrónico a kicteric@gmail.com o al teléfono en Estados Unidos (602) 284-9751.

Appendix E

Survey Codebook

Variable Name	Label	Measure ment Level	Coded Value
ID	ID	Scale	
PROG	Grupo segun programa	Nominal	0=Control; 1=GMP
NeighID	Neighborhood ID	Nominal	1=GMP1; 2=GMP2; 3=Trad1; 4=Trad2
Fecha	Día de diciembre	Nominal	
Colonia	Neighborhood name	String	
Hora	Time of inverview	Scale	
Uno.1	¿Cuántos años tiene viviendo en esta casa?	Nominal	0 = 2 to 5 months; 1 = 6 to 8 months; 99 = Don't know / Did not answer
Uno.2	Antes de vivir en esta casa, usted vivía en	Nominal	1 = En Hermosillo pero en otra colonia; 2 = En otra ciudad del Estado de Sonora; 3 = En otro estado; 4 = En otro país
Uno.3	La casa donde usted vivía antes era	Nominal	1 = Propia; 2 = Rentada; 3 = Prestada; 4 = Vivía con familiares; 5 = Otro
Uno.4	Su casa anterior era	Nominal	1 = Construida por una compañía constructora; 2 = Construida por usted mismo
Uno.5	Si su casa anterior era construida por usted mismo, ¿Cuál casa le gusta más?	Nominal	1 = Mi casa anterior; 2 = Esta casa; 0 = No aplica
Uno.6	Esta casa es	Nominal	1 = Propia; 2 = Rentada; 3 = Prestada; 4 = Otro
Uno.7	Cuando usted y su familia se mudaron por primera vez a esta casa, la casa	Nominal	1 = Nunca había sido habitada por otra familia; 2 = Otra u otras familias ya habían habitado la casa
HHSize	Habitantes en la vivienda	Nominal	
menos12	Cuantas personas menores de 12 años viven en esta casa	Nominal	
Docea17	Cuántas personas de 12 a 17 años viven en esta casa	Nominal	
Dieciochoa24	Cuántas personas de 18 a 24 años viven en esta casa	Nominal	
Veinticincoa34	Cuántas personas de 25 a 34 años viven en esta casa	Nominal	
Treintaycincoa	Cuántas personas de 35 a 44 años viven en esta casa	Nominal	
Cuarentaycincoa54	Cuántas personas de 45 a 54 años viven en esta casa	Nominal	
Cincuentaycincoa64	Cuántas personas de 55 a 64 años viven en esta casa	Nominal	
SesentaycincooMás	Cuántas personas de 65 o más viven en esta casa	Nominal	
Family	De las personas que viven en esta casa, ¿Todos son familiares?	Nominal	1 = Si; 2 = No
Relacion	Cómo están relacionados	String	x = No aplica

Dos.1	Usted cree que en comparación con casas de su colonia o fraccionamiento	Nominal	1 = Mi casa usa más electricidad; 2 = Mi casa usa la misma cantidad de electricidad; 3 = Mi casa usa menos electricidad; 4 = No sabe/No contestó
Dos.1.2	Usted cree que en comparación con casas de otra colonia o fraccionamiento	Nominal	Use the same codes as Dos.1
Dos.1.3	Usted cree que en comparación con casas más nuevas	Nominal	Use the same codes as Dos.1
Dos.1.4	Usted cree que en comparación con casas más antiguas	Nominal	Use the same codes as Dos.1
Dos.2	Sabe usted si su casa tiene alguno de los dispositivos de eficiencia energética	Nominal	1 = Si tiene; 2 = No tiene; 3 = No sabe
Dos.3	Focos ahorradores o fluorescentes	Numeric	1 = Ya venía con la casa; 2 = Ya venía pero no lo instalamos; 3 = Nosotros lo compramos; 4 = No tenemos; 5 = No sé; 99 = didn't answer
LED	Focos LED	Nominal	Use the same codes as Dos.3
AAC	Aire Acondicionado Central	Nominal	Use the same codes as Dos.3
AAV	Aire Acondicionado de Ventana	Nominal	Use the same codes as Dos.3
AAMS	Aire Acondicionado Mini Split	Nominal	Use the same codes as Dos.3
Cooler	Cooler	Nominal	Use the same codes as Dos.3
Abanicos	Abanico(s)	Nominal	Use the same codes as Dos.3
AislanteTMuros	Aislante térmico en muros	Nominal	Use the same codes as Dos.3
AislanteTTecho	Aislante térmico en techos	Nominal	Use the same codes as Dos.3
CalentadorPaso	Calentador de agua de paso	Nominal	Use the same codes as Dos.3
CalentadorGas	Calentador de agua de gas (tanque)	Nominal	Use the same codes as Dos.3
Dos.4	Sabe quién pagó por los dispositivos que ya estaban instalados en su casa	Nominal	1 = La compañía que construyó las casas; 2 = INFONAVIT o FOVISSSTE; 3 = El municipio; 4 = El Gobierno Federal; 5 = Están incluidos en el precio de la hipoteca de la casa; 6 = Otro; 99 = No aplica
Dos.5	Qué piensa del consumo de electricidad de los Focos Ahorradores	Nominal	1 = Usa mucho menos; 2 = Usa menos; 3 = Usa lo mismo; 4 = Usa más; 5 = Usa mucho más; 6 = No sé
FocoLED	Qué piensa del consumo de electricidad de los Focos LED	Nominal	Use the same codes as Dos.5
AireAC	Qué piensa del consumo de electricidad de los Aires Acondicionados Central	Nominal	Use the same codes as Dos.5
AireAV	Qué piensa del consumo de electricidad de los Aires Acondicionados de Ventana	Nominal	Use the same codes as Dos.5
AireMS	Qué piensa del consumo de electricidad de los Aires Acondicionados MiniSplit	Nominal	Use the same codes as Dos.5
RefrigeradorN	Qué piensa del consumo de electricidad de los Refrigeradores nuevos	Nominal	Use the same codes as Dos.5
RefrigeradorU	Qué piensa del consumo de electricidad de los Refrigeradores usados	Nominal	Use the same codes as Dos.5
CalentadorAPaso	Qué piensa del consumo de electricidad de los Calentadores de agua de paso	Nominal	Use the same codes as Dos.5
CalentadorAGas	Qué piensa del consumo de electricidad de los Calentadores de agua de gas	Nominal	Use the same codes as Dos.5

Dos.10	Qué aparatos o dispositivos se han descompuesto o dejado de funcionar en su casa	Nominal	0 = Ninguno; 1 = Focos ahorradores; 2 = Focos LED; 3 = Aire Acondicionado; 4 = Refrigerador; 5 = Calentador de agua de paso; 6 = Calentador de agua de gas; 7 = Otro
Dos.10.Otro	Otro	Nominal	x = Ningún otro
Dos.11	Si se le ha descompuesto alguno de los dispositivos ahorradores en su casa, ¿Qué hizo al respecto?	Nominal	1 = Lo cambié por uno igual, nuevo o usado; 2 = Lo cambié por uno no ahorrador, nuevo o usado; 3 = Lo mandé a arreglar; 4 = No hice nada, lo dejé de usar (todavía está descompuesto); 5 = No se me ha descompuesto ninguno de estos aparatos
Dos.11.Ejemplo	Dé un ejemplo	Nominal	x = No aplica; xx = No contestó
Dos.12	Desde que vive en esta casa, ¿Le ha hecho alguna mejora o cambio?	Nominal	1 = Si; 2 = No; 3 = No es mi casa, no le puedo hacer cambios
Dos.13	Qué mejoras le ha hecho	Nominal	x = No le ha hecho mejoras
Costo	Cuánto le costó aproximadamente	Scale	99 = No sabe / No contestó; 999 = No le ha hecho mejoras
Tres.1	Cuánto pagó de electricidad en su último recibo	Scale	99 = No recuerda
Tres.2	Cuántos kWh consumió según su último recibo	Nominal	1 = No me fijo en la cantidad de kWh; 2 = No recuerdo
Tres.3	Qué meses cubrió su recibo anterior	String	
Tres.4	Conserva sus recibos de electricidad	Nominal	1 = Si; 2 = No
Cine	Ahora es más probable o menos probable ir al cine	Nominal	1 = Más probable; 2 = Igual; 3 = Menos probable
Concierto	Ahora es más probable o menos probable ir a un concierto u obra	Nominal	1 = Más probable; 2 = Igual; 3 = Menos probable
Expogan	Ahora es más probable o menos probable ir a la ExpoGan o Fistas del Pitic	Nominal	1 = Más probable; 2 = Igual; 3 = Menos probable
Parque	Ahora es más probable o menos probable ir a un Parque de Diversiones	Nominal	1 = Más probable; 2 = Igual; 3 = Menos probable
Paseo	Ahora es más probable o menos probable dar un paseo dentro de la ciudad	Nominal	1 = Más probable; 2 = Igual; 3 = Menos probable
Salir	Ahora es más probable o menos probable salir de la ciudad	Nominal	1 = Más probable; 2 = Igual; 3 = Menos probable
Cuatro.2	En los últimos 6 meses ha pagado por...	Nominal	0 = Ninguna; 1 = Cualquier tipo de clases (arte,pintura,baile,deporte,música) para usted o sus hijos; 2 = Talleres de capacitación para aprender un nuevo oficio o una nueva habilidad que le permitiera mejorar su ingreso; 3 = Cursos educativos o campamentos de verano para los hijos
Comida	Qué tan seguido ha sentido que el dinero no le va alcanzar para comprar comida	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
Servicios	Qué tan seguido ha sentido que el dinero no le va alcanzar para pagar los servicios	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
Gasolina	Qué tan seguido ha sentido que el dinero no le va alcanzar para pagar gasolina o transporte	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca

Hipoteca	Qué tan seguido ha sentido que el dinero no le va alcanzar para hacer el pago de la casa	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
Escuela	Qué tan seguido ha sentido que el dinero no le va alcanzar para pagar por los gastos de la escuela de mis hijos	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
Ropa	Qué tan seguido ha sentido que el dinero no le va alcanzar para comprar ropa y zapatos para la familia	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
Deudas	Qué tan seguido ha sentido que el dinero no le va alcanzar para pagar deudas	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
Ahorrar	Qué tan seguido ha sentido que el dinero no le va alcanzar para ahorrar	Nominal	1 = Todos los días; 2 = Al menos una vez por semana; 3 = Una vez al mes; 4 = Rara vez pienso en eso; 5 = Nunca
cuatro.4	Si tuviera la oportunidad de volver a elegir una casa para compra ¿buscaría una casa que le garantizara usar menos recursos?	Nominal	1 = Si; 2 = No; 3 = No sé
cuatro.5	Si tuviera la opción entre compra una casa con aditamentos para ahorrar agua, gas y electricidad o recibir el dinero equivalente ¿Qué escogería?	Nominal	1 = Los aditamentos ecológicos; 2 = Que me dieran el dinero equivalente; 3 = Un descuento en mis pagos mensuales de hipoteca
Lavadora	Lavadora Consumo de electricidad 1 al 6	Nominal	99 = No sabe/No contestó
Televisio n	Televisión Consumo de electricidad 1 al 6	Nominal	99 = No sabe/No contestó
focos	Iluninación (focos) Consumo de electricidad 1 al 6	Nominal	99 = No sabe/No contestó
AA	Aire Acondicionado Consumo de electricidad 1 al 6	Nominal	99 = No sabe/No contestó
Refrigera dor	Refrigerador Consumo de electricidad 1 al 6	Nominal	99 = No sabe/No contestó
Computa dora	Computadora Consumo de electricidad 1 al 6	Nominal	99 = No sabe/No contestó
Cinco.2	Cuando compra aparatos eléctricos grandes ¿Considera su consumo eléctrico al decidir cuál comprar?	Nominal	1 = Si; 2 = No
Cinco.3	Cuando compra aparatos eléctricos chicos ¿Considera su consumo eléctrico al decidir cuál comprar?	Nominal	1 = Si; 2 = No
Cinco.4	Usted considera que el consumo eléctrico en la casa tenga efectos negativos en el medio ambiente natural	Nominal	1 = Si; 2 = No
Cinco.5	Usted está de acuerdo en que haya leyes más estrictas para proteger el medio ambiente	Nominal	1 = Si; 2 = No
Cinco.6	Usted estaría de acuerdo en pagar una cuota anual para la protección del medio ambiente	Nominal	1 = Si; 2 = No
Cinco.7	Usted cree que es necesario cambiar sus hábitos para reducir el impacto negativo en el medio ambiente	Nominal	1 = Si; 2 = No
Seis.1	Quién es el jefe de este hogar	Nominal	1 = Madre; 2 = Padre; 3 = Hijo(a); 4 = El solo; 5 = Hermano

Seis.2	Edad del jefe del hogar	Scale	Age
Seis.3	Grado de escolaridad del jefe del hogar	Nominal	1 = Primaria; 2 = Secundaria; 3 = Preparatoria; 4 = Escuela Normal; 5 = Estudios técnicos o comerciales; 6 = Licenciatura o profesional; 7 = Maestría; 8 = Doctorado
Seis.4	Con cuántos ingresos cuenta este hogar	Nominal	1 = Solo los del padre; 2 = Solo los de la madre; 3 = Ingresos combinados del padre y madre; 4 = Ingresos combinados de más miembros del hogar
Seis.5	Ingreso total del hogar	Nominal	1 = Hasta $2,200 pesos; 2 = Entre $2,201 y $4,250; 3 = Entre $4,251 y $6,500; 4 = Entre $6,501 y $10,750; 5 = Entre $10,751 y $21,300; 6 = Más de $21,300 pesos
Seis.6	El ingreso del mes anterior fue	Nominal	1 = Lo normal; 2 = Más de lo normal; 3 = Menos de lo normal
GMPknowtheprog	Conoce o ha oido hablar del programa Hipoteca Verde de INFONAVIT	Nominal	1 = Si; 2 = No
GMPdescription	Puede describir brevemente en qué consiste	Nominal	x = No lo conoce
GMPbelong	Sabe si su casa es parte del programa Hipoteca Verde	Nominal	1 = Si es parte del programa; 2 = No es parte del programa; 3 = No sé
GMPbelonghow	Cómo lo sabe	Nominal	x = No aplica
GMPopinion	En general ¿Cuál es su opinión sobre el programa Hipoteca Verde?	Nominal	1 = Es muy bueno, debería continuar; 2 = Es muy bueno pero ya no es necesario, la gente ya busca cómo ahorrar; 3 = Ni tengo ninguna opinión del programa; 4 = Es un gasto innecesario; 5 = Es malo no sirve para nada; 6 = Otro; 99 = No sabe/No contestó

Appendix F

Residential Electricity Tariffs in Mexico

In Mexico, the unit cost per kWh of residential electricity is calculated by region, and depends on the average temperature of the Summer season (defined as the six months with the highest temperatures). There are seven residential tariffs (see Table A1). Hermosillo currently has a 1F tariff. The tariffs are calculated using data from the Secretariat of Environment and Natural Resources (SEMARNAT). Apart from the regional tariff, the cost of electricity varies depending on the monthly consumption, and is defined by a tiered system (see Figure A1). When the average monthly consumption recorded by a household exceeds the higher consumption limit defined for its region, it falls into a special 'high-consumption' tariff called DAC (*Tarifa Doméstica de Alto Consumo*). In regions with hot and dry climates where summer temperatures are extreme, the use of air conditioning systems determines the peak demand (De Buen, 2004; in Solis, 2008; translated by the author).

Table F1
Residential Tariffs

Rate	Up to:		Min. Avg Temp. in summer months
1	250	kWh/mo.	< 25ºC
1A	300	kWh/mo.	> 25ºC
1B	400	kWh/mo.	> 28ºC
1C	850	kWh/mo.	> 30ºC
1D	1,000	kWh/mo.	> 31ºC
1E	2,000	kWh/mo.	> 32ºC
1F	**2,500**	**kWh/mo.**	**> 33ºC**

Note: The case study has a 1F rate.
All data obtained from Comisión Federal de Electricidad's website (2016), table by the author.

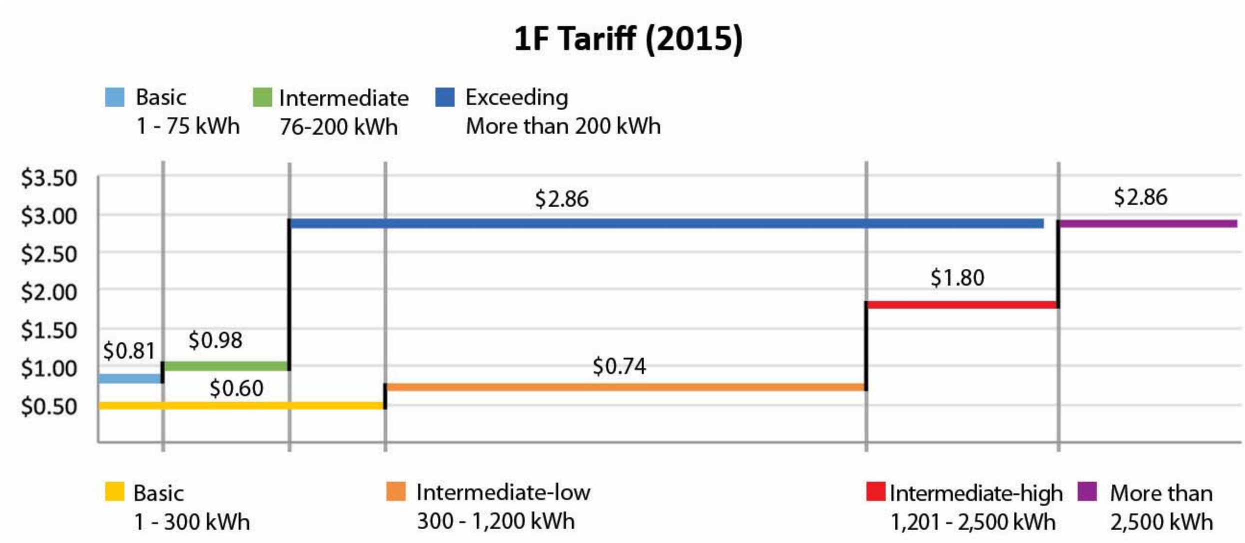

Figure A1. Residential tariffs 1D and 1F for year 2015, including non-summer(top) and summer (bottom) rates.
NOTES: All information obtained from CFE (2016) and translated by the author. All electricity rates are in MXN Pesos and correspond to the year 2015.

References to Appendix F

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Appendix G

Supplementary information on INFONAVIT

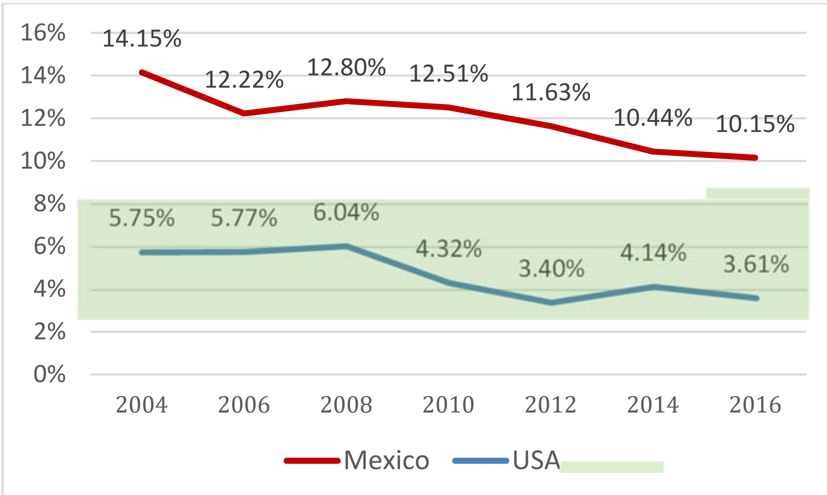

Figure G1. Mortgage rates in Mexico and the US, from 2004 to 2016. The green bar depicts the range of mortgage rates for INFONAVIT, which goes from 4% to 10% and depends on the mortgage holder's income. From 2015 on, the INFONAVIT's mortgage rate went up to 10.5%
NOTES: Chart by the author with data compiled from CONDUSEF (nd); USBANK (nd); Milenio Digital (2014); INFONAVIT, 2014.

Monto del salario integrado en VSMMVDF	Tasa anual de interés ordinario en %	Monto del salario integrado en VSMMVDF	Tasa anual de interés ordinario en %
1.0 a 1.5	4.00%	3.6	7.50%
1.6	4.20%	3.7	7.70%
1.7	4.40%	3.8	7.90%
1.8	4.60%	3.9	8.00%
1.9	4.80%	4.0	8.00%
2.0	5.00%	4.1	8.10%
2.1	5.10%	4.2	8.20%
2.2	5.20%	4.3	8.30%
2.3	5.30%	4.4	8.40%
2.4	5.40%	4.5	8.50%
2.5	5.50%	4.6	8.50%
2.6	5.60%	4.7	8.60%
2.7	5.70%	4.8	8.70%
2.8	5.80%	4.9	8.80%
2.9	5.90%	5.0 a 6.0	9.00%
3.0	6.00%	6.1	9.10%
3.1	6.30%	6.2	9.20%
3.2	6.60%	6.3	9.30%
3.3	6.90%	6.4	9.40%
3.4	7.00%	6.5 a 10.0	9.50%
3.5	7.30%	10.1 y más	10.00%

Figure G2. INFONAVIT Annual interest rates chart for 2014.
SOURCE: INFONAVIT, 2014.

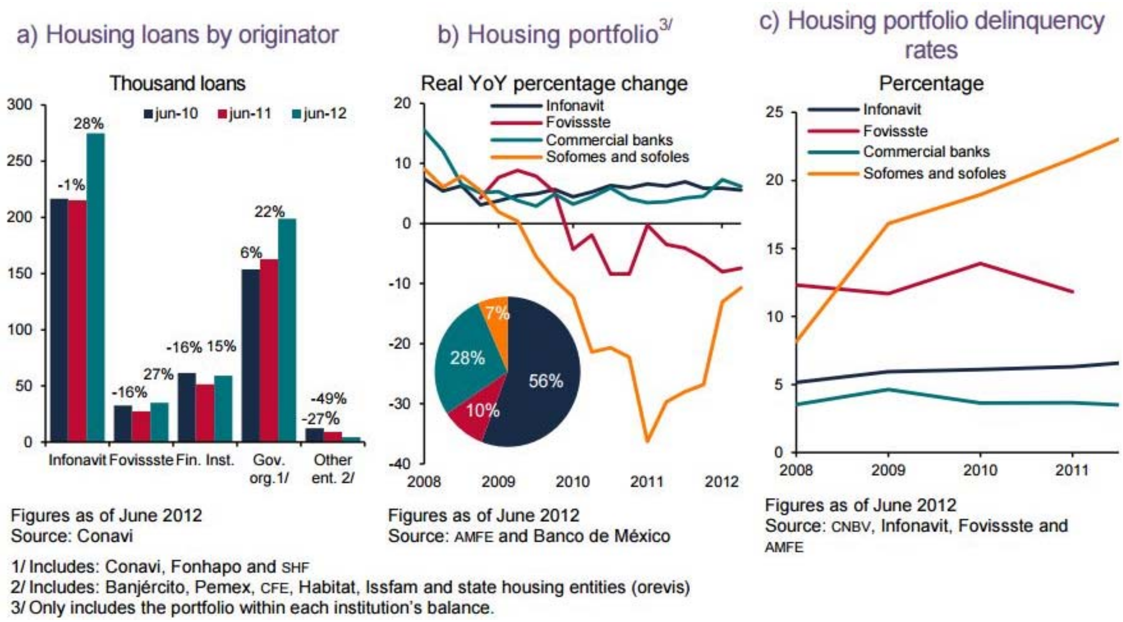

Figure G3. Housing market development indicators for 2012, calculated by Banco de Mexico.
SOURCE: Banco de Mexico, 2012.

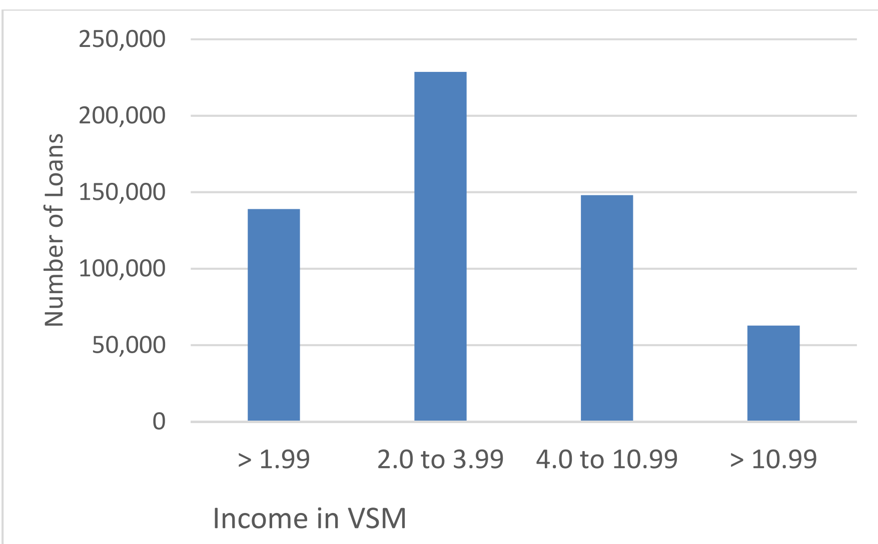

Figure G4. Number of credits granted by INFONAVIT in 2015, per income level.
NOTES: 1 VSM in 2015 equals MXN$2,025, or around US$115 dollars (at the currency exchange rate in May 2016). Chart by the author with data from Créditos Hipotecarios, 2015.

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