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"Socially neglected effect" in the implementation of energy technologies to mitigate climate change: Sustainable building program in social housing

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ABSTRACT

The residential sector is the third largest energy-consuming sector in Mexico and an important contributor to energy related carbon dioxide emissions after transport and industry. The objective of this study is to evaluate the implementation and social acceptance of energy efficient technologies and renewable technologies in the so called sustainable social housing program in Mexico City, and compare the real reduction of CO_2 emissions to the theoretical potential. To do so, two estimations are developed: 1) the technical and economic CO_2 emission reduction potential of energy efficiency and renewable energy technologies in new social housing in Mexico City, and 2) the real avoided emissions based on social acceptance of technologies obtained by housing surveys and physical revision of performance status of implemented technologies. We found that due to lack of information and training to households an important part of dwellers ended up rejecting mitigation technologies developing what we called the socially neglected effect of mitigation technologies. These results were used to estimate three scenarios for year 2025: baseline, mitigation and neglected effect. Due to the neglected effect a reduction of 25% with respect to the baseline scenario was obtained instead of 45% of emission reduction in year 2025. In the case of efficient lighting and refrigerators, where Minimum Energy Efficient Standards are in place the socially neglected effect disappears once the replacement of old to new technologies takes place. This result shows that minimum energy performance standards are the main mitigation policy to eliminate socially neglected effect in the long run. Obligatory standards for installation of solar water heaters can be developed as well, although it is important to develop additional follow-up policies for adequate installation of these technologies.

Introduction

Climate change is one of the greatest and most urgent challenges facing humanity. Cities are an essential part of the problem, as they consume 60 to 80% of the energy produced globally and are responsible for a similar percentage of CO_2 emissions in the world (Kamal-Chaoui and Robert, 2009). In 2014, Mexico City's Metropolitan Area (MCMA), composed by Mexico City and 59 municipalities of the State of Mexico, was ranked as the fourth largest urban agglomeration, with a population of 20.84 million people, projected to grow to 23.87 million in 2030 (CONAPO, 2016). In 2013 emissions from Mexico City were around 37.5 Mt. CO_2e, including electricity consumption accounting for 6% of total emissions in the country (SEDEMA, 2012; INECC, 2013).

According to the growth rates of housing it is estimated that each year 579,036 new homes will be required nationwide in urban areas; from which 48,966 will be needed in Mexico City (SHF, 2016). This could imply a growing demand for energy and an increase in CO_2 emissions if further mitigation policies are not implemented in the country. Nationwide, the residential sector accounted for 15% of total final energy used in 2013 (743 PJ), being the third largest energy consuming sector below transportation and industry (SENER, 2014). Within Mexico City, residential final energy consumption accounts for 14% of CO_2e emissions (including electricity consumption (SEDEMA, 2012), also after transportation (59%) and industry (25%).

Several programs to reduce energy consumption in the residential sector have been developed nationwide since the early 1990s (Friedmann and Sheinbaum, 1998). These programs have had important achievements, especially mandatory minimum energy efficiency standards for residential appliances (Martínez-Montejo and Sheinbaum-Pardo, 2016). In 2007, the National Housing Commission (CONAVI) promoted the green mortgage for sustainable housing that provides additional funds to install energy and water efficient technologies, thermal insulation, as well as solar heaters in new and existing dwellings. From 2007 to 2010 the green mortgage was a voluntary program, but since 2011, it started to be mandatory for all new urban

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dwellings[1]. The Institute for National Housing Funds for Workers (Instituto del Fondo Nacional de la Vivienda para los Trabajadores - INFONAVIT) that give loans for social housing (Table 1), developed this program in new homes (Isunza, 2011). By 2014 it was estimated that 90 thousand dwellings per year were constructed under green mortgage model. More recently, CONAVI introduced new mechanisms for sustainable social housing, under the Nationally Appropriate Mitigation Actions (a set of policies and actions that countries undertake as part of a commitment to reduce greenhouse gas emissions): Mexican sustainable housing NAMA for new and existing dwellings (CONAVI, 2016). As pointed out in the CONAVI document, unlike previous Mexican programs, which have focused on promoting and measuring the impact of specific eco-technologies, the NAMA approaches energy efficiency from a 'whole building' approach. With this perspective, efficiency benchmarks are set for total primary energy demand based on building type and climate. Building developers and home-owners are then able to employ any combination of interventions that achieve the targeted efficiency level (CONAVI and GIZ, 2012).

At the Mexico City level, the local government entity responsible for financing social interest housing is the Housing Institute of Mexico City (INVI) which is responsible for enforcing legal action and to design, propose and contribute to the integration, coordination, analysis and implementation of housing policy and housing programs in Mexico City. From 2008 to 2012, a sustainable building project for social housing was implemented in Mexico City as part of the City's Climate Change Action Plan (SEDEMA, 2008; INVI, 2008). Some of the technologies that have been incorporated in the Sustainable Housing Program are: solar water heating systems, efficient lighting (compact fluorescent lamps, CFLs), photovoltaic cells for outdoor lighting, water saving devices (aerators, low-flow showers and taps dual-flush toilets), water recovery systems, grey or soapy water treatment for reuse in toilets, and rainwater harvesting systems for watering gardens and washing cars.

The objective of this study is to evaluate the implementation and social acceptance of energy efficient technologies and renewable technologies in the sustainable housing program in Mexico City, and compare the real reduction of CO_2 emissions to the theoretical potential. To do so, two estimations are made: 1) the technical and economic CO_2 emission potential of energy efficiency and renewable energy technologies in new social housing in Mexico City, and 2) the real avoided emissions based on social acceptance of technologies obtained by housing surveys and physical revision of performance status of implemented technologies.

There are several studies on consumer appropriation of energy saving technologies. Egan et al. (1996) studied how customers interpret and use comparative graphics of their energy use. In the early eighties Khazzoom (1980) introduced the concept of rebound effect, meaning that technological progress makes equipment more energy efficient, and a price decrease normally leads to increased consumption in the same commodity or in the acquisition of others. Since then, many discussions and estimations of the rebound effect have been developed (Berkhout et al., 2000; Binswanger, 2001; Herring, 2006; Gillingham et al., 2016). In the case of the rebound effect, it is assumed that either energy efficient or renewable energy technologies are adopted by the consumer. However, there are multiple cases of not socially acceptance of technologies or "socially neglected effect", especially related to energy and environmental governmental programs. For this reason it is highly important to evaluate sustainable housing programs and the reason of the "socially neglected effect" of energy technologies. The discussion on socially acceptance of renewable energy and energy savings technologies in households is gaining importance in recent years.

[1] There have been some criticism about these program because most of the new dwellings were built in housing compounds outside the city limits. For example Centro Mario Molina (2012) presents a life cycle analysis that shows an important increase in home-work trips that increased emissions from transportation, from inhabitants in social housing compounds.

Table 1
Social housing in Mexico City (thousands).

	Population	Total dwellings	New housing	New social housing	INVI Housing
2010	8847	2454	4.78	2.99	2.07
2015	8919	2601	11.08	1.13	1.69
2020	8991	2758	13.23	8.20	2.29
2025	9065	2924	14.03	8.69	2.43

Data for population and dwellings from 2010 to 2025 is from CONAPO (2016). New housing from 2010 to 2015 is from CONAVI (2016); INVI housing from 2010 to 2015 is from INVI (2012). Projections for 2020 and 2025 for the two last columns are estimated based on the annual rate of growth of total dwellings.

Many recent academic articles discuss behavioral, cultural, comfort and other social variables that influence real energy savings and avoid greenhouse gas (GHG) emissions. Some of them are cited below.

In a study of energy intervention in the residential sector in the south of Spain authors found that in many cases there is no direct relationship between estimated energy demand and real energy use, and the low energy rate (the reduction in electricity tariff due to implementation of energy efficient technology) is combined with deficiencies in comfort conditions (Sendra et al., 2013). Gabriel and Watson (2013), studied how occupants and their dwellings are adapting to reduce home energy consumption and established that drawing on people's experiences of installing solar hot water systems, sustainable home adaptation was not a straightforward process whereby occupant aspirations were delivered through building adaptation. The role that comfort, habit, and knowledge play in the energy savings for space heating system in London were also developed by Huebner et al. (2015). They explained that some important variables are a deficit in the quality and quantity of instruction on how to use the heating systems.

Moezzi and Kathryn (2014) discussed a notion of "social potential" that affords a broader possible contribution of social sciences to improved understanding of building energy use and how policies might reshape this use. They suggest social potential as a formulation that complements and transcends the technical and behavioral savings potential concepts underpinning much of today's building energy efficiency policies, programs, and research. Heinonen and Junnila (2014) studied residential energy consumption patterns in urban and rural households in Finland, and they found that behavioral differences seem significant between different housing modes.

A research on retrofitting social housing in the UK show that retrofit programs will reduce carbon emissions to some degree, whereas the bigger challenge is addressing habitual household energy consumption (Elsharkawy and Rutherford, 2015). Morgenstern et al. (2015) in relation to the heat consumption measured by meters, they found that it is influenced by both the dwelling characteristics and the behavior of the occupant, but heating charges would ideally relate to occupant behavior only. In a research by Huebner et al. (2015) on comparative contribution of building factors, socio-demographics, behaviors and attitudes, they found that retrofitting and behavior change initiatives remain important avenues to reduce consumption. Another important study on energy technologies conducted in the municipality of Kil in west central Sweden assessed using a questionnaire. Results indicate that respondents have such a low level of information and knowledge about new energy technologies that they are unable to discriminately rank them (Assefa and Frostell, 2007). Monreal et al. (2016) explore energy consumption through the appreciation and appropriation of domestic lighting in the UK, explaining that moving towards more sustainable lighting futures, more attention should be paid to how lighting is appreciated and appropriated through everyday practices in the home.

Huelsz et al. (2011), analyzed passive solar systems in dwellings constructed under the green mortgage in five regions of Mexico. They found that less than 50% of the dwellings were developed correctly,