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HOGARES SOLARES

# Design and development of a pilot program to address energy poverty in Mexico

## MILESTONE 2

INICIATIVA CLIMÁTICA DE MÉXICO

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## Executive Summary

Iniciativa Climática de México (ICM) has supported key stakeholders for the development of a solar residential program for electricity users in Mexico that are benefitted of a subsidized tariff thus, there is not a financial reason for installing a PVDG System.

ICM and its stakeholders have performed financial feasibility and pre-feasibility studies of the project for the utility, and the government, and deduces an impact for the client as the project is designed to present a 15 to 20 per cent discount in their electricity bill. But was does that means for a household? and how can that be translated in a reduction of poverty, specifically of energy poverty in Mexico?

The present study focuses on the positive impact on household welfare, understood as the change in consumption of subsidized product or other products due to a change in the price of a subsidized product. This type of study is usually conducted prior implementing a fiscal policy to understand what the impact of the policy will be for the households. In this case, the Project is proxied as the policy that causes a change in the price of the subsidized product.

The result, as expected is positive for the households that participate in the project. Furthermore, accompanied by the communication in EE that the project has, and by conducting a survey before and after, ICM and the projects stakeholders can measure the positive impact that the project is having in translating the benefits in household welfare to ways to address multidimensional energy poverty.

## Literature Review

In recent times, the advancement of technology has increase energy consumption for the satisfaction of individual needs. New investment in energy infrastructure has accompanied the increment in energy consumption, but it has not been enough nor ubiquitous, thus, it has increased social inequality and the poverty gap. The lack of resources, infrastructure, or technology as well as the inability to pay energy bills, has promoted the use of other sources, such as wood, kerosene, and fuel, to satisfy household´s energy requirements, resulting in health damage and higher emissions.

The link between lack of access to energy and poverty has been recognized and has acquired more relevance resulting in a special treatment to study energy and the relationship with social factors. The Agenda 2030 through its 7$^{th}$ Sustainable Development Goal (SDGs) recognizes affordable and clean energy for all as a strategy to end poverty and improve health and education, reduce inequality, and spur economic growth.

The energy poverty concept has been developed from the efforts to characterize how energy needs are satisfied in a household, as well as the improvement of its measurement, going from simple indicators with binary answers to multidimensional approaches with multiple indicators. According to Culver (2017), 4 different classifications of energy poverty can be found in the literature: access to services and fuels, income and expenditure in energy, people capabilities, and multidimensional or complex definitions. While the first classification is limited only to considering whether people have access to energy without any consideration of its quality or supply; the second focuses on the inability to afford energy prices because of expensive prices or low income. Therefore, the most comprehensive definitions are which consider multidimensional approaches, including qualitative and quantitative aspects, as well as access to services, income, and subjective characteristics. However, due to the lack of available information, measurements of multidimensional energy poverty tend to be complicated.

In the specific case of Mexico, there are studies and attempts to define energy poverty, but there is not an official definition in the legislation. 99.5% of the Mexican population has access to electricity services, while only 85% has access to modern and clean cooking technology. However, such values do not reflect whether the energy supply is adequately used or whether the quality of the electrical service is sufficient to meet the needs of Mexicans. Consequently, several studies have been carried out to measure energy poverty in Mexico based on the consideration of other aspects.

According to García (2016), 11 million households in Mexico cannot satisfy their absolute energy needs and therefore, experience deprivation of at least one of the economic goods proposed in his research. On the other hand, Peñaloza (2019) identified that 1.2 million households suffered from severe energy poverty, they cannot satisfy 40 per cent of their energy needs, and that the lower socioeconomic stratum households were 12 times more likely to be in severe energy deprivation than someone in medium stratum and 251 times more susceptible than the upper stratum population.

Mexico's solution to reduce energy poverty and achieve 99.5% of energy access is its tariff system. Depending on the region of the country and the climate, the residential electricity system in Mexico can be classified into 8 highly subsidized tariffs. The electricity subsidy represents one of the most significant expenses for the federal government, and it is destined to subsidize one of the main emitters of greenhouse gases (GHG) in the country. The budget exercised as a subsidy to electricity tariffs grew 24.6% per year in real terms from 2016 to 2018, going from $48.29 thousand million pesos to $83.94 thousand million pesos. The electricity subsidy represents a spending on regressive policies that are an unsustainable burden for Mexico's government and its citizens.

The NDC estimates that the electricity sector will emit 202 MtCO2e in 2030, while the resulting emission factor of the grid would be 0.44 tCO2e/MWh in a business as usual (BAU) scenario. However, to comply with the NDC, the emission factor should be 0.31 tonCO2e/MWh, a value that requires a significant penetration of clean energy generation.

The decarbonization of the energy sector contributes to the fight against energy poverty by facilitating the distribution of renewable alternatives in marginalized communities. The Hogares Solares Program is one alternative that could contribute to reduce electricity cost, mitigate climate change, achieve the energy transition goals, and comply with the Sustainable Development Goals (SDG) in terms of poverty alleviation.

## Business Case of the Hogares SolaresProgram

The Hogares Solares Program (HSP) was developed as an initiative between ICM and different stakeholders to democratize energy, protect the climate and achieve greater social welfare. The HSP intends to assess the feasibility of redirecting the current residential electricity subsidies into investments in energy efficiency (EE) and solar photovoltaic (PV) distributed generation (DG) measures, partially funded by the state and the user.

The HSP is a high impact effort designed to reallocate the residential tariff subsidy as funds for the implementation of EE measures and PVDG systems in the homes of residential users with technical feasibility to satisfy their current electricity demand through renewable energy, as well as to generate an additional volume to feed the grid. As a result, residential users will further enjoy a 15 to 20% reduction on their electricity bills. It is expected that PVDG will become competitive for 100% of the residential sector, compared to the current situation limited to a 0.5% niche of non-subsidized residential users.

The feasibility of the program will be demonstrated by quantifying the costs and benefits for the subsidized residential user by calculating the direct welfare effects of the project; the State, through the avoided subsidy; the electricity company; and the technology provider following the implementation of PVDG systems and EE measures under the HSP framework.

## Methodology

The benefits and impacts generated through the HSP will be assessed by estimating the project's direct effects on welfare. Following Araar and Verme (2012), a first static incidence analysis (SIA) will be used to examine the current distributional status of subsidies across households without considering the impact of the Project, followed by an impact on welfare for the beneficiaries that enroll in the HSP.

The SIA provides the baseline against which to evaluate any program or project that changes subsidies. The SIA can provide insights concerning the government's cost burden on subsidies, on the beneficiaries and the extent of such benefits. The analysis will also give insights on the targeting performance of the program, hence its effectiveness on poverty reduction and income redistribution.

The SIA of the HSP was developed based on the approach proposed by Komives et al (2009), Angel-Urdinola and Wodon (2005) and Ore et al (2017). In such an approach, it is necessary to calculate the average electricity consumption and the financial value of the subsidy.

The calculation of the average price of electricity per household was performed using data from the National Survey of Household Income and Expenses (ENIGH) 2018. The ENIGH provides a statistical overview of the behaviour of households regarding income and expenses. Beyond indicating the origin, amount, and distribution of available resources per household, the ENIGH provides information regarding the occupational and socio-demographic characteristics of its members, as well as the existing housing infrastructure and availability of household appliances. Furthermore, the ENIGH offers state-level representations, providing estimates for both urban and rural areas.

The average unit price of electricity (AUP) faced by each household is obtained by dividing the total electricity expenditure per household over the total quantity of electricity consumed. Based on the ENIGH 2018 dataset, the AUP for Mexico was obtained by dividing electricity consumption over the corresponding tariff schedule. Due to the complexity of the tariff system in Mexico, the subsidized tariff was applied by state instead of municipality using values as of January 2021. Table 1 shows the tariff structure applied to the selected states.

**Table 1: Description of the different electricity tariffs used for the analysis.**

| Electricity Tariff | Basic consumption | Intermediate Consumption | Excess Consumption | High Consumption | States for which the tariff was applied for the analysis |
|---|---|---|---|---|---|
| **1** | <=75 kWh | >75 & <= 140 | >140 | | Aguascalientes<br>Tlaxcala<br>Estado de México<br>Jalisco<br>Ciudad de México<br>Querétaro<br>Hidalgo<br>Guanajuato<br>Puebla<br>Oaxaca<br>San Luis Potosi |
| | 0.855 | 1.034 | 3.026 | | Zacatecas |
| **1A** | <=100 kWh | >100 &<= 150 | >150 | | Morelos<br>Nayarit<br>Chiapas<br>Colima |
| | 0.759 | 0.884 | 3.026 | | Michoacán |
| **1B** | <=125 kWh | >125 &<= 225 | >225 | | Guerrero<br>Veracruz<br>Quintana Roo<br>Yucatán |
| | 0.759 | 0.884 | 3.026 | | |
| **1C** | <=150 kWh | >150 & <=300 | >300 & <=450 | >450 | Nuevo Léon<br>Coahuila<br>Campeche |
| | 0.759 | 0.884 | 1.137 | 3.026 | Tabasco |
| **1D** | <=175 kWh | >175 &<= 400 | >400 &<= 600 | >600 | Chihuahua<br>Durango<br>Tamaulipas |
| | 0.759 | 0.884 | 1.137 | 3.026 | |
| **1E** | <=300 kWh | >300 &<= 750 | >750 &<= 900 | >900 | Baja California Sur |
| | 0.627 | 0.788 | 1.023 | 3.026 | Sinaloa |
| **1F** | <=300 kWh | >300 &<= 1200 | >1200 &<= 2500 | >2500 | Baja California |
| | 0.627 | 0.788 | 1.917 | 3.026 | Sonora |

On the other hand, the financial value of the subsidy (S) for each household is calculated by subtracting the AUP paid by the household from the operating cost and multiplying the resulting value by the total amount of electricity consumed. For the case of Mexico, instead of using the operating cost per kwh, the values of the DB1 and DB2 tariffs will be used even if they were officially published in 2019 but have not yet been implemented. To simplify the analysis, state tariffs were used instead of municipal tariffs. For the geographic region of Valle de Mexico, the three corresponding tariffs were averaged, and the resulting tariff was applied to the municipalities and mayoralties of both Mexico City and the State of Mexico. Table 2 shows the applicable DB1 and DB2 tariffs.

**Table 2: Applicable DB1 and DB2 tariffs for the different Mexican Geographical Division.**

| Geographical Division | Categories | | States |
|---|---|---|---|
| | DB1 | DB2 | |
| | < 150 | >150 | |
| **Baja California** | 0.7060 | 0.8045 | Baja California Norte<br>Baja California Sur |
| **Bajío** | 11.052 | 0.9471 | Aguascalientes<br>Guanajuato<br>San Luis Potosí<br>Quintana Roo<br>Zacatecas |
| **Centro Occidente** | 14.857 | 12.732 | Colima<br>Michoacán |
| **Centro Oriente** | 13.827 | 1.849 | Tlaxcala<br>Hidalgo<br>Puebla |
| **Centro Sur** | 15.600 | 13.368 | Morelos<br>Guerrero |
| **Golfo Centro** | 10.749 | 0.8705 | San Luis Potosí<br>Tamaulipas |
| **Golfo Norte** | 0.7820 | 0.6333 | Nuevo León<br>Colima |
| **Jalisco** | 15.844 | 13.578 | Jalisco<br>Nayarit |
| **Noroeste** | 0.8682 | 0.6860 | Sinaloa<br>Sonora |
| **Norte** | 13.021 | 11.532 | Durango<br>Chihuahua |
| **Oriente** | 15.090 | 12.931 | Veracruz |
| **Peninsular** | 0.9857 | 0.8160 | Campeche<br>Quintana Roo<br>Yucatán |
| **Sureste** | 13.169 | 11.285 | Chiapas<br>Oaxaca<br>Tabasco |
| **Valle de México Centro** | 0.7329 | 0.6281 | Ciudad de México |
| **Valle de México Norte** | 0.9450 | 0.8098 | Estado de México |
| **Valle de México Sur** | 0.9101 | 0.7806 | |

$$Si_{i,r} = (\mathrm{DB1}_{\mathrm{i,r}} - \mathrm{CFE}_{\mathrm{i,r}}) * \mathrm{h}_{\mathrm{i,r}} + (\mathrm{DB2}_{\mathrm{i,r}} - \mathrm{CFE}_{\mathrm{i,r}}) * \mathrm{k}_{\mathrm{i,r}}$$

**$S_{i,r}$** = Amount in pesos for Avoided Subsidy in month i, applicable to region r.
**$DB1_{i,r}$** = DB1 tariff in MXN/kWh in month i, applicable to region r.
**$DB2_{i,r}$** = DB2 tariff in MXN/kWh in month i, applicable to region r.
**$CFE_{i,r}$** = CFE Tariff in MXN/kWh in month i, applicable to region r.
**$h_{i,r}$** = Sum of the consumption in kWh of the End Users of the Program in month i, applicable to region r, whose consumption in month i is equal to or less than 150 kWh.
**$k_{i,r}$** = Sum of the consumption in kWh of the End Users of the Program in month i, applicable to region r, whose consumption in month i is greater than 150 kWh.

If the subsidy calculation is positive, it can be assumed that the household received a subsidy. A negative calculation of the subsidy implies that the household did not receive a subsidy but rather cross-subsidized other households. The calculation of the financial value of a subsidy received by households is known as the price gap approach. The foregoing is relevant for understanding the effect that subsidies have on the use of public funds, since it accurately measures the government cost burden of providing the subsidy (Komives et al, 2005).

## Impact of the Program: Estimating welfare changes due to Hogares Solares

Following the report of Maboshe et al. (2017) on the welfare impact of a change in the electricity subsidies, ICM analyzed the welfare impact of two Hogares Solare pilot projects developed for two regions of Mexico. Although the same methodology was followed for both projects, the welfare impact considered the independent characteristics of the pilot projects. Table 3 shows the different characteristics that were considered for the analysis.

**Table 3: Characteristics of the Pilot Project in 2 different Mexican Regions.**

| | **Mexico City** | **FIPATERM** |
|---|---|---|
| **Geographic location** | Mexico City | Sonora and Baja California |
| **Number of Solar Rooftops** | 530 | 1500 |
| **Electricity tariff** | 1 | 1F |
| **Mean average kWh Consumption per year that the system will cover** | 1200 | 3000 |
| **Characteristics of the beneficiary household** | Concrete rooftop | Concrete rooftop |
| | Single family home | Single family home |
| **Mean average kWh consumption per year per household** | Up to 1300 kWh | Up to 3500 kWh |

The number of beneficiary households for each project is chosen randomly with the characteristics mentioned above, and the following formula is used to measure the direct impact:

$$(x)\ \partial \text{logYdir} = \text{Si} * (1 - \varepsilon)\ \partial \text{logP}$$

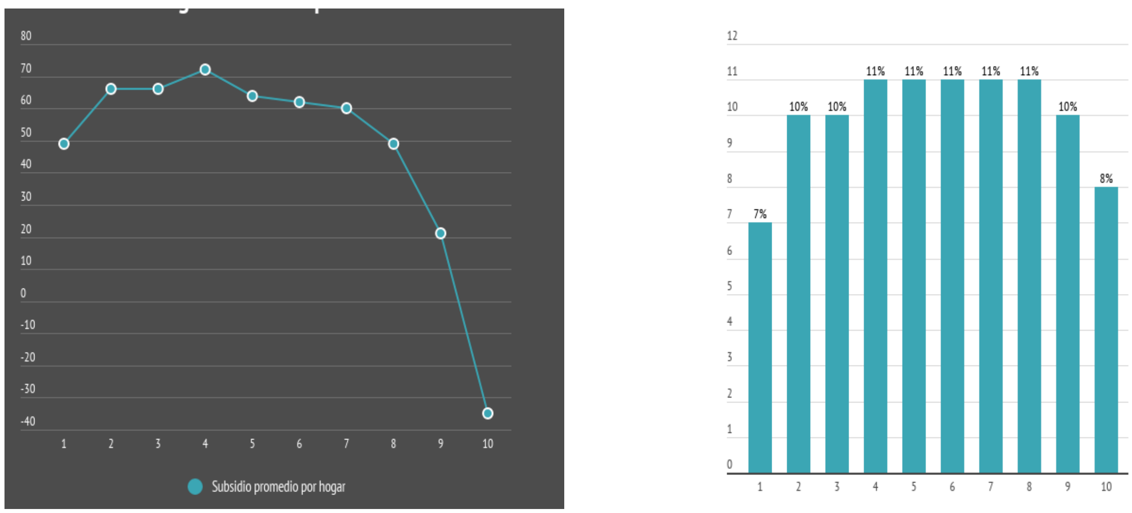
**∂logYdir** is the direct expenditure effect.
**si** represents the budget share of electricity expenditure for a given household.
**ε** represent the price elasticity of demand for electricity.
∂logP the electricity price change with the installation of the PVDG System in their household.

The price elasticity of demand benefits the analysis by considering how the change in price affects consumer behavior in the short run. The value considered for the price elasticity of demand was -0.14 and was obtained from both the World Bank (2009) and the demand model derived by CFE. Over time, price is not the only factor affecting demand, but the long-term impact of the project is beyond the scope of this paper.

## Results

The total amount of electricity subsidies reported in this paper is estimated as the difference between the market value of electricity consumed per household and the discounted electricity expenditures reported by the survey. The analysis shows that on average all deciles benefit from government spending to subsidize households' average electricity consumption. Only households in the richest quintiles pay an average of MXN 34 per month, which is well below the cost of the service for electricity consumption. The following graphs show the incidence analysis of the Mexican subsidy by decile.

**Image 1: Results of the incidence analysis of the Mexican subsidy by decile.**

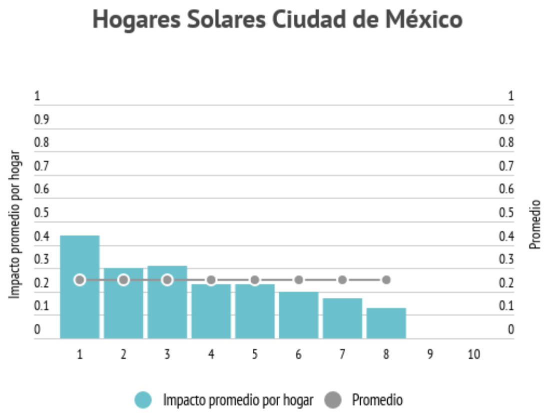


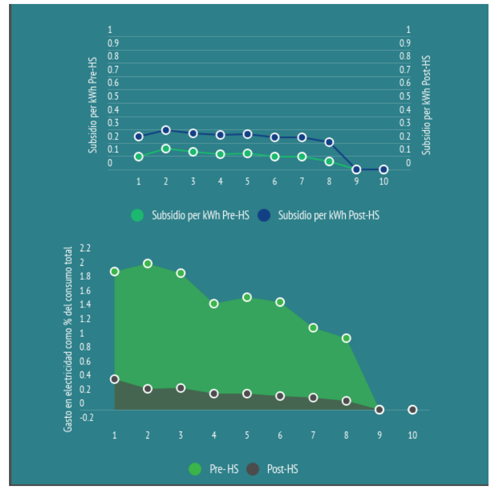

## Direct Impact on Welfare Hogares Solares Mexico City

The Mexico City Pilot Project will consist of approximately 500 households that consume on average 1200 kWh a year. To model the impact of the Project, 500 households were chosen randomly. On the one hand, the housing infrastructure included a concrete roof and served as a single-family dwelling. Socioeconomically, the household should be among the first and eighth decile, with an average electricity consumption of 1300 kWh per month. If the household’s monthly electricity consumption exceeds 1200 kWh, which would be generated through the PVDG system, the excess will be paid through the electricity bill and the tariff 1 scheme.

During modelling, it was assumed that the households would have a 20% reduction in the yearly electricity consumption of 1200 kwh. The results show that there is an average welfare impact of 0.25%, as well as that the project is pro-poor since the poorest deciles will obtain a higher welfare impact. It was also observed that the program influences affordability because it reduces the proportion of household spending on electricity consumption, without increasing the price per kwh. This can be observed in all deciles, from the first to the eighth, with the second decile receiving the greatest impact.

**Image 2: Welfare Impact Results for the Pilot Project in Mexico City.**



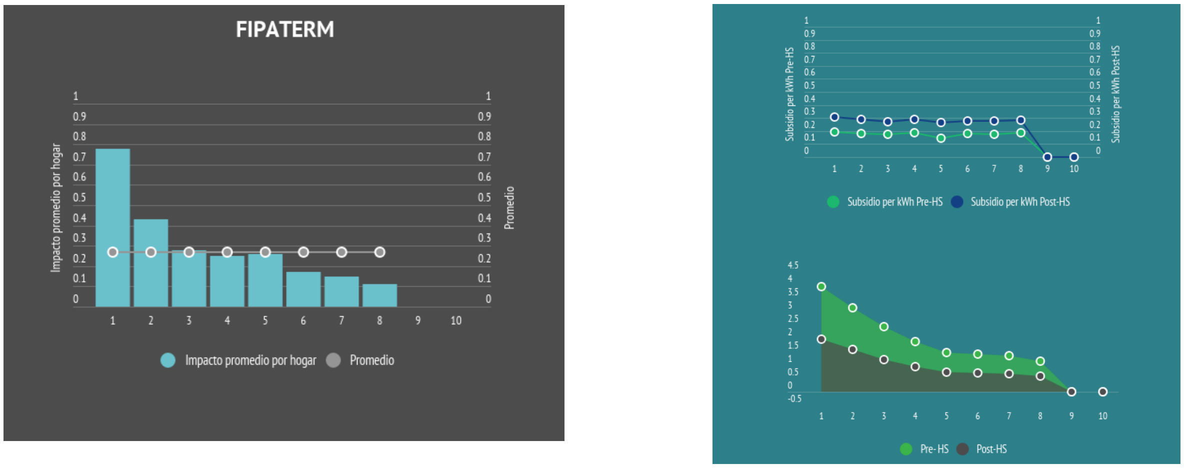




## Direct Impact on Welfare Hogares Solares FIPATERM

The Mexico City Pilot Project will consist of approximately 15000 households that consume on average 3000 kWh a year. To model the impact of the Project, 1500 households were chosen randomly in the states of Sonora and Baja California. The housing infrastructure included a concrete roof and served as a single-family dwelling among the first and eighth decile, with an average electricity consumption of 3500 kWh per month. If the household's monthly electricity consumption exceeds 3000 kWh, which would be generated through the PVDG system, the excess will be paid through the electricity bill and the tariff 1F scheme.

The households were modelled to have a decrease of 20% of their consumption for the first 3000 kWh a year. The results show that there is an average welfare impact of 0.25%, as well as that the project is pro-poor since the poorest deciles will obtain a higher welfare impact. It was also observed that the program influences affordability because it reduces the proportion of household spending on electricity consumption, without increasing the price per kwh. This can be observed in all deciles, from the first to the eighth, with the fifth decile receiving the greatest impact.

**Image 3: Welfare Impact Results for the Pilot Project in FIPATERM.**




The results for both projects are as expected, positive for the households that participate in HSP. Furthermore, the results give us a detailed picture of how the project will benefit differently each household by its consumption level. This information provides a possibility to provide bigger discounts to households in the lower quintiles so to increase the pro-poor qualities of the program.

Furthermore, it provides the opportunity to put in place indicators to measure how the households benefitted by HSP are making use of their welfare increase in the short, medium, and long term. It is ICM's belief that to accompany the project with a comprehensive campaign on energy efficiency and energy consumption savings, can have a positive impact in how these households address their energy needs such as entertainment, cooking and cooling food, cooling and heating services, and hygiene. All of which are main components to measure multidimensional energy poverty in Mexico.

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