The Impacts of Massive Adoption of Distributed Photovoltaic Systems in Mexican Households: A Simulation Approach

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See footnotes at end of test.

Overview

Mexico plans to implement a program to support the adoption of distributed photovoltaic generation (DPVG) in households aiming to reduce the burden of substantial energy subsidies and increase the share of renewable sources used to generate electricity. In this study, we assess the current conditions under which the residential electricity sector operates, and quantify the potential effects that the massive adoption of DPV systems would have on household expenditure and welfare, government revenue, and environment. Based on the optimistic results, our study provides strong support for further design and implementation of a DPVG program.[1]

The context

About 90% of total energy consumption in Mexico comes from fossil fuels, making the country the 13th largest GHG emitter in the world (Mexico represents approximately 1.4% of global emissions).[2] The environmental goals derived from the COP-21 held in Paris (December 2015) require that 35% and 43% of domestic energy should come from renewable sources by 2024 and 2030, respectively. Additionally, the Mexican Energy Reform of December 2013 opened an important window to introduce renewable sources in the electricity generation mix.

To be more concrete, electricity generation explains more than 20% of total GHG emissions and the residential sector accounts for 25% of total electricity consumed. In this context, taking advantage of the fact that more than 75% of the country has an isolation greater than 5 kWh/m2/day, seems to be a very promising opportunity.[3]

On the other hand, the federal government, through the state-owned electricity company (CFE), promotes excessive residential electricity consumption by subsidizing 98% of Mexican households, which on average pay approximately 40% of the total electricity cost -i.e., generation, transmission, distribution and commercialization costs. The resulting fiscal burden has consistently increased during the last decade and currently represents more than 0.5% of the GDP. Moreover, given the universal and uniform application of this subsidy, the tariff scheme magnifies the inclusion error, wasting valuable resources. All this happens in a country where poverty and inequality are significant social problems.

With all the above in mind, an ambitious plan aiming to deploy DPV systems among Mexican households could help solve some of the challenges the country is currently facing.

Empirical methodology

We simulate the implementation of a massive distributed photovoltaic generation (DPVG) program in the Mexican residential sector. In doing so, we first use the System Advisor Model (SAM) provided by the National Renewable Energy Laboratory (NREL) and simulate the performance of residential PV systems for typical users located in each CFE distribution region and tariff category. We consider a representative system that has one single orientation (190° azimuth and 5° inclination), 1:1 DC-AC conversion efficiency, 1.6% inverter efficiency, and 0.5% performance degradation per year. We also use information of a typical meteorological year and assume a standard investment cost of 1.87 USD per WDC. The annual operation and maintenance cost is assumed to be 3.74 USD per KW of PV capacity installed.

Second, we use the 2014 National Household Income and Expenditure Survey (ENIGH-2014) collected by the Mexican National Institute of Statistics and Geography (INEGI), the CFE tariff schedules, and the taxes in effect during the sample period to recover the quantity of electricity consumed by each household.

Third, we establish some requirements to select the group of households that are able to adopt solar panels in their rooftops. Since our goal is to provide an upper bound of the potential program effects, we assume that each household that qualifies as an adopter, does install the corresponding DPVG technology. Concretely, we restrict our attention to dwellings which can support the solar panel structure. We only include independent houses and exclude departments in multi-floor buildings, or commercial premises used as housing. We assume solar panels can only be installed by houses that are occupied fully by the owners. We also assume that only those households with a generation capacity able to cover the total electricity consumption needs are the ones adopting the solar panels. Finally, to simulate the program impact, we assume connection to the grid is done under a net metering scheme with 2014 end-user electricity tariffs.[4]

As a result of all the above, half of the residential users will be potential DPV system adopters. Finally, to simplify our empirical exercise, we do not consider any specific financing alternative and assume that households pay the initial investment in full during the first period. We also assume a uniform discount rate equal to 2%, which is equivalent to the average real interest rate for time deposit during the last five years in Mexico. Finally, we suppose each household electricity spending grows at a 0.5% annual rate (measured in real terms).

Results

The main outcomes of our simulation are as follows. Average annual levelized savings for household electricity spending is 47.6 USD. The implicit payback period is 16 years and the associated internal rate of return (IRR) is approximately 6%. These three figures change to 47.7 USD, 12.4 years, and 9.7%, when efficient opportunity cost pricing is assumed, instead of the current subsidized pricing policy of CFE.

Government savings amount to approximately 1.6 billion of USD annually. This number correspond to the avoided electricity subsidy net of missed revenues from value added tax (VAT), while public lighting spending will remain in place.

The emissions savings are: 69 thousand tons of SO_2, 46 thousand tons of NO_X, and 12 million tons of CO_2. Those numbers correspond to a 1% reduction of total emissions projected under the INDC mitigation unconditional scenario (Mexico Gobierno de la Republica, 2015), and approximately 9% of the 2020-2030 emission reduction target for the electricity generation sector. Addionally, there will be about 13 million m^3 of water savings.

Conclusion

The implementation of a massive DPVG program in the Mexican residential sector would bring more gains than losses. That is true both in economic and environmental terms. Even though residential users are quite heterogeneous, we identify patterns that are common to most of them. Hence, from the perspective of a representative user (e.g., the average user), the initial investment outlay is more than compensated by the reduction in CFE electricity bill.

On the other hand, the current electricity consumption subsidy plays a negative role since for many users it is more attractive to continue paying low energy prices than afford a costly capital investment necessary to install a DPV system.[5] Even for a vast group of households that has an estimated positive net present value from the DPV system adoption, the corresponding payback period is too long to support such an investment. The situation would be quite different if electric prices reflected the true opportunity costs. In that case net present values and IRR would be higher, and the payback period would be considerably shorter. However, returning to opportunity cost pricing seems not to be an option under the current political situation. Moreover, a social tariff scheme that correctly target the poor and excludes high-income households from the subsidy is not even discussed. In that context, a partial transformation of the electricity consumption subsidy to a DPV system adoption subsidy could be a good policy alternative.

From the government perspective, each household adopting the PV technology can represent a reduction in the subsidy account. A low politically costly way to do so would be through a mechanism under which the government replaces the current electricity consumption subsidy with a (temporal) DPV system adoption subsidy. In this setting, residential adopters would not suffer from the negative financial effect implied by the costly capital investment during the transition, and the government would simply transfer the resources from one subsidy account to another. In the medium- to long run, all agents involved would benefit from this policy.

Footnotes

[1] For a full version of this paper, see Hancevic et al. (2017).

[2] See, for example, Damassa et al., 2015, or Mexico Gobierno de la Republica, 2015.

[3] Other countries, such as Germany and Spain, are currently recognized as the world leaders in installed PV systems. However, Mexico's solar potential resources are far superior and could be considered among the largest in the world (see SENER, 2016).

[4] There are at least two alternative ways of selecting the set of potential adopters. One is to estimate the probability of household DPVG technology adoption using some specification that incorporates household and dwelling characteristics. Unfortunately, the number of households that already adopted some DPV system is quite small in Mexico and then it is not possible to estimate such probability. The second alternative is to conduct a meta-analysis looking closer at emerging countries. Regretably, to the best of our knowledge there are not studies that estimate adoption in emerging countries. In addition, the meta-analysis approach could suffer from serious errors due to the matching of variables and the absence of information on characteristics that are relevant for Mexico but probably not for other countries (or vice versa).

[5] For a detailed discussion about the relative advantages/disadvantages of implementing a capital subsidy scheme (that support energy efficienct and clean technology adoption) versus the current electricity consumption subsidy see Hancevic et al. (2017).

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