USAID
FROM THE AMERICAN PEOPLE

EE4D
Energy Efficiency for Development

ENERGY EFFICIENCY FOR DEVELOPMENT PROGRAM (EE4D)

SUCCESS STORY: AIR CONDITIONING ELECTRICITY MONITORING IN SONORA, MEXICO

November 2020

INTRODUCTION

Energy efficiency policies support important goals in developing countries, such as reducing fuel imports, reducing energy cost burdens in low-income households, and reducing power sector capital requirements to meet increasing electricity demand.

The United States Agency for International Development's (USAID's) Energy Efficiency for Development Program (EE4D), in partnership with the Lawrence Berkeley National Laboratory, supports planning and implementation of effective energy efficiency policies for partner countries. EE4D technical assistance tools and research projects help to identify high-priority end uses and technologies, and support the design and implementation of government regulations and initiatives to encourage their adoption.

Energy efficiency is often described by its advocates as a win-win proposition, whereby end users enjoy positive returns on investments while society gains greater energy security and environmental benefits. Adoption of energy efficiency technologies usually requires an up-front investment that pays off over time in the form of lowered energy bills. Continued political support for energy efficiency measures requires that policymakers can demonstrate both the cost-effectiveness of the investment and the relevance of the policy for national goals. For this reason, credible data about energy use, markets for technology, and related costs are indispensable components of technical analysis. Unfortunately, these data are often scarce in developing countries, posing a significant barrier to effective policy development.[1]

EE4D worked to solve this data deficiency in Mexico by conducting a first-of-its-kind analysis on residential air conditioning use for the state of Sonora, where summer temperatures routinely approach 105°F. This analysis, although limited in scope, provides a critical piece of evidence that will help Mexican policymakers to set effective policy. Furthermore, an economy that incorporates energy efficiency measures can address some of these problems and boost the amount of financial resources a government has at its disposal.

MEASURING AIR CONDITIONER ELECTRICITY USE IN SONORA, MEXICO

Mexico has a long history of successful energy efficiency programs for appliances, including minimum energy performance standards (MEPS) and financial incentives, and each of these has included residential air conditioners in their scope. Currently, baseline level residential air conditioner energy efficiency in Mexico lies at an important technology threshold,[2] beyond which both energy efficiency and price increase significantly. In recognition of the critical role that data characterizing residential air conditioner energy use could have in informing government action in Mexico, EE4D undertook a dedicated technical assistance project to begin to close this data gap.

During the summer of 2019, EE4D conducted a pioneering direct measurement of residential air conditioners in Sonora. While residential air conditioners are the subject of MEPS in Mexico, to date, these regulations have not specifically required the use of an important efficiency technology (variable-speed, or "inverter" units) due to uncertainties about net financial benefits to consumers. The EE4D measurement helps clarify this picture, and may also be helpful in designing effective financial incentive programs and construction codes to increase insulation.

[1] This situation is by no means unique to developing countries, but is heightened there.

[2] Specifically, further improvement of mini-split air conditioners requires variable speed compressor (inverter) technology, which provides efficiency improvement of at least 50 percent over the current baseline, so the innovation curve is not gradual, but jumps discontinuously.

BACKGROUND

Prior to its 2019 Sonora analysis, USAID and Berkeley Lab organized a *Mexico Cooling Summit* in early 2018 to discuss the impact of air conditioning growth and potential mitigations options.

At that event, Berkeley Lab presented macro-level analysis of 2016 seasonal and regional electricity trends confirming that 1) the residential sector contributes the most to summer electricity use, 2) use is highly concentrated in the north of the country, and 3) a cooling peak suspected to be residential in origin is evident in the late night and early morning hours (Fig. 1). One output of the workshop included a *Mexico Cooling Initiative* incorporating multiple strategies for reducing air conditioner electricity consumption, including 1) MEPS, 2) incentive programs, 3) building codes, 4) solar-reflective surfaces, and 5) advanced technologies and controls.

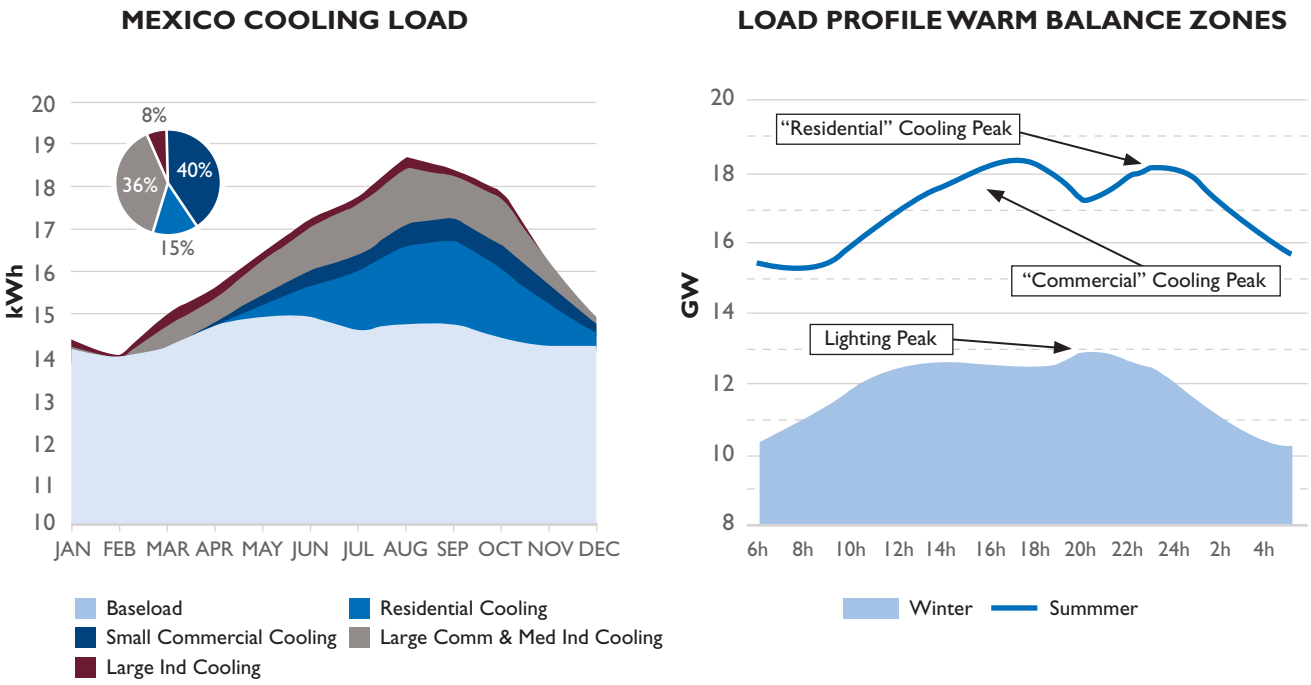

FIGURE 1: CONTRIBUTION TO MEXICAN ELECTRICITY DEMAND FROM COOLING

During the Mexico Cooling Summit, data scarcity was identified as a key barrier to energy efficiency success in that country. On average, Mexican households only use about 1,000 kWh of electricity per year due to the mild climate in the densely-populated Central Valley, which includes Mexico City. In the hot northern and coastal areas, however, air conditioning use can force consumption to more than twice this amount. While ownership rates of air conditioners are compiled by government surveys, only rough estimates have been made of electricity consumption of this equipment based on assumptions and surveys of typical use patterns. In order to provide a more direct measurement of air conditioner electricity consumption, USAID's first step was to partner with Xinampa, Inc., a California-based technology startup, and the Commission of Ecology and Sustainable Development of the State of Sonora (CEDES) to conduct a field study measurement of households in Sonora's largest city, Hermosillo. The research team collaborated with a local air conditioning contractor and installer to identify 20 participating households. Xinampa installed electricity meters directly into air

conditioner circuits and indoor temperature sensors, and paired these with distributed sensor networks in order to remotely gather high time-resolution data. Data collection began in June 2019 and continued through September, thereby capturing the majority of the summer season.

While limited in scope, this study succeeded in helping CEDES and the National Energy Efficiency Commission better understand how air conditioning is used in Mexico and created a critical dataset that can be used to provide an evidence base for future programs.

TOTAL ELECTRICITY CONSUMPTION

The USAID study confirmed that individual air conditioner use in the hot and dry summer in Northern Mexico is extremely high. The average consumption of air conditioners in the sample was measured to be 1,070 kWh (Fig.2). In other words, one appliance uses as much electricity in a few months as a typical Mexican household uses in a year.

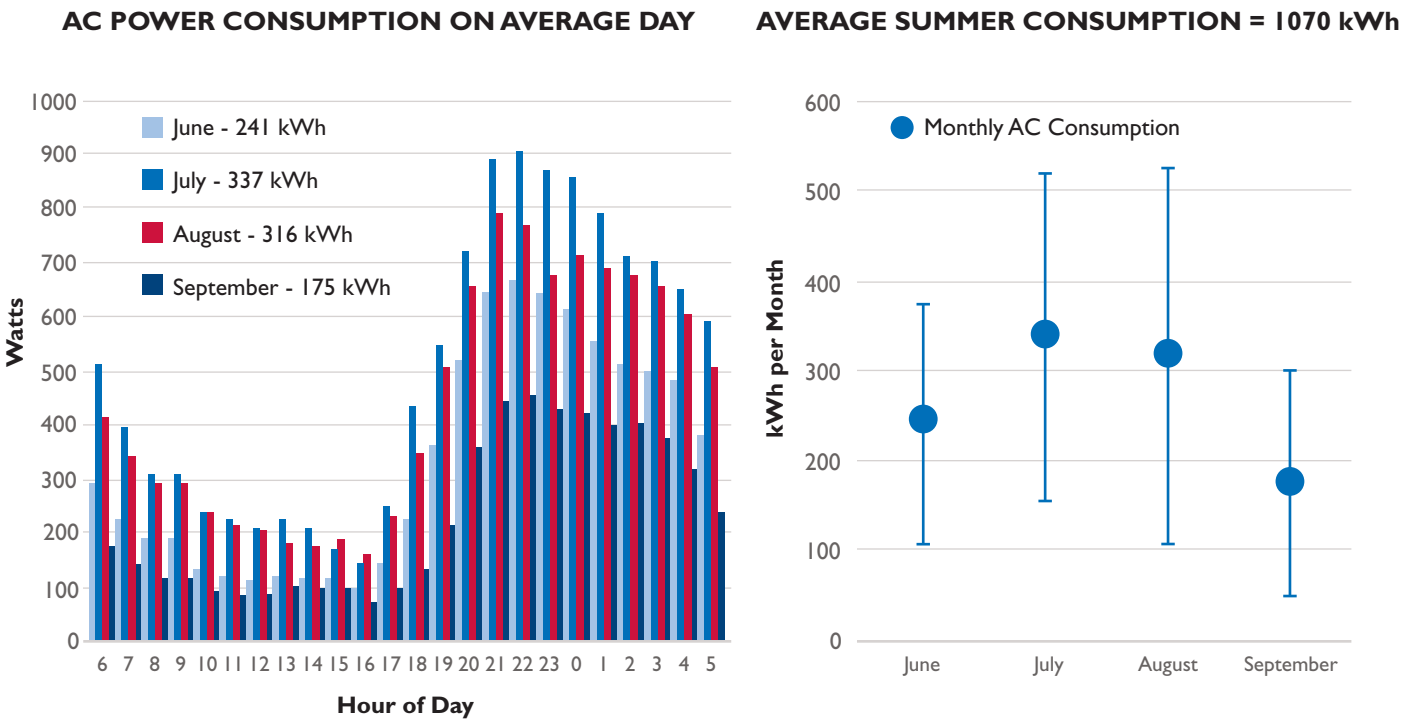

FIGURE 2: TYPICAL AIR CONDITIONER POWER CONSUMPTION BY MONTH (LEFT); TOTAL MONTHLY AIR CONDITIONER POWER CONSUMPTION (RIGHT)

HOURLY LOAD PROFILE

The study was also able to confirm that the nighttime peak observed in the macro-level data correlates well with residential air conditioner use. The study found a consistent pattern of use, whereby household air conditioning use starts up in the evening and grows rapidly till it peaks between 10 PM and 2 AM, then gradually decreases, becoming very low again by late morning. This finding supports the macro-level data suggesting that the residential cooling peak is mainly a nighttime phenomenon (Fig. 2), suggesting that electricity storage is likely a critical component of Mexico's energy planning.

CONCLUSIONS AND IMPLICATIONS

This project is representative of ways in which technical assistance can provide expert advice in developing specific policies and programs, as well as support key datasets that underpin energy efficiency efforts, thus removing an important information barrier. Specifically, the study provided credible evidence of two critical factors: high use and nighttime peak.

High Use – Most importantly, the study provides the first-ever field measurement of electricity consumption of minisplit air conditioners in Mexican households.[3] Over the summer, all measured units used more than 500 kWh, and more than half used over 1,000 kWh. Adjusting for the cooler months of May and October, which were not directly measured, estimated average annual air conditioner use is 1,277 kWh, placing a high economic burden on families, most of whom own more than one air conditioner. It is well-known that electricity bills can be dramatically lowered through the use of inverter-type air conditioners, but these models command only a small fraction of the market due to a price premium of about 3,000 pesos ($150 USD). This investment becomes cost-effective if usage is more than 750 kWh per year. Between 500 kWh-750 kWh per year, inverters are cost effective from a societal perspective, that is, taking account of the cost of government electricity subsidies (Fig. 3). The study therefore provides strong evidence supporting uptake of high-efficiency inverter air conditioners in Mexico, at least in Sonora. The data suggests that in the highest-use households, efficient equipment pays for itself over time, and even for many lower-use households, a government subsidy on equipment would produce net benefits.

Nighttime Peak – The confirmation of the late-night air conditioning peak points to a potential stumbling block in Mexico's energy transition, and possibly a way to deal with it. Most of Mexico's clean energy strategy to date has relied on a rapid transition to solar electricity, which is abundant and so far performs favorably in reverse auctions relative to wind and natural gas plants. Since solar electricity is not directly available at night, the nighttime residential cooling peak poses a serious problem, unless electricity storage is scaled up significantly.

Aggressive energy efficiency adoption can help reduce high electricity bills of Mexican households that use air conditioners and alleviate the barrier to cleaner electricity production posed by growing air conditioner use. While mass adoption of inverter-type air conditioners is an aspirational goal of Mexican policymakers, clear evidence of cost-effectiveness has been lacking until now. The Sonora field study plays a crucial role in the development of energy efficiency policies, including mandatory regulations, cross-subsidies, and awareness campaigns.

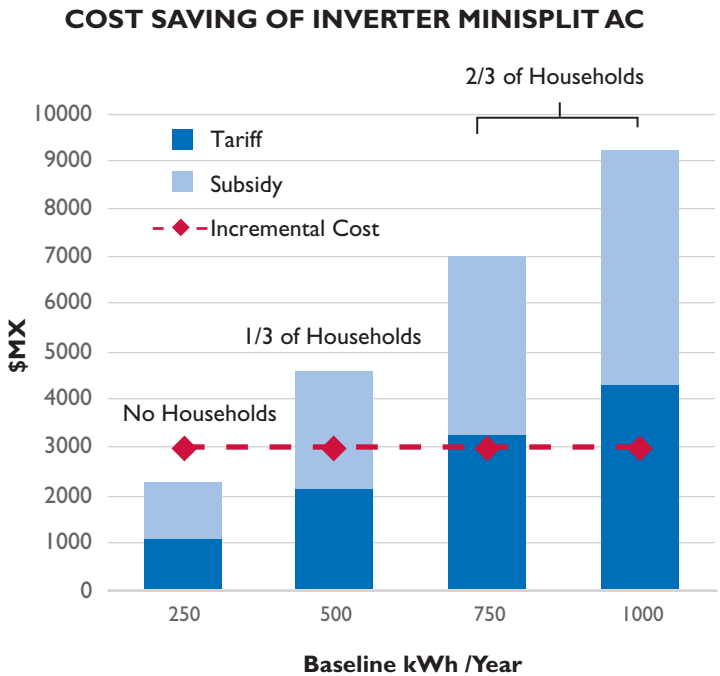

FIGURE 3: COST EFFECTIVENESS OF INVERTER AC IN MEXICO

[3] Minisplits are single-room cooling units with an indoor fan connected through piping to an outdoor compressor unit, and have widely replaced window-mounted air conditioners throughout the world.