From candles to light
The impact of rural electrification

Access to electricity through solar-powered home systems has had effects on the use of time, and a positive impact on school-age children: children in homes with solar panels spend more time on schoolwork, which has translated to more years in primary education and higher rates of enrollment in secondary school. The intervention model used is affordable for the clients, and the savings it generates covers the monthly service fees.


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According to Peru's latest population and housing census, conducted in 2007, 25.9% of households reported a lack of electric lighting. This percentage reached its highest level in the department of Cajamarca, where 59.8% of households reported that they did not have electric lighting.

In 2010, ACCIONA Microenergía Perú (AMP) installed 600 solar-powered home systems (SHS) in households located in 31 rural communities in the districts of Namora, Tumbadén, and San Pablo (the percentage of households without electric lighting in these districts in 2007 was 82.1%, 96.1% and 72.8%, respectively). In 2012 AMP installed 700 additional SHSs in the same area. All these communities are located within a radius of 1.5 to 3 hours from the city of Cajamarca—AMP is headquartered in Cajamarca, so for logistical reasons it preferred to work in communities that were not too far from the city. The average number of household served per community is 35.

The model tested by AMP is fee-for-service. Families pay a monthly fee of 10 Peruvian Soles (US$3.6) for the service, which includes equipment rental, maintenance of the equipment for 20 years, and amortization of the equipment, which allows for the replacement of components over its 20-year useful life.[1] The equipment is the property of AMP, and the families do not have to cover the costs of purchasing the solar-powered systems or replacing their components. This kind of business model is designed to make the solar-powered home systems affordable and sustainable over time for low-income populations (other business models are based on having the families purchase the equipment; sometimes through financing arrangements as cash purchases have high opportunity costs for low-income families.)[2]

1 A family's monthly payment is equivalent to approximately 20% of the official fee approved by the regulator. The Peruvian government's Social Electric Compensation Fund compensates AMP for the remainder.

2 In certain cases this fee-for-service model becomes financially unsustainable for the provider when the electrical grid is unexpectedly expanded, which jeopardizes their customer base before they can recoup their investment in equipment.

Each SHS has the capacity to generate 7.2-11.5 kWh of direct current per month, which is enough power for lighting, operating low-power appliances, and charging mobile phone batteries.[3] The investment cost for the equipment is approximately US$700 in Peru. The solar panel has a 20-year useful life, but the batteries must be changed every 5 years and the regulators every 10 years. This cost, along with installation, operation, and maintenance of the equipment, is covered by the monthly fee clients pay to AMP.

In 2012, AMP, with financial support from the MIF's Social Entrepreneurship Program and technical assistance from the MIF, planned to expand the number of households served by SHS in communities in the same geographical area. The increase would benefit 1700 households located in the provinces of Cajamarca, San Pablo, San Marcos, and Celendin: households in communities that are not served by the Ministry of Energy and Mines' National Rural Electrification Plan, or households in communities that do have electrical grids but that are not connected.

This expansion phase was used to design a quasi-experimental impact evaluation that would measure the effects of rural electrification on the welfare of families who had been using the panels for over two years. For purposes of the study, the families who had used the panels were compared to similar families who lacked access to electricity, planned to participate in the expansion of the project, and were located in communities in which interventions had not yet taken place.

Evaluation

The 2007 population and housing census was used to identify, from the list of communities that would be served by AMP's expansion project, the communities that were most similar to the 31 communities served in 2010. Households that experienced the intervention in 2010 (the treatment group) and households that had signed an agreement for the intervention in 2013 (the control group) were interviewed. The project also planned to expand coverage in communities in which interventions had taken place in 2010; these households were not considered for the study to avoid selection bias—for example, heads of household who chose to participate only after their neighbors had been using the solar panels for two years might be more risk-averse.

Of the 600 households treated in 2010, 548 were interviewed (the remainder could not be contacted), and 781 households of the 1,700 scheduled for treatment in 2013 were interviewed. Before the study was carried out, matches were made based on variables that *a priori* were believed would not be affected by the intervention, in order to ensure the households would be comparable.[4]

Results

The evaluation was able to confirm that AMP had accurately targeted poor populations with the program: 80.8% of clients lived below the poverty line and 98.3% could be considered as vulnerable—having a higher than 10% chance of falling into poverty, equivalent to a per capita daily income of less than US$10. The households used the panels principally for lighting their homes (100% of households used them for illumination). Smaller percentages of households used the panels for other purposes: to charge cell phones (19%), to watch TV (5%), and to listen to the radio (4%)[5].

For purposes of illustration, a small radio played for 4 hours a day consumes 0.12kWh per month; three compact fluorescent light bulbs used 5 hours a day, 4.95kWh per month; and a cell phone battery charger used 1 hour a day, 0.15kWh per month, for a monthly total of 5.22kWh. Adding a 14" color television used 2 hours a day consumed an additional 3kWh per month for a total of 8.22kWh (the panels generate between 7.2 and 11.5 kWh per month).[6]

3 The average energy consumption per capita in Peru was 1.248kWh in 2011 (World Bank, WDI). This figure ranges from 53kWh per month for a typical household in socioeconomic level E, to 1.050kWh per month for a typical household in socioeconomic level A (Supervisory Agency for Energy Investment).

4 Variables such as the number of household members, characteristics of the dwelling, age and gender of the head of household, years of education of the head of household, whether the household benefits from the JUNTOS program, head of household's economic activity, etc.

5 The low power consumption is also observed in similar households connected to the grid. AMP offered to double the capacity of the system, but the offer was rejected by customers because of the associated rate increase.

6 Calculations were based on a 50W television, a 1W radio, an 11W light bulb, and a 5W charger.

The use of panels for lighting has allowed the beneficiary households to reduce their spending on candles by 85% and their spending on batteries by 94%—candles are the preferred lighting source for these families, and they also use batteries to operate flashlights.[7] While the reduction in spending is apparently small (the equivalent of US$2.50 for candles and US$1.10 for batteries), it is not a negligible percentage of the beneficiaries' average monthly per capita income (equivalent to US$68), and is equivalent to the monthly fee for the solar panels. Since the beneficiary households have more hours of light, they can dedicate time to additional activities that have the potential to generate income or reduce expenses. An example would be collecting firewood. All households in the sample (treatment and control) use firewood as cooking fuel, but now households with panels buy less wood and have cut spending on (but not consumption of) firewood, for monthly savings of about $4.90 in comparison to the control group.

FIGURE 1: Percentage of households that purchased candles in the previous month

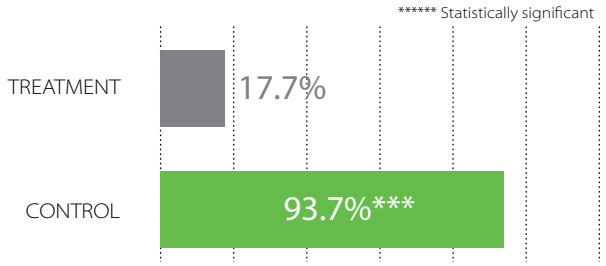
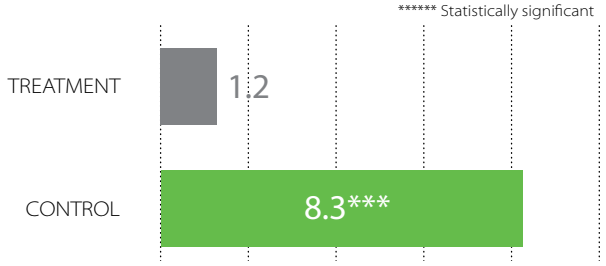


FIGURE 2: Amount spent per month on candles to light the home (Peruvian Soles)



The evaluation was able to quantify the additional time that people in households with solar panels stayed awake: 25 more minutes for men and 42 more minutes for women, on average, compared to the control group. Women dedicated this time to caring for their children (26 more minutes), cooking and preparing food (30 more minutes), and on doing laundry (12 more minutes). In general, people spent more time on personal hygiene (12 more minutes for men and 9 more minutes for women). It should be noted that the proportion of people engaged in these activities does not differ between the two groups. Thanks to the solar panels, more women in the treated group weave for family members (10 percentage points higher), and also spent more time weaving (11 more minutes).

With respect to productive activities, the proportion of men and women who dedicated time to productive activities is the same in both groups (97% of men and 95% of women were economically active); however, while the number of hours dedicated to such activities is the same for men in the treated and control groups, the women with solar panels spent less time on agricultural activities (1 hour 2 minutes less). A larger proportion of these women, however, spend time on home-based businesses (2.9 percentage points higher). Such businesses include bodegas (small convenience stores), selling clothing, knitting blankets and other articles, etc.

The program's most interesting effects are on school-age children. While the proportion of children enrolled in school and doing homework is the same in both groups, children in households with solar panels spend more time on their homework (8.8 more minutes, on average), which has resulted in more years of schooling for children in primary school who have been exposed to the program since they were very young and therefore have spent proportionately more of their lives in the program (0.4 years of additional schooling on average after 2 years 9 months of exposure to the panels). This difference in years of schooling is not seen in older children, but a larger proportion of these children are enrolled in secondary school (in comparison to the control group). This result is particularly interesting, given estimates on the economic return of education that indicate that for every additional year of schooling, incomes increase by between 7% and 11%.[8]

7 The beneficiary households experienced a decrease in the purchase of batteries for flashlights, but not in the purchase of batteries for radios. Compared with the control group, purchase of batteries for radios was the same in both groups.

8 See Psacharopoulos and Patrinos. "Returns to Investment in Education: A Further Update." World Bank Policy Research WP 2881, September 2002; and Duflo, "Schooling and Labor Market Consequences of School Construction in Indonesia: Evidence from an Unusual Policy Experiment," American Economic Review, 91(4): 795-813, September 2001.

The program has had no effect on reducing respiratory ailments. Any reduction of air pollution inside the home resulting from the use of solar panels is offset by pollution caused by using firewood for cooking. The evaluation detected no reduction in the incidence of burns or accidents from using candles. The program does not seem to have had an effect on fertility rates, possibly because television penetration is still very low; only 5% of households use solar panels to power TV set. The hypothesis is that the frequency of sex decreases as people spend more time awake thanks to the lighting and use TV as an alternative to sex as a form of recreation, and that they have access to more information.[9]

The program does not seem to have had an effect on per capita income or poverty levels. However, given the encouraging results related to children's education, it is possible that the program will have an impact on these children's ability to generate more income in the future.

Policy considerations

AMP seems to have achieved a balance between the company's financial viability and its focus on low-income customers (80.8% of its clients are poor). Working in coordination with the Peruvian government, and having obtained the first rural electric concession based exclusively on solar-powered home systems, it has reduced the possibility of an unexpected power grid expansion that would eat into its customer base before it recoups its investment in equipment. This coordination reduces risk to the fee-for-service model used by AMP and gives it financial viability. Because evidence suggests that the increase in coverage comes mainly from extensive growth of the network (extending the network to new communities) rather than intensive growth (connecting unconnected homes in communities that are already electrified), the fee-for-service model needs to plan for national expansion to stay viable in the long term. In Peru, the state, through the Ministry of Energy and Mines, has developed a National Plan for Rural Electrification that identifies geographic areas with potential for implementing solar-powered systems for domestic or communal use, precisely because of the technical and economic impossibility or inconvenience of connecting these areas to large-scale power systems (for example, dispersed populations and households with low purchasing power and poor road infrastructure). These plans, and the coordination with the government, support the fee-for-service model's financial viability without compromising its focus on low-income populations.

With respect to the project's results, while households have the ability to connect low-power consumption appliances, the assessment indicates that only a small percentage of beneficiaries use the available energy to connect their radios or charge their phones. These households' economic benefits and welfare would improve further if the energy provided by the panels were harnessed beyond its use for lighting (saving on batteries for radio, greater access to information through radio and TV, etc.). Addressing the problem would increase the benefits that electricity brings to these homes.

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9 "The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits. An IEG Impact Evaluation." The World Bank, Washington, 2008.

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