How to achieve full electrification:

Lessons from Latin America

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Abstract

Electricity coverage in Latin America has increased substantially in recent decades, rising from 50% of the population in 1970 to more than 95% in 2015. Growth slowed in the 1990s since many countries experienced difficulties in extending their networks further, in particular to serve those living in isolated and rural areas. In spite of this, the process of electrification was not interrupted and at the beginning of the 2010s decade most countries in the region were able to offer access to electricity to almost all of their populations. In this paper, we examine the main strategies used in Latin America to increase coverage and argue that only a combination of policy efforts has made it possible to achieve the current situation. We also examine the remaining obstacles, at policy and institutional levels, to achieving full coverage.

Keywords: Electrification, Latin America, Rural Areas, Renewable Energies, Subsidies, Peru.

1. Introduction

Around 95% of the population living in Latin America (LA) now enjoys access to electricity. This degree of coverage can be considered a success, given the low levels existing in some countries of the region in 2000, when the UN Secretary-General's Advisory Group on Energy and Climate Change established the Millennium Development Goals (MDGs). Yet, the International Energy Agency (IEA) has calculated that some 28 million people in LA remain without access to electricity, many of whom live in the rural areas of Haiti, Peru, Guatemala, Nicaragua, Argentina, Colombia, Bolivia and Honduras. Moreover, the high electrification levels throughout the region hide important differences in per capita consumption of the service. Thus, while consumption is high in Argentina, Uruguay, and Venezuela, for example, it is markedly lower in Bolivia, Nicaragua and Peru.

Most studies analyzing the factors that determine the electrification process of developing countries have focused on economic and geographic conditions. For example, Lipscomb, Mobarak and Barhan (2011) study the effects of electrification in Brazil in the period 1960-2000 taking into account the geological placement of hydropower plants. They show that placement depend on factors that are exogenous to the government and that can be predicted based on geological characteristics like river gradient, water flow, and distance to the Amazon. However, electrification is also determined by the demand characteristics, like the industrial or population density. Wolfram et al. (2012) examined the patterns of electrification across the developing world and found that electrification is consistently correlated with GDP per capita. Some papers have also stressed the importance of political institutions. Brown and Mobarak (2009), in contrast, analyzed a group of 57 countries in the period 1973-1997 and showed that in poor countries democratization has meant an increase in the weight of the residential consumption of electricity in relation to that of

industrial consumption. This suggests that democratic governments better reflect the interest of the population and dedicate more resources and efforts to the electrification. Wolfram et al. (2012), while failing to find a correlation between electrification and the level of democracy, suggest that if China has been more successful than India in electrifying the country it is because the pressure of a strong authoritarian government in China has facilitated infrastructure roll-out.

Differences in levels of electrification and consumption not only reflect disparities in the geographic, economic and political conditions, but also point to the adoption of different policies and regulations aimed at reducing the electrification gap. Taking this into account, the objective of this paper is to provide an overview of the electrification policies implemented in LA in recent decades, a subject that has received very little attention in the literature. We examine the policies implemented for extending electricity coverage and making the service more affordable, including the promotion of renewable energies aimed at reducing the electrification costs in rural areas.

Our paper proceeds as follows. Section 2 documents levels of electrification in LA. We show that most of the expansion of the service in the last decades has taken place in urban areas, currently reaching in most of the countries electrification rates above 95% of the population. There are also significant differences in the level of electricity consumption across countries, implying that access to the service does not guarantee its use. In Section 3, we describe the main features of the process of liberalization and privatization in LA in the 1990s (Victor, 2005). We survey some of the mixed opinions on the overall outcome of these reforms. Using recent evidence in Balza et al. (2013), we also underscore the importance of the creation of regulatory frameworks and the establishment of independent agencies to supervise competition.

Sections 4 and 5 discuss the process of electrification in the rural areas of LA. We first introduce the stages in the evolution of the electrification programs of developing countries: donor-oriented, market-participation and participation paradigms (Martinot et al. 2002; Kruckenberg, 2015). We then describe the various business models adopted to promote the creation of energy markets such as the dealer, concessionary or the community-led models (Glemarec 2012). Finally, we emphasize the role of off-grid technologies, such as solar panels and micro-grid systems, as necessary mechanisms for completing the electrification process in rural areas (e.g. Coelho and Goldemberg, 2013).

Section 6 reviews the universal service policies that are used in LA countries to complement the electrification policies (Pantanali and Benavides, 2006; OLADE, 2013). Specifically, most countries use subsidy schemes that help low-income users meet their connection costs and the price of the service. We also report some of the difficulties of designing social subsidies that incentivize consumption by the poor (e.g., Komives et al., 2005).

Section 7 presents the case of Peru to illustrate some of the electrification policies implemented in LA. Peru's case is especially interesting because it combines direct funding and regulatory innovations to stimulate private-sector participation as well as community involvement. As many other countries in LA, Peru's current coverage is very high in urban areas, but it is finding difficult to complete the electrification of rural areas. Finally, the last section of the paper offers our main conclusions of the LA experience.

Needless to say, guaranteeing access to electricity for all is a key element of development.[1] In the rural areas of developing countries the main application of electricity is for light and watching television, given that most households are too poor to be able to afford other appliances, such as fridges or heating (Nieuwenhout et al., 1998; Khandker et al., 2012; Khandker et al., 2013). Many studies have identified the benefits of these applications for children's education, as a result of the increase in the number of study hours, the acquisition of knowledge attributable to television, and the increase in the number of hours that parents dedicate to their children (Asaduzzaman et al., 2010; Barkat et al., 2002; Barron and Torero, 2015). Electricity also allows households to spend more time on leisure and productive activities, as women tend to work more hours outside of the home while children can attend school more frequently (Van de Walle et al., 2013; Khandker et al., 2013; Dinkelman, 2011). Likewise, electricity allows beneficiary households to increase their income and welfare, and to dedicate more time to non-agricultural activities (Grogan and Sadanand, 2013; Lipscomb, Mobarak and Barham, 2013; Chakravorty et al. 2014).

Increased access to light and electricity also contributes to improving communications and the diffusion of information in remote locations, which in turn helps reduce poverty. In communities with electricity, inhabitants can spend more time talking with their neighbors at night, acquiring more knowledge – for example, on health-related issues – and they can begin to plan the organization of collective service provisions. For example, Beuermann et al. (2012) describe how the increased penetration of mobile phones in Peru has moderated poverty, increased agricultural production and reduced child labor. Electrification also has

[1] Since the seminal work of Aschauer (1989), several studies have analyzed the impact of infrastructure on the growth of developing countries (Canning and Bennathan, 2000; Esfahani and Ramirez, 2003; Yeaple and Golub (2007).

health-related benefits, reducing the use of biomass for cooking and moderating levels of household indoor pollution (Bruce et al., 2011).

2. Electrification rates in Latin America

Since the eighties, governments, international donors and cooperation agencies have actively worked to boost the electrification of LA. Most of the resulting increase in coverage, as experienced in countries such as Bolivia, Peru and Honduras (Figure 1), has been generated in urban areas, where per capita income is higher, and the costs of expanding the grid are low. But electrification rates have remained low in rural areas, especially in Central America and the Andes. Indeed, more than 28 million people in LA remain without access to electricity, many of whom live in Haiti, Peru, Guatemala, Nicaragua, Argentina, Colombia, Bolivia and Honduras (Figure 2). Low coverage levels can be explained by the poverty of the population and the geographic conditions of some regions, but also by the delays in the introduction of electrification policies and their inappropriate designs. On the other hand, it should be stressed that service provision in many rural areas is inefficient and unreliable. This means that still major investment is needed to modernize the grid and its management (Niez, 2010).

Insert Figures 1 and 2

Another salient feature of LA electricity markets are the significant differences in the levels of consumption across countries, which suggests that access to electricity alone does not mean that all consumers can reap all the benefits of the service. Figure 3 shows that while per capita consumption is quite high in Argentina, Uruguay and Venezuela, it is significantly lower in countries like Haiti, Guatemala, Nicaragua, Bolivia, Honduras and El Salvador. Consumers in these latter countries may well not use the service due to high

prices or because they cannot afford energy-using appliances. For example, Figures 4 shows that in most countries a large percentage of population still use biomass for cooking and heating, rather than clean energies, with significant effects for their health. This situation affects, for example, 12.5 million people in Brazil, 10.7 in Peru, 9.6 in Guatemala and 7.1 in Colombia.

Insert Figures 3 and 4

Among electrified households, consumption patterns might also differ significantly. Barnes et al. (2005) examined household fuel use in 45 cities from 3 continents and found that per capita total energy use is very similar across income classes, but that households with a high-income level tend to use more higher-energy-value fuels, such as electricity or gas. Moreover, middle-income households use about twice as much electricity as low-income households and rich households use about four times more. World Bank (2008a) explains that although there are substantial variations by country, the expenditure by the poor on electricity is around one-half to two-thirds that of the non-poor. Thus, for example, the richest quintile of Uruguayan consumers uses only 1.3 times more electricity than the poorest quintile, but in Guatemala those in the richest quintile use 4.5 times more.

3. The process of electricity liberalization and privatization in LA

Part of the increase in the access to and consumption of electricity described in the previous section can be attributed to the reform of the electricity markets that took place in LA at the end of the last century. Until the 1990s, the power sectors of LA were organized under the dominance of state owned firms that were vertically integrated. The general approach was that the public provision of network services could harness economies of scale, make an efficient use of scarce managerial skills and offer the service at an affordable

price (World Bank, 1993). By the mid-1990s, however, the economic situation of the region together with the inefficiencies and managerial problems of these firms led many governments to reform the sector. Many countries privatized their public monopolies and liberalized the energy market with the objective of attracting investors and promoting free-market competition (Victor, 2005; Calzada et al. 2009).

These pro-competition reforms were not unique to the energy markets but part of a broader movement toward the introduction of market forces into many sectors such as telecommunications, transport and water. The macroeconomic fluctuations of the 1970s and 1980s in most LA countries reduced largely public investment in the power sector. As the global economy slowed down, many countries simply could not afford to invest in their power sectors, leading to a decline in the quality of public services and multiple shortages in their provision. At the same time, consumer demand steadily rose due to the development of the region and the urbanization process, resulting in considerable dissatisfaction with public supply. Consumer prices in the state-owned power sectors were heavily subsidized, which meant state-owned power firms ran continual losses.

Against this backdrop, energy sector reforms became a means for governments to gain much needed capital through the sale of public infrastructure, and to reduce public spending on subsidized tariffs (Wamukonya, 2003). International institutions were also a large driving force behind power sector reform. At this time, the 'Washington consensus' pro-market doctrine was being embraced by institutions such as the World Band and the International Monetary Fund. In 1993 the World Bank made power sector loans conditional on commitments to private sector participation and liberalisation (World Bank 1993). Many other institutions, including the Inter-American Development Bank, began similar practices shortly after (Williams et al. 2006).

Liberalization and privatization are often presented in the literature as an attempt not only to improve efficiency in the power sector, but also to bring about a wholesale change in ideology, with electricity going from a public service to a market commodity. Initially, power sector liberalization brought in much needed private sector investment to LA. By the end of the 1990s, the region had the largest share of private electricity projects among all developing regions worldwide. More than 38% of total investment in the developing world's power sector was concentrated in LA (Henisz et al. 2005). Although the promised investment did arrive, it was largely concentrated in the more profitable areas with low cost and large demands, and opinions are mixed on the overall outcome of the reforms. However, there is evidence that the power sector reforms did bring about efficiency savings, while extending coverage, increasing consumption and reducing prices in several countries (Henisz et al. 2005 and Balza et al. 2013).

The privatization process in LA countries often took place in conjunction with the vertical unbundling of the sector into its three basic business units - generation, transmission, and distribution. Most governments transferred generation, and to a lesser extent distribution and transmission, to the private sector. At the same time, they established new regulatory frameworks and market mechanisms to encourage competition. These transformations changed profoundly the institutional framework and the regulatory instruments available to supervise the sector, opening the door to new scenarios that favored the mix of public and private intervention to solve policy problems. For example, greenfield projects were auctioned off by public authorities across LA to stimulate the expansion of national grids to regions without coverage (World Bank, 2002).

Balza et al. (2013) show that in LA intensity of private investment in the power sector was not significantly related with an increase of coverage.[2] By contrast, they do find that the liberalization and the creation of independent agencies had a positive impact in the expansion of the service. During the 1990s, new regulatory models were established to introduce more competition in different areas of the market, especially in generation, but also in transmission and distribution. Moreover, price regulations and subsidy schemes were established to allow fair conditions for domestic consumption, regulated users and the financial sustainability of the firms (Levi-Faur and Jordana, 2006).[3] To implement these sophisticated regulations and provide some credible commitments to foreign investors, most countries created independent regulatory agencies, with highly qualified staff and strong organizational autonomy (Figure 5). Simultaneously, similar institutions were created for other basic services such as telecoms, transportation and water as a part of a large public sector reform. Expecting regulatory returns, governments delegated responsibilities to these newly created agencies in the areas of supervision, licensing, price setting and arbitrage, among other regulatory issues (Jordana and Levi-Faur, 2005; Jordana, 2012).

Insert Figure 5

In recent years, a few countries in the region have partially reversed these policies as a consequence to the changes in the political ideology of the governments and the disappointment with the results of the reforms. This is the case of Bolivia, which in 2010 initiated a nationalization process that reversed many of the changes introduced in the 1990s and nationalized several firms, while in Venezuela several firms have been

[2] In spite of this, investment in electricity increased the quality of service and efficiency in generation, due to a reduction of electricity losses and the expansion of generation capacity.
[3] Murillo and Martínez-Gargallo (2007) show that even those countries that have introduced the strongest market liberalization policies and which have privatized their national incumbent operators maintain price controls and a strict regulation of the sector.

nationalized in the last few years. In spite of this, most LA countries have consolidated a model of regulated competition and have tried to compensate the unwanted effects of the liberalization with the development of electrification policies. One obvious effect of privatization and liberalization is that private investors tend to focus their efforts on urban areas where they can exploit high-income consumers and benefit from economies of scale and density. In rural and remote areas, by contrast, the service is not profitable enough to attract the massive interest of investors. To compensate for this situation, specific electrification programs have been implemented by national governments since the nineties. Some countries such as Brazil and Peru have passed specific rural electrification laws and many others have created rural electrification funds. On the other hand, most LA countries use social tariffs to increase the affordability of the service. Next sections explain the evolution of these programs and their results.

4. Rural electrification strategies

In the last decades, the complexity of electrifying the rural areas of developing countries has been identified and recognized by domestic governments and international agencies. New programs have sought to adjust electrification strategies to the socio-economic and geographic conditions of each region, to adopt off-grid technologies in rural areas and to increase coordination between all institutions and local communities participating in the electrification process.

4.1 Evolution of the electrification policies

Kruckenberg (2015) identifies and describes three stages in the evolution of the electrification programs of developing countries. The first stage, the “donor paradigm”, occurred between the 1970s and the 1990s, when international donors and cooperation

agencies intervened in rural areas through the diffusion of new technologies. Typically, these programs were based in the transmission of small-scale renewable-energy technologies such as biogas, cooking stoves, wind turbines and solar heaters, which were barely self-sustainable (Martinot et al., 2002). Development agencies sought to demonstrate to the local authorities and communities how these technologies could solve their energy needs. However, many of the projects suffered major shortcomings and failed: often they did not allocate resources to maintain and operate the equipment that were delivered to the communities, the beneficiaries were not trained to use or repair the systems, and there were no specific regulations or institutions available to guarantee the long–term sustainability of the projects (Martinot et al., 2002; Krukenberg, 2015).

The second stage, the "market-oriented paradigm", was initiated after the 1992 UN Conference on Environment and Development (The Rio Earth Summit), when new forms of multilateral assistance were adopted for the diffusion of renewable energy such as solar home systems, biogas for lighting and cooking and small-scale mini-grids (Martinot et al. 2002). The new programs designed by development agencies aimed at promoting these technologies by creating business models for firms and cooperation agencies in which funding programs shouldered part of the costs and risks. These programs were based on the expectation that renewable energies were economically profitable in rural areas, but that their adoption required giving local firms some institutional and financial support. Many of these initiatives were adopted in the rural areas of countries such as Argentina, Brazil or Chile. However, usually they were only successful in richer communities that were already undergoing development and that had access to other public services such as water, telecommunications, health and educations.

This suggests that effective approaches to reach poor communities required complementing private sector involvement with more active public policies. In this sense, it is important to recall that in many LA countries the pro-market period coincided with a process of administrative and political decentralization that transformed public policy-making in many different areas (Falleti, 2010). For example, Faguet (2004) explains that in Bolivia there was an important decentralization process that led to higher investment in human capital and social services as the poorest regions of the country were able to choose projects according to their greatest needs. This process also implied important drawbacks: some studies of this period alerted that decentralization could be related to corruption and regulatory capture, since municipal governments were often at the mercy of local power elites (Bardhan, 2002).

Finally, the third stage in electrification, the "participation paradigm", was introduced during the 2000s decade. Cross-sector partnerships have become popular within formal debates on international development. Krukenberg (2005) explains that Target 8 of the UN's Millennium Development Goals called for a new "global partnership for development" involving various collaborations between business and development agencies. For example, the World Summit for Sustainable Development in Johannesburg in 2002 called for "type II" partnerships between actors such as governments, international organizations, companies, NGOs, and scientific organizations, as a way to accelerate development (Forsyth, 2010).

Within this new paradigm, electrification projects recognized the multi-level and cross-sector nature of socio-technical change. Electrification programs today include a greater variety of stakeholders (donor organizations, government agencies, banks and micro-finance institutions, utilities, firms, NGOs, and local communities) with the objective of

creating more sustainable energy services. New projects seek to attract investment and create cost-sharing models, foster knowledge transfer and capacity building, improve the integration of donor-initiated and private markets, and promote the involvement of local stakeholders. The main difference between this model and earlier approaches is that it recognizes the importance of strong relationships between organizations to foster the introduction of new technologies. The diffusion of renewable energies to a large extent depends on the creation of appropriate inter-organizational relationships. According to Kruckenberg (2015), strong ties between organizations facilitate fine-grained knowledge transfer, extensive collaboration and the development of problem-solving capabilities; whereas weak ties enhance access to non-redundant information and prevent the insulation of more durable partnerships in the wider sector.

4.2 Instruments of electrification: Business models for rural electrification

In recent decades, various methods of intervention have been adopted in developing countries, influenced by the electrification strategies defined above.[4] The "dealer model" was introduced in the nineties and harnesses pre-existing local retailers to sell energy-generating equipment – predominantly photo-voltaic (PV) solar technologies – directly to off-grid consumers. Its objective is to expand the market by making credit and partial subsidies available from qualified dealers. Specifically, policy intervention involves offering subsidies to local dealers to reduce the per unit installation cost of electricity systems. These subsidies are expected to be passed on to the consumers to create lower retail prices, thereby increasing demand and access, while also ensuring a profit for the dealers themselves (Glemarec 2012). In spite of this, this business model is difficult to implement

[4] Our descriptions of these models, as well the explanation of the community-led model we offer below, is based on Barnes and Halpern. (2001).

due to the difficulties to attract dealers and also to their resistance to extend credits and subsidies to consumers. As a consequence, these programs are often concentrated in affluent regions with small-scale electricity supply firms that have the skills and technology required to supply services directly to consumers. While the dealer model was initially developed in several Asian and African countries, it can be found in LA applied in combination to other business strategies.[5] For example, although the dealer model usually allows accredited dealers to sell anywhere in the country, in some projects of the World Bank in Honduras and Nicaragua subsidies are provided only for sales in designated priority areas. On the other hand, in Bolivia, in Decentralized Infrastructure for Rural Transformation Program establishes that the dealers must offer operation-and-maintenance services (World Bank, 2008b).

The "concessionary model" was also introduced in the nineties in countries such as Argentina, Bolivia, Chile and Peru. It involves tendering to private firms the generation, transportation and distribution of electricity in rural and remote regions, while the government maintains the regulation and subsidization of the service. Since firms compete for the concessions, this mechanism should lead to cost reductions and better services. In spite of this, the concessionaires are responsible for running the service and maintaining the equipment during the life of the contract, which makes more difficult for public authorities to control the quality of the service that is delivered.

In the concessionary model, an essential objective is to encourage private firms to compete for the concessions and to regulate the winners. Moreover, before the tender public authorities must identify the country's unprofitable regions in which the electricity sector

[5] Barnes and Halpern (2001) explain that in Sri Lanka and Indonesia a combination of Global Environment Facility funds and World Bank credits were to be offered to dealers to on-lend to customers.

needs to be expanded. Unattended regions can be split into different areas and the concessions for these regions can be tendered simultaneously or sequentially. In each region firms bid to obtain an exclusive contract to supply the service. The bids can reflect the number of households that the firm accepts to attend for a given public subsidy, or the minimum subsidy the firm requires for extending access to a given number of households. One advantage of this mechanism is that it is well targeted to meet the needs of rural communities: governments set tariffs that are affordable to the rural poor identified by the program. On the other hand, it uses market forces to select the provider in each region that is willing to offer the service at the lowest cost. Typically, the biggest issue is gaining sufficient competition in the tender process to keep firms' subsidies low. If there is not enough competition and subsidies are high this model could be excessively costly (Barnes et al. 2001; Calzada and Miralles, 2009). Concessionary tenders have been widely used across LA to distribute private sector concessions. For example, tenders have been used in Argentina under the Project for Renewable Energy for Rural Markets (PERMER) starting in 1999 (Best, 2011, Alazraki et al., 2007); the Rural Electrification Plan (REP) in Peru, beginning in 1993 and given new impetus in later periods, and the project *Luz Para Todos* (Light for All) launched in in Brazil in 2003 (Gómez and Silveira, 2010).[6]

Finally, a third approach adopted in recent projects is the "community-led model". This could be viewed as a decentralized application of the concessionary model (bottom-up approach), typically geared toward off-grid and mini-grid electricity supply expansion. Local leaders, organizations, community members and entrepreneurs work together to produce a business plan to best serve the needs of their community. The project is submitted to a

[6] Calzada and Miralles (2009), Coelho and Goldermberg (2013)) and Maurer and Barroso (2011) give a broad overview of concessionary auction mechanisms, with examples from Brazil, Colombia, Chile, Peru, Panama and Mexico from Latin America.

national regional agency that, if giving approval, assigns partial funding through loans or subsidies for the installation or repair of infrastructures. New projects typically involve a financial contribution from the communities themselves, which is believed to invoke an attitude of community ownership and responsibility for long-term maintenance.

One of the main criticisms of the concessionary model is that the projects developed by the concessionaires are largely disconnected from the interests of the local communities whom they serve. For example, the technology used by a concessionaire might not have enough capacity to meet the (perceived) needs of the communities, or may be installed in inadequate places. The community-oriented approach tries to solve this limitation by engaging local governments and communities in the design of the projects and by developing local skills that are essential for the operation and maintenance of the equipment.[7] In spite of this, the biggest drawback of this model is the inability to generate economies of scale, and the tendency to require large government subsidies and/or loans to adequately fund the projects.

An example of this type of projects is the Rural Electrification Fund launched in Chile in 1994, were local operators working in conjunction with community groups bid to provide the services in some regions. The operators were selected according to a number of criteria, including a cost-benefit analysis, the operators´ investment commitment, and the social impact of the project. The central government allocated subsidy funds to the regions based on the number of unelectrified households and the electrification of the region in the last years. Local consumers paid the connection costs from the distribution plant to their homes and the costs of wiring within their homes, which was roughly 10% of the total

[7] For a review of the literature examining demand-driven projects see Mansuri and Rao (2004 and 2013) and Bardhan and Mookherjee (2005).

projects costs. These payments to the operator were staggered over an agreed period, thus reducing their immediate financial burden. Between 1995 and 1999, this model increased rural electrification in Chile by 50% (Jadresic, 2000; Tomkins 2001; World Bank, 2008a).

Finally, microfinance could be an alternative to overcome liquidity constraints in electrification projects. A typical concern in many projects is the high costs of installation. In regions with strong microfinance networks, consumer credit through microfinance institutions (MFIs) has been used to promote access to clean energies systems (Glemerac, 2012). In LA, however, the current capacity of MFIs is insufficient to target rural areas and to unlock the potential of the energy market for microfinance loans (IEA 2011). MFIs in LA are highly commercialized and currently geared toward urban and middle-income regions. Most micro-loans have been supplied to established micro-enterprises in need of capital for expansion, rather than toward the rural poor in isolated regions (Morris et a. 2007). Unlike MFI's in Asia and Africa, few MFIs in LA offer explicit energy lending portfolios. This has been attributed to poor government planning, with politically motivated promises of free give-aways of electrical services stifling demand for microfinance loans and hindering the market (Allderdice et al. 2007). MFI's have been involved in a small number of donor-led electrification programs such as World Bank/UNDP sponsored programs in Bolivia, the Dominican Republic and Nicaragua. Each of these projects has used microfinance to help individual households and communities purchase solar electrification products. In all these case, the loans have been embedded in a broader business loans, rather than explicitly given for energy purposes (Morris 2007).

5. The use of sustainable technologies for rural electrification

The main obstacle to the electrification of rural areas is the high cost of expanding the grid into low populated regions. Many of the households that remain without electricity in LA are in highly remote areas, for example in the Andes or in Amazonia, and their extreme poverty and high connection costs prevents them from attracting the interest of electricity distributors. In the late 1990s, most LA countries implemented specific electrification programs in their rural areas. Initial programs focused on expanding the grid to the more profitable consumers of urban and peri-urban areas. Centralized governments built large hydroelectric dams and power plants, as well as lengthy distribution and transmission lines. But the electrification of rural areas required a different strategy to control the amount of investment required. Today, donors, NGOs, private firms and communities collaborate with the governments to develop small-scale localized energy generation systems.[8] In these rural locations, the adoption of renewable energies has emerged as a cost-effective solution, often with the use of off-grid and small-scale systems.

Renewable technologies such as photo-voltaic panels, micro generators, hydroelectric plans or wind power have many advantages: they need less initial investment than is required by having to expand the electricity grid; reduce the dependence on imports of fossil energies; increase the security of provision by diversifying the energy sources; have less environmental impact; and their retail prices are lower than those of fossil fuels. Their main drawbacks, however, are that they might involve higher operative costs than hydroelectric or thermal plants, are less attractive for private investors, and in many cases there is no

[8] Several papers have analyzed the design of these programs (Brass et al., 2012; Sovacool and Drupady, 2012; Kruckenberg, 2015). Other studies have found that decentralized electrification can be more cost-effective than grid extension, even for communities that lie only 5 km from the grid (Adkins et al., 2010; Contreras, 2008; Diniz et al., 2011). Palit and Chaurey (2011) analyze off-grid rural electrification in South Asia.

operator to maintain the equipment. For this reason, renewable energies are often considered an intermediate step to the connection of households to the main grid. The idea is that they can facilitate access to the electricity service for many communities and that they can eventually be substituted should consumption increase sufficiently (ladder of investment).

Photo-voltaic (PV) panels have been widely used as a cost-effective means for expanding electricity supply and their costs have fallen significantly in recent years (Glemarec, 2012). This technology, however, like many off-grid energy solutions, can only serve one or a few households and is limited in the voltage it can produce. As such, it might constrain consumption when the demand for high-powered household equipment increases. Some authors claim that PV panels might generate dissatisfaction among users, because the limited power provided does not allow them to develop economic activities that require electric machinery such as retail shops, grain mills, carpentry or sewing businesses. Coelho and Goldemberg (2013) have analyzed electrification programs in Brazil. They report that initially 50 kWh per month was sufficient to meet a family's immediate needs, including light in the evening, the pumping of water, and television. But soon consumers started installing refrigerators and other electric equipment; they even began cooking with electricity. They argue that in this situation installing meters and charging for the electricity consumed becomes essential. Further limitations identified include the fact that new businesses dependent on solar panels cannot stay open late when the energy produced is insufficient to power their essential equipment (Green, 2004; and Hajat et al., 2009).

Another problem of PV panels is that they are usually installed by dealers (decentralized dealer model) and so there is no long-term contract established between consumer and retailer. This means panel and battery maintenance is dependent on the community

members, who usually do not feel especially responsible for the equipment and/or do not have the capacity to maintain it (Barnes et al., 2001). As a result, when batteries are exhausted they may not be replaced.[9] In spite of this, some new electrification projects do dedicate considerable efforts to advising household members on how to use and maintain solar panels, and they might even train local technicians to install the equipment and maintain them. A good example of this is the Acciona MicroEnergy project in Peru, which has installed more than 5,000 PV panels since 2008, also taking care of the maintenance of the batteries (Arraiz and Calero, 2015).

An alternative to PV panels are micro-generators, which can be fueled by hydro, wind or thermal power, or by traditional fossil fuels. These technologies can also power mini-grid systems servicing small communities, although they are more expensive. According to Brass et al. (2012), diesel generators typically cost two to three times more per kilowatt-hour than grid electricity and are susceptible to fluctuating fuel costs. In comparison, renewable systems are often cost competitive, but require higher upfront costs per end user.[10]

Micro-generators are also limited in terms of their generation capacity, with their ultimate suitability and cost effectiveness being determined by the characteristics of the local environment. In Brazil, in 2008 there were 1,267 small, diesel-fueled, power plants. (Coelho and Goldemberg, 2013). The strategy adopted by this country of extending electricity lines to slum areas and distant villages has succeeded in universalizing access to electricity.

[9] Obermaier et al. (2012) explain that, in Brazil, 56% of the equipment installed by the electrification programs at the end of the nineties (PRODEEM) was not in use a few years later.
[10] Brass et al. (2012) review an extensive literature on distributed generated projects and offer different estimates of the costs of adopting renewable energies.

However, because of the difficulties and costs to create and maintain these plants, many new projects have adopted renewable energies.

Many LA countries use hydroelectric plants to generate electricity, but usually they produce several megawatts in order to benefit from scale economies. By contrast, the adoption of small hydroelectric plants remains quite limited. Taking into account the rainfall rates and the high topographic relief of many countries, the use of small plants would be especially appropriate for many remote areas, for example in the Andean mountains.

A further solution for rural areas is the use of wind power systems that incorporate batteries within the homes to store electricity. However, it is estimated that wind turbines are only more economical than PV systems in areas with high average wind speeds (Fuente and Álvarez, 2004).

As discussed above, one limitation of off-grid systems is that they cannot be so readily adapted to an expansion in consumption. Hence, the success of electrification projects might in part depend on the firms' and on the government's ability to make accurate predictions about the future evolution of consumption in each place (Gertler et al, 2011). In the case of the rural regions connected to the grid a potential problem is also the existence of a reduced generation capacity (Crousillat et al., 2010). In these instances, in order to extract the full benefits of electrification, the grid expansion has to be complemented with an increase in generation equipment.

Finally, it should be stressed that the presence of renewable energies for the production of electricity in LA today is significant, although their use in rural areas is relatively recent and remains modest. According to the International Energy Agency (IEA), renewable energies currently represent around 29% of total energy production in LA, and according to

OLADE they account for 25% of total production in LA and the Caribbean (Figure 6). This is a relatively high figure compared to the 5.7% share renewable energies represents in the OECD countries. In practice, however, most of the renewable production in LA is generated by the large hydroelectric plants and by biofuels.

Insert Figure 6

6. Universal service policies and social tariffs

Most countries in LA complement their electrification policies with universal service policies that seek to make the service more affordable for electrified households. Specifically, most countries use subsidy schemes that help low-income users meet their connection costs and the price of the service.[11] This practice contrasts with the trend in OECD countries to eliminate social tariffs, where they are believed to create inefficiencies and to have little impact on the energy poor. In LA, social tariffs constitute an essential part of social policies and might have an important redistribution effect (Pantanali and Benavides, 2006). In many cases, social tariffs have been created to moderate the increase in energy prices following the introduction of renewable energies, plans to increase market efficiency, or to protect the vulnerable population in periods of economic difficulties. Thus, for example, in Argentina social tariffs were introduced after the 2001 crisis.

In most countries, social tariffs are tied to energy consumption, although several countries also link them to other indicators such as the geographical location of the households or measures of household income. For example, in Argentina, Brazil, Chile, Colombia and Peru the beneficiaries of social tariffs have to be included on the census as low-income consumers. In these countries it is believed that electricity consumption is not sufficient on

[11] Some exceptions are Barbados, Belize, Costa Rica, Grenada and Guyana (OLADE, 2013).

its own to determine households' income and other variables such as the size and location of households are used to determine their energy needs. In Peru, the SISFOH (Sistema de Focalización de Hogares) is a system that collects information about the households socioeconomic characteristics and that calculates a poverty index that allows classify households into 7 categories or stratums. This information is then used by different national agencies to determine the beneficiaries of social programs.

Some countries, including Peru, Ecuador and Nicaragua, finance social tariffs with cross-subsidies, but there are other countries in which cross-subsidies are not allowed and social tariffs are financed by the electricity companies or with direct contribution of the State. For example, in Peru and Dominican Republic social tariffs are financed by those users that consume more than 100 and 500 Kwh per month, respectively. In Argentina cross-subsidies are forbidden and social tariffs are supported by public funds, while in Brazil tariffs are financed by a fund named Global Reversion Reserve, financed with payments from the energy providers.

OLADE (2013) has analyzed the use of social tariffs in LA and shows that in most countries, the percentages of beneficiaries of these tariffs is higher than the percentage of people living below the poverty line, and higher than the percentage living below the extreme poverty line.[12] Figure 7 shows that some exceptions are Bolivia, Dominican Republic and Paraguay, and even in these countries the percentage of people obtaining subsidies is higher than the percentage that are below the extreme poverty line. There may

[12] CEPAL (2014, p. 64) defines the poverty line as the minimum income necessary to meet the basic needs of a person. It is based on the value of a basket of basic food necessary to cover the nutritional needs of the population, taking into account the consumption habits, the availability of food and the prices in each country. The extreme poverty line ads to the previous measure the income required by households to meet basic non-food needs. This measure takes different values in urban and rural areas and changes every year.

be political and technical circumstances that make difficult to avoid that non-poor households get subsidies. Komives et al. (2005) warn of the complexities of designing social subsidies that only incentivize consumption by the poor. For example, they report that in Guatemala and Colombia many non-poor households figure among the low-volume customers that may benefit of social tariffs. In urban Colombia, the poorest quintile consumes more than the subsistence level. Yet, the administrative and political costs of improving the selection of the beneficiaries of these tariffs can be high.

Insert Figure 7

OLADE (2013) reports considerable differences in the maximum consumption levels established at which consumers can benefit from subsidies. These range from 70 kWh/month in Bolivia to 900 kWh/month in Mexico (this threshold is applied in the summer season and in some specific regions). In spite of this, most countries adopt a limit between 200 and 300 kWh/month, and many countries offer a range of consumption levels with different discounts. Thus, for example, in Peru there is an initial range for 0-30 kWh/month and another for 30-100 kWh/month. In Ecuador, there are three thresholds: 110 kWh/month in the Sierra, 130 kWh/month on the Coast, and 120 kWh/months for the elderly. These differences are justified on the grounds that there is no single general consumption level that reflects the needs of all households. Clearly, the consumption requirement might depend on the size of the family, the geographic location of the household, the season of the year, and cultural habits.

The discounts applied to the regular tariff vary according to the country and the consumption level. Many countries apply decreasing subsidies. For example, in Peru the subsidy is 62.5% for consumption between 0 and 30 kWh/month and 49% for a consumptions between 31 and 100 kWh/month. By contrast, in Ecuador the subsidy is

50% for the three ranges used. The countries that apply the smallest subsidies are Nicaragua (15%) and Bolivia (25%), and the countries that apply the highest discounts for specific groups of consumers are Argentina and Brazil (100%) (OLADE, 2013). The use of these increasing subsidies is considered important in giving the right consumption signals to consumers. Subsidies modify the consumption patterns of households and should not stimulate unnecessary consumption and waste.

Finally, another interesting aspect of OLADE's report is that it estimates the impact of social tariffs on the budgets of beneficiary households that are below the extreme poverty line, according to the World Bank' definition (households that obtain less than 1.25 US$ per day per household member, for a family of five members, i.e., 2,281 US$/year). After making various assumptions, they found that in several LA countries, including Bolivia, Honduras and Peru, the impact of social tariff was small, since it only increased the acquisitive power of these households by less than 30 US$/year, which represented around 1% of their annual income (Figure 8). The higher impact was found in Dominican Republic and Mexico, where households below the extreme poverty line obtained 235 and 493 US$/year, respectively, which was around 10 and 21% of the households' income. In spite of these results, there is still a shortage of information on how subsidies can change the consumption patterns of the population.

Insert Figure 8

Subsidies seek to improve opportunities to access modern energy options at affordable costs. But some authors consider that social tariffs often fail to achieve this policy objective and suggest the use of alternative measures, such as direct welfare payments or investments in social services. Komives et al. (2005) argue that the absence of any administrative selection of subsidy beneficiaries might mean that subsidies are regressive: both because

many poor households do not have an electricity connection, and because those with a connection use less electricity than rich households. In this sense, the adoption of a progressive distributive policy would mean that a large part of the population do not receive any subsidy.

Another criticism of subsidy programs is that they can distort firms' long-term investments. McRae (2015) has identified an important anomaly that affects subsidy programs in Colombia. Subsidies should create sufficient demand in poor neighborhoods to encourage private operators to improve distribution networks. But he explains that, paradoxically, many Colombian regions receiving large subsidies have precarious distribution networks. This generates a vicious cycle: households with informal connections receive low quality service for which they do not pay; distribution firms tolerate nonpayment because they receive financial support from the government; and the government subsidizes these users to retain their political support and to avoid civil conflict. The explanation for this situation is that governments cannot observe real consumption levels and as a consequence in areas with a large number of informal connections firms receive greater fiscal transfers than the cost of providing the service. Since the profits obtained are high, the incremental profit from improving the network is lower than the capital cost. As a result, operators opt not to invest in the expansion and upgrading of their networks.

Similar distortions attributable to subsidies have been described in other countries. On the one hand, Krishnaswamy and Stuggins (2007) explain that in the Dominican Republic the government paid 75% of the cost of the electricity used in informal settlements, and this policy incentivized firms to expand the number of households included in the program. On the other hand, Rehman et al. (2012) explain that in the Big 5 in Asia inefficient subsidies have distorted the utilities' incentives to invest. All in all, these papers conclude that

government policies aimed at maintaining services for nonpaying, unmetered households may perpetuate the existence of low-quality connections by creating a disincentive for distribution companies to invest, even when the investments result in the households paying for the service. McRae (2015) suggests to address this problem by making the subsidies dependent on the quality of the service and shifting out household demand in order to increase the profitability of upgrading the distribution networks.

7. A case study: Peru's electrification process

Peru's experience of electrification is interesting in the sense that it has sought to combine direct funding and regulatory innovations to stimulate private participation as well as community involvement. Electrification in Peru still shows important shortcomings.[13] In 2012, although coverage in urban settings was already reaching about 99% of the population, still remained about 65% in rural areas. Amazonian and Andean departments were the territories with the lowest levels of electrification, owing to a highly dispersed rural population and very difficult terrain. According to the IEA, in 2014, still more than 2.5 million people did not have access to electricity in the country.

During the 1990s, most of the Peruvian electricity sector was privatized, particularly as regards energy generation and distribution. Efforts were made to attract investment so as to increase electricity generation and to renew its distribution networks. Later, during the 2000s, transmission networks were also privatized. At that time, the country policy priorities were focused on improving the efficiency of the electricity system as a whole, and coverage was expanded rapidly as a consequence of increasing electricity production. To attract investment, companies were under no obligation to connect users lying more than

[13] For a general analysis of the energy sector in Peru see Fontaine (2010), Leung and Jenkins (2014) and Calzada, Costas and Jordana (2009) and Quintanilla (2009).

100 meters from their networks, a measure that possibly impeded a more rapid increase in coverage. However, already in the early 2000s, two key instruments were adopted to address the electricity gap in the country and to expand universal coverage.

First, in 2001 the government created the FOSE (*Fondo de Compensación Social Eléctrica* - Electricity Social Compensation Fund), a cross-subsidy system to adjust electricity tariffs, which included a reduction in tariffs for customers with an energy consumption below 100kWh/month using fixed and proportional discounts. This Fund was managed by the electricity regulatory agency, OSINERGMIN, financed through a surcharge in the tariff paid by regulated consumers with monthly consumptions above 100 kWh, and benefited about 60% of electricity users in the country. Second, the Ministry of Energy and Mines directly invested in rural electrification, a process implemented by the National Rural Electrification Office (DGER) and other related agencies. Following the construction of these electricity systems, they were handed over either to state-owned distribution companies or to the municipalities for operation. The combined effect of all these efforts contributed to a significant increase in rural electrification, climbing from 24% in 2001 to 65% in 2012.

In 2006, a fund (*Mecanismo de Compensación para Sistemas Aislados*, MCSA) was introduced to supplement and rebalance the tariffs of off-grid systems. The objective of this fund, financed by electricity customers and complemented with government funds, was to guarantee that grid and off-grid costs are the same, from the point of view of private investors. Off-grid customers only pay 20% of the tariff and off-grid generation companies are compensated from the fund's resources. This social tariff for off-grid systems constitutes an innovative measure in LA.

However, in 2012 a broader program aimed to solve energy coverage shortcomings more comprehensibly was introduced, the FISE (*Fondo de Inclusión Social Energético*). This fund promotes universal service in energy and is financed by the State, energy firms and large electricity and gas users. The FISE aims at expanding energy coverage over the country, the development of the compensation mechanisms for residential consumers, and the promotion of renewable technologies, including solar panels, for electricity generation in off-grid areas (Law 29852, 2012). Led by the Peruvian government and temporary managed by OSINERGMIN, the FISE has introduced several innovative initiatives, as for example the distribution of vouchers to promote the use LPG cook stoves or the reduction of electricity prizes for final consumers in rural areas (initiated in 2016). It has also sought closer collaboration with private firms in strategic areas with the objective of reducing public investments.

Another example of the efforts to complete the electrification process in the country is the recent organization of several universal service auctions. Their objective is to offer the lowest possible subsidies to companies investing in electricity generation in designated places, making use of renewable technologies. In 2013, the government auctioned 240 MW that were allocated to 19 small hydroelectric systems. In 2014, it organized the first auction for the provision of off-grid systems in rural areas, and the winner firm obtained a concession for the installation, operation and maintenance of 500.000 autonomous solar panel systems. Finally, in 2016 the government has auctioned 1300 GWh that have to be provided through renewable energies such as biomass, aeolic and solar systems, and 450 GWh through hydroelectric plans of less than 20 MW (Quintanilla, 2016). Overall, this large-scale initiative is highly characteristic of the concessionary model, but it includes two particular innovations. First, it uses solar panels to cover almost all the territory and,

second, it involves close collaboration between the Ministry and the regulatory agency in the design and management of the universal service policy (FISE, 2016).

8. Conclusions and policy implications

The electrification process in Latin America can be considered a success story. By the end of 2015, 95% of the population had access to electricity, up from just 50% in 1970. As such, the LA experience can serve as an example for many countries of Africa and Asia where coverage levels continue to be low despite many decades of electrification efforts. The main drivers of electrification in LA have been related to economic growth and democratization. The power sector reforms, characterized by privatization and regulated market competition, have also attracted investment at crucial points in the process, but more significantly, the establishment of independent regulatory agencies has provided policy stability and a transparent environment.

However, still 28 million people in LA today remain without access to electricity. Many of these people live in remote, rural areas, where extending the electricity network is extremely challenging. Innovation, especially in the form of new renewable energy technologies, is proving essential in extending access to electricity without having to expand the electricity network. Rural electrification policies, adapted to the socio-economic and geographic conditions of the area, will be key in achieving full coverage levels. These policies also need to promote the close coordination of all the institutions and local communities involved in the electrification process. Rural electrification has an extremely positive impact on communities but its effects also depend on the presence of other services. Electrification

has a greater impact if it is complemented by investment in water, education, health and infrastructure.[14]

The Peruvian case presented in the last section of the paper represents a clear example of a new generation of public policies that are used to address in a more coherent and active form all the difficulties still exiting in the country to reach full electricity coverage. After many years of fragmented and limited initiatives, the FISE fund created in 2012 combines a variety of regulatory instruments and public resources with the objective of universalizing the access and use to clean energies. This initiative has been complemented with several universal service auctions that aim at completing the electrification of rural areas though the use of off-grid technologies that are adapted to the circumstances of the rural communities.

The next challenge faced by LA is to increase overall consumption levels. Indeed, today, several countries have high levels of electricity access but low levels of consumption per capita. Moreover, there are huge disparities in levels of household consumption within countries. Increasing consumption in rural areas, though, is crucial for development. Renewable energy technologies, such as solar panels, have helped increase access but may prevent future consumption growth. In the long term they will have to be replaced by other technologies, following the ladder of investment. Social tariffs can also increase consumption but they need to be well designed to avoid distortions in consumption patterns and investments.

[14] New initiatives has been developed in recent year that seek an integrated management of environmental resources. See for example the project Nexus Observatory, promoted by the UN-FLORES Institute (https://nexusobservatory.flores.unu.edu/).

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