Lessons Learned from Rural Electrification Experiences with Third Generation Solar Home Systems in Latin America: Case Studies in Peru, Mexico, and Bolivia

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Received: 24 November 2019; Accepted: 10 December 2019; Published: 13 December 2019

Abstract: There are 17 million people without access to electricity services in Latin America. This population lives in small isolated and scattered communities with low incomes where it is difficult to achieve 100% access to electricity by the grid extension. Therefore, it is necessary to create market mechanisms and promote off-grid electrification in which photovoltaic (PV) technology plays a fundamental role. This research assesses successful projects developed in Peru, Mexico, and Bolivia, where 3rd Generation Solar Home Systems (3G-SHSs) are being introduced to support off-grid initiatives. To do so, we applied a mixed-methods approach including a comparative case study analysis, an extensive literature review, focus group discussions, and field research. Thereby, the lessons learned reveal that confidence, commitment, and flexibility are the main pillars of rural electrification. Additionally, it is demonstrated that the combination of various business models—an energy service company, fee-for-service, pay-as-you-go, and a microfranchising—with 3G-SHSs is powerfully effective in terms of sustainability. Our findings are useful to policy makers, researchers, promoters, and other stakeholders to rethink intervention strategies in rural areas. Access to electricity must be a state policy to facilitate the participation of new actors, especially of the private sector and communities, and the introduction of innovative business models and high-quality technology.

Keywords: electricity access; off-grid electrification; business models; 3rd generation solar home systems; photovoltaic; rural areas; sustainability

1. Introduction

Energy, one of the main factors in achieving the Sustainable Development Goals (SDGs), is essential to improve people’s living conditions, reduce poverty, and face climate change. This is particularly important in remote areas to support social, economic, and environmental development [1,2]. Providing energy access is a challenge when there are drastic differences between energy use in urban and rural areas [3,4]. This, together with low incomes of the rural population, geographic conditions, unsuitable policies design, deficient institutional frameworks, and limited financial options [5,6], demand innovative ways to overcome the current weaknesses of rural electrification. As much as
anything, remote and isolated areas have no electricity access because a grid extension is difficult or even economically infeasible. Here, diesel generators could be costly due to fuel price volatility, as well as their maintenance. As a solution, off-grid systems are being deployed to achieve 100% electrification [7], where photovoltaic (PV) technology plays a fundamental role. All over the world, 485 million people are expected to gain access to electricity in 2030 through decentralized systems such as solar PV systems and mini-grids, and 185 million people will gain access by grid expansion [8].

PV technology, the most cost-effective and efficient solution, is widely used to bring electricity to remote areas in developing countries [9–11], especially with Solar Home Systems (SHSs), which are suitable for satisfying small energy needs. Despite the fact that their costs are lower than those of expanding the electrical grid, there are so many barriers that make the implementation of SHSs challenging [9,12]. Often, off-grid electrification programs fail because of the insufficient involvement of the government, weak policies that inhibit private participation, financial difficulties that entail that business models are poorly designed, the withdrawal of the concession area, and limited capacity buildings that suggest that projects did not adapt to local circumstances [2,9,10,13]. Generally, in developing countries, governmental changes affect the promotion of political statements and formal institutions to support off-grid electrification [14]. Furthermore, many of these projects lack the local community’s participation, trained people, and funds to ensure operation and maintenance (O&M) activities [7,10,15]. This implies that some authors assert [2,16,17] that energy access programs have been defined in a rigid manner, where stakeholders have pre-defined tasks and users are considered as pure beneficiaries without any specific role within the project. The lack of an appropriate application of technical standards is also a weakness that usually inflates costs and reduces the quality of SHSs [18,19]. This has been well-demonstrated in several studies [20–24]. For instance, batteries, which have been considered one of the weakest components of SHSs, have had lower lifetime periods. This has demanded regular replacements, increasing the total costs of SHSs by 40%, and reducing the reliability of electricity service [20]. Furthermore, only affordability has determined SHS capacity, rather than the power needs of the population [25]. This is the case of Indonesia’s Solar Home System Project (ISHSP) from 2003 to 2007 [13], the Prodeem, the Brazilian program for rural electrification using photovoltaics (1994), and the Vunivau solar home systems, phase I and II (2002–2005) [7,10]. Therefore, the lack of sustainability in the management of projects is determined by the lack of commitment from key stakeholders (including local communities), low economic benefits, and changing conditions [26].

Decentralized strategies, which have relied on only techno-economic assessments, are being shaped to face the challenges of rural electrification. Emerging from multicriterion analysis, other factors such as political, environmental, and social concerns are also being evaluated to support decision-making [27]. Economic linkages, access to financing, the creation of institutional arrangements, and local participation are becoming more relevant in off-grid electrification [13,19]. This means that innovation in business models and a demand-driven approach are the keys to improving the financial status of villages and knowing how to build a dynamic market for energy access using off-grid solar technologies [13,19]. Among successful cases that have considered these aspects, we can name, from 1997 to 2002, the Sri Lanka’s Energy Services Delivery Project (ESDP), where a suitable financial model and credit facilities were included [13]. In Bangladesh, there is the Infrastructure Development Company Limited (IDCOL) (2002–present), which works together with 16 other partner organizations. IDCOL is responsible for providing grants and refinances the systems, taking care of the technical quality of SHSs, building capacities, and monitoring [7,10,22]. The latter are in charge of offering microfinancing to consumers, the installation and O&M of PV systems, and training local people [7,10]. However, this project is still facing a lack of government support via suitable energy policies to accelerate project development [7].

Aggressive and well-designed programs are needed to face the barriers related to energy poverty, largely in rural areas where the level of development is usually low [28,29]. Rural electrification programs must focus on political and institutional strengthening, business models to make electricity
service affordable, technological quality, community involvement, and sustainability matters. Once the multiple weaknesses of rural electrification are described, this research assesses and contrasts the initiatives that the public and private sectors are carrying out together to solve the problems related to electricity access using SHSs. To do that, we have selected rural electrification projects of three countries from the Latin America region with wide experience in PV rural electrification: Peru, Mexico, and Bolivia. We studied the Light at Home Program in Peru (Programa Luz en Casa Peru), the Light at Home Program in Mexico (Programa Luz en Casa Mexico), and the Development of Microfranchises for Access to Clean Energy in Rural Areas Project (Desarrollo de Microfranquicias Rurales para el Acceso a Energía Renovable) in Bolivia. The present research identifies the lessons learned from these ongoing projects in terms of policies, stakeholders, business models, technology, payment capacity and management, technology and quality, O&M, and community participation. These lessons work to pinpoint the key factors that support off-grid electrification sustainability, which would be useful to policy makers, researchers, experts, promoters, and other stakeholders involved in rural electrification. This study highlights that off-grid implementation must rely on adaption to changing circumstances, and must generate commitment among partners and confidence within communities. We organize this paper as follows: Section 2 presents the theoretical background, followed by a description of case studies in Section 3 and the methodology applied in Section 4. Afterward, Section 5 presents the lessons learned from the projects, and Section 6 shows the sustainability factors identified. In Section 7, we present a discussion. This article summarizes the results and policy implications in Section 8.

2. Previous Considerations for Off-Grid Electrification

The quality, affordability, and reliability of energy access depend on robustness and well-designed mechanisms in communities [30]. A combination of different business models and innovative technological solutions can be considered to support SHSs introduction. This combination involves the definition of responsibilities and tasks among partners, affordability of electricity service, capacity building, sustainability guarantee, and technology support for streamlining management. Furthermore, the solutions to deploy SHSs must adapt to local conditions. Here, we outline concepts applied to deploy SHSs in the cases analyzed, based on an extensive literature review. This section seeks to facilitate the reader’s understanding through the introduction of a theoretical background of off-grid electrification.

2.1. Business Models

We classify business models according to project management, financing facilities for the rural population, opportunities of local entrepreneurship involving communities, and technological support.

2.1.1. Management Models

• Public–Private Partnership (PPP)

A PPP is a contractual agreement in which the resources and skills of the public and private sectors are combined to provide services. The private sector provides its resources, knowledge, capacity management, and technology, and the public sector establishes regulations and protects the public interest. A PPP also includes the participation of non-governmental organizations (NGOs), microfinance companies, multilateral banks, communities, and universities [31–35]. In the context of energy access, the PPP is called pro-poor public–private partnership (5p), or public–private partnership for development (PPPD) (in recent years), which aims to provide energy services to poor communities [35–37]. The PPPD was introduced and improved by the Spanish Agency for International Development Cooperation (AECID) to support the achievement of SDGs, especially the SDG17, in different contexts of development, such as access to energy, humanitarian aid, and the development of small businesses [37]. The PPPD has a protocol to guide its design and implementation [38].
The main idea is to involve community participation and rural development [39], where a proper organization of economic and institutional issues and flexible funding to the population are required [2]. In fact, the 2030 Agenda for Sustainable Development fosters these partnerships to focus initiatives on shared visions and goals [40]. Based on past experiences, conventional approaches fail when they are led only by one actor: The public or private sector [2]. The most cost-effective way to expand energy access requires a shift in how practitioners conceive technology and program structures [35], so a PPPD can be one of the best options to overcome rural electrification constraints [2].

- **Energy Service Companies (ESCOs)**

  An ESCO comes from regulated energy markets to provide energy services by regulated providers. Some of these services can be O&M, sales, demand-side management, energy audits, and assisting customers [41]. In emerging markets, this model delivers sustainable energy solutions while creating jobs [42,43]. Generally, this scheme facilitates the implementation of small networks throughout communities, provides a cost-effective electricity service, and improves the living conditions of inhabitants [43]. An ESCO provides solar electricity and meets incentives via established tariffs (fee-for-service model) to guarantee service provision and obtain affordable electricity prices [2,43]. On the other hand, although this concept is highly recommended for rural contexts [30], according to Lemaire (2009) [43], consumers pay for that service every month, and fees are not enough to cover the installation costs of SHSs. Furthermore, in previous experiences, the ESCO has designed O&M costs based on information provided by manufacturers or a percentage of initial investment of equipment (between 1 and 3%), leading to a negative financing balance. This practice, which does not consider real conditions, has made ESCO permanence in rural communities unsustainable [15].

2.1.2. Funding Models

- **Fee-for-Service Models**

  In this model, the government establishes an agreement with a company or a social enterprise to delegate the control of a geographical area (concession model) or to limit the competition (leasing or dealer model) [44]. The company usually works as a small or micro utility (ESCO), which installs and operates SHSs to deliver electricity, and their customers pay for the service received periodically. Fee-for-service seems to be used regularly in rural areas in which well-implemented banks are not available [9,43]. When this scheme includes a cross-subsidy established by centralized governments, the introduction of off-grid technology is facilitated [45].

- **Mirocredit Schemes**

  Local dealers sell their products to communities via personal guarantees or collateral. This model, which is commonly applied to promote SHSs, excludes poor families without the ability to provide collateral [35,46]. This model is the most expensive for the poor [47]. Private companies are responsible for maintenance, while financial support comes from another institution that works closely with the first one [9]. Credit suppliers may be banks and microfinance institutions (MFI) [47]. However, some countries have no rural banking or MFI entities; thus, the lack of access to credit is the biggest challenge for entrepreneurs in developing countries [9,48].

2.1.3. Business Models for Local Entrepreneurship

- **Microfranchising**

  Microfranchising is based on a relationship between a franchisee (small business) and a franchisor (large business or brand). The franchisee produces or commercializes a product or service of a project designed by a franchisor. The franchisor is responsible for the publicity, support, marketing, and training [49,50]. Microfranchising, whose social approach comes from the connotation “micro” to help the poor at the base of the economic pyramid, is designed to offer opportunities to the poorest to
own and operate a business, improve capacities, and live in a state of economic self-reliance [49,51]. This business model is considered a channel to reach end-users in remote areas [52]. It reveals satisfactory results by the generation of employment and the increase in revenues, especially to people with a low level of education and incomes [53]. In the energy access field, microfranchising has been introduced to deliver bills, collect revenues, and read meters, and communities take part as agents of distribution utilities [2,54]. There are also experiences where microfranchisees were expected to become entrepreneurs, but most of them only engaged in billing and collection tasks [30], or where franchisee revenues were poorly designed, which discouraged collection [54]. From another perspective, in some countries of Africa, microfranchises are set up to deliver solar lanterns and help to improve people’s incomes, instead of only giving lanterns away. Not only sales agents but also teachers of schools, who are trusted members of communities, participate as microfranchisees to raise trust in the technology through training sessions about the benefits of solar power [55]. All these experiences show that there is a link between energy and incomes through enterprise development after electrification [56].

2.1.4. Technological Models

• Pay-As-You-Go (PAYG)

The PAYG model uses mobile phone technology based on banking facilities to roll out renewable energy in developing countries. PAYG allows the end-user to pay for a contracted service (fee-for-service model), acquiring a product or renting a system. It facilitates payment management to the supplier in that customers pay affordable installments [57–61]. This model is useful to request support, commercialize equipment, and solve commercial incidences. However, it is important to emphasize that technology cannot replace the technical staff in promoting, delivering, installing, and maintaining PV systems [58].

2.2. Technical Quality of SHSs

In order to reduce electricity costs and contribute to the deployment of the solar market and create confidence, the quality assurance of SHSs is a crucial factor to be taken into account, especially in rural areas [20–24,62–64], where the lack of an effective quality and the application of standards has been a weakness [18,19]. The purchase of an off-grid product or SHSs can represent a large investment for a rural family, which cannot afford to waste money on something that does not work well or will not last [65]. In this sense, the technical quality assessment of SHSs has two objectives. The first one is technical: To assess the lifetime of systems and their components, according to international standards, and their compliance with design goals, safety, and reliability [66]. It involves the application of tools such as standards, certifications (assessing equipment, services, and management procedures), accreditation, inspection bodies, metrology, and market surveillance [67]. The standard used to assess the technical quality of SHSs is the IEC 62257-9-5: the 2018 “Integrated Systems—Laboratory Evaluation of Stand-Alone Renewable Energy Products for Rural Electrification”, which is part of the IEC 62257 series: “Recommendations for Renewable Energy and Hybrid Systems for Rural Electrification” [68]. The second objective is social: To identify technical problems linked to the social acceptance of the technology to improve its reliability [66]. The SHS market quality is supported by the Lighting Global Program (2010) to make modern SHS products affordable and available to off-grid users [69]. In spite of this fact, manufacturers are concerned about certification process complexity for several reasons: There are only two accredited laboratories (Schatz Energy and Research Centre (SERC) and China’s SMQ Lab) to certify SHSs globally; it is necessary to re-certify products every two years with the updated standard; the certification process lasts approximately 16 weeks in the laboratory; after passing laboratory tests, the equipment has to be evaluated on-field [70]. Furthermore, certification costs are high, around $18,000 US (From conversations between the Solar Energy Institute (Instituto de Energía Solar de la Universidad Politécnica de Madrid-IESUPM) and manufacturers), and fees usually
increase [71]. Manufacturers consider this process a bottleneck [70]. Thus far, there are only 38 certified products [71].

2.3. Off-Grid Projects Sustainability

Sustainability is widely understood as the linkage between economic, social, and environmental components, and it is known as the triple-bottom-line perspective [2,72,73]. Sustainability, which is becoming highly important to learning how to manage projects, fosters treating social and environmental factors at the same level as economic aspects when doing business, emphasizing a long-term view [72,74,75]. According to Martens and Carvalho (2017) [73], sustainability applied to the project management context is reflected in the follow elements: (i) Environmental policies and resource saving, which implies that stakeholders are interested in environmental sustainability topics, (ii) the economic and competitive advantage, which involves the project’s performance in terms of costs, funding and economics, taking care of commitments, and ethics, (iii) stakeholder management, which demands the engagement of stakeholders, as well as relationship between stakeholders and between them and society and labor practices, and (iv) sustainable innovation business models, which means a management of organization culture and innovation that includes social concerns in business. However, supporting sustainability in real practice is a difficult task [74]. In the context of energy access, sustainability is emerging as a critical matter for policy makers and development practitioners. Previous experiences indicate that off-grid technology still needs to be made affordable, to give financing possibilities to the poor and remove non-economic barriers [47].

3. Case Studies Selected and Background

In Latin America, 17 million people still live without electricity in rural areas, often in places difficult to access and far from the grid [8]. In Peru, Mexico, and Bolivia, the electrification rate was 94.8, 98.5, and 93%, respectively, in 2016 [76,77]. Even though the electrification rate is clearly higher than other regions such as Sub-Saharan Africa, the number of people without access to electricity is large: 1.64 million people in Peru, 1.81 million people in Mexico, and 758,000 people in Bolivia [76–78]. These people live in small, isolated, and scattered communities with low incomes where it is difficult to achieve 100% access to electricity by the electrical grid. They live in poverty or extreme poverty, and their economy depends mainly on agriculture and livestock. It is expected that Latin America achieves near-universal access to energy in 2030 thanks to a wide range of technology and business models [8]. However, due to the fact that electricity companies cannot solve problems of access to electricity on its own because of the associated high costs, the implementation of adequate business models is essential to include new participants and mature and innovative technology such as PV. This section summarizes the cases studies selected that constitute a collection of successful experiences from which relevant lessons can be learned.

3.1. The Light at Home Program in Peru: Cajamarca and Napo

Acciona.org Peru, a non-profit organization, has been providing electricity with SHSs in Cajamarca and Napo since 2009 and 2016, respectively. The management model implemented is an ESCO, whose structure is shown in Figure 1. The initial investment of these projects was mainly funded by the ACCIONA/acciona.org Foundation through acciona.org Peru and co-funded by the Multilateral Investment Fund and the Inter-American Development Bank (MIF-IDB) with a credit, the National Fund for Scientific and Technological Development and Technological Innovation (FONDECYT), and the AECID. The cooperation agencies and the multilateral bank are responsible for following up and monitoring. Acciona.org Peru owns SHSs and customers pay a monthly fee for the energy service, which includes a daily amount of available electricity.
Figure 1. Management model implemented in Cajamarca by acciona.org Peru.

In 2010, the Supervisory Agency for Investment in Energy and Mining (OSINERGMIN) regulated the maximum tariff of the electricity service (fee-for-service model) according to the power of the solar panel and the electricity supply to the client. This regulated tariff ensures enough income for acciona.org Peru to cover investment, operation, and management costs, guaranteeing a sustainable service. The tariff is combined with the Electric Social Compensation Fund (FOSE) [79]. The FOSE is a cross-subsidy that covers 80% of the regulated tariff. The part of the tariff not covered by the subsidy establishes the maximum tariff paid by clients. These clients, who are living in a region without access to the electrical grid, can access an affordable electricity service through the FOSE. Electricity customers whose consumption is higher than 100 kWh per month feed the FOSE through a low percentage of their electricity invoice. Beneficiaries of the Light at Home Program pay a tariff that is lower than the monthly cost of alternative energy sources such as candles or batteries. There are photovoltaic electrification committees (CEFs) that collect fees and offer preventive maintenance to end-users.

Since 2012, 12 Light at Home Centers (Centros Luz en Casa) (CLCs) have been set up in Cajamarca. These are technical assistance centers in which local technicians provide support to consumers and have a small business through a franchise contract to sell electrical appliances compatible with solar systems such as TVs, radios, tablets, DVDs, small battery chargers, bulbs, and fans. In these centers, the population buys different appliances to have access to more energy services than just lighting. This project has provided access to electricity services to 3900 rural households (16,000 beneficiaries) with SHSs.

In 2016, acciona.org Peru started to develop the Light at Home Program in Napo, located in the Loreto region (Peru) in the heart of the Amazon forest. The goal of this program is to install 1400 SHSs in the Amazon communities close to the Napo River. Today, there are more than 400 SHSs installed. The project expects to expand to other river basins in the Amazon region. A new regulated tariff was published in 2018, and the project includes fee-for-service and PAYG models to facilitate the management of payments in the CLC. There are two CLCs in this region.

3.2. The Light at Home Program in Mexico

During the 2012–2016 period, the Light at Home Program in Oaxaca facilitated access to SHSs to more than 7500 households (30,100 users) located in communities with less than 500 inhabitants where the grid extension was not planned. Acciona.org Mexico promoted the project through a PPPD that included the participation of the government of Oaxaca, AECID, and the Mexican Agency for...
International Development Cooperation (AMEXCID) to cover the initial investment. Figure 2 shows the structure of the PPPD implemented in Oaxaca.

The PPPD promoted the partial subsidized sale of SHSs. The customers had to pay half the cost of the equipment, which meant approximately $150 US. Furthermore, when the customers were not able to pay the fee, they had access to the micro-finance program in cooperation with KIVA International Organization (a crowd lending, non-profit organization) [80]. The customers had the chance to reduce their monthly fees for one year, which were even lower than alternative energy costs (batteries, candles, kerosene, etc.). In Oaxaca, there are six CLCs that operate in the same way as in Cajamarca (microfranchises) to solve equipment failures and sell high-efficiency electrical appliances compatible with SHSs. Municipalities and CEFs participate in project management as service suppliers and communicational channels. CEFs are also in charge of fee collection.

This successful program has prompted the new government of Oaxaca to show interest in extending the project to other zones and in expanding services such as water supply, sanitation, and cooking. Thus, acciona.org Mexico has reached a new agreement with the government of Oaxaca. Today, there are more than 1000 SHSs being installed.

3.3. The Development of Microfranchises for Access to Clean Energy in Rural Areas in Bolivia

This project started in 2014 under the “+energy” brand to commercialize SHSs through a microfranchising model promoted by ENERGETICA and supported by the MIF-IDB, AECID, the German Corporation for International Cooperation (GIZ), and municipalities (Figure 3 shows the PPPD implemented). There are two ways to carry the subsidized sales in this project. The first involves direct sales by 60 microfranchisees (local entrepreneurs) to the end-users. The second consists of distribution sales through agreements with municipalities [81]. Both of them also offer Light Solar Panel Kits, Solar Battery Kits, and other equipment such as bulbs, TVs, radios, water pumps, and productive systems mainly for the farming sector and equipment maintenance.
In 2017, this project registered 12,510 beneficiaries: 11,800 families with SHSs, 650 micro and small businesses that have acquired productive systems (grain mills, water pumps, electric fences), and 60 communities that have acquired systems for social purposes (pumping of drinking water, lighting of schools, and health centers). In the same year, the project generated 60 jobs with an increase in incomes 20% or more. Total sales have exceeded $2.09 million US.

4. Materials and Methods

Primary information comes from a mixed-methods approach that combined the assessment and contrast of cases studies, the review of scientific documentation, interviews through focus group discussions, and field research. Thanks to this approach, we have identified the lessons learned from cases analyzed and the main factors needed to guarantee the sustainability of off-grid electrification. To do that, the Solar Energy Institute (Instituto de Energía Solar) of the Technical University of Madrid (Universidad Politécnica de Madrid) (IES-UPM) organized a workshop on exchange experiences in Cochabamba (Bolivia) from 13 March to 16 March, 2017. The representatives of the acciona.org Foundation, acciona.org Peru, acciona.org Mexico, ENERGETICA, PHOCOS Bolivia, and the Mayor University of Saint Simon (Cochabamba, Bolivia) were invited to attend the event. Fifteen participants were present, including project managers, researchers, local partners, and other stakeholders.

On the first day of the workshop, the participants made oral presentations to provide general and detailed information on projects. On the second and third days, we used a participatory methodology, a “focus group,” to gather valuable information. A focus group is a helpful qualitative method to examine how knowledge and ideas interact within a cultural context [82], where a moderator introduces topics to be discussed by the participants [83]. This method creates a reflection space to facilitate the understanding and an in-depth comprehension of a specific topic [82]. It makes it possible to obtain insight ideas and expert knowledge [84]. On that basis, we applied semi-structured interviews by a facilitator from IES-UPM. The topics we analyzed and discussed were (i) policies to promote energy access in each country, (ii) business models, (iii) PV technology and quality assurance, (iv) local participation, and (v) management and project sustainability. We conceived those aspects as crucial in rural electrification because of the deficiencies described in Section 1. On the fourth day, we visited a few communities to verify SHS installations and to meet microfranchises. We interviewed a microfranchise and a client of ENERGETICA. This fieldwork reinforced triangulation analysis and research reliability. We analyzed the information gathered and organized the main results according to

Figure 3. PPPD implemented in Bolivia by ENERGETICA.
the topics discussed, heeding the main differences among cases studies. We also strengthened our findings with a review of scientific and specialized literature.

5. Lessons Learned and Findings from the Case Studies

This following section summarizes the lessons identified from the cases analyzed by means of a comparative assessment. The most relevant aspects for a successful promotion of off-grid electrification with PV technology are presented, namely: Public policies, stakeholders and agreements, business models, payment capacity and management, technology and quality, O&M, local training, and awareness campaigns.

5.1. Public Policies

The regulatory framework establishes the fundamental principles to deploy off-grid systems in these countries, which has been the basis for the intervention of acciona.org and ENERGETICA. Thanks to the political backing at the national, regional, and above all local level, the projects have built trust in communities to ensure their implementation and permanence. In Peru and Mexico, acciona.org has worked in areas where grid expansion by the government is not planned. While in Bolivia, thanks to the fact that municipalities have jurisdiction for rural electrification, ENERGETICA is working in a large number of provinces within the country. Linking local government aid allows ENERGETICA to achieve broad population participation.

In Peru, energy access is state policy [85], which ensures that a change in the current government will not affect progress in eradicating energy household poverty. In fact, there is an exclusive regulation for off-grid electrification [86]. The General Directorate of Electricity (DGE) of the Ministry of Energy and Mines (MINEM) awarded the concession area to acciona.org Peru through the General Directorate of Rural Electrification (DGRE) (2008) [87]. Acciona.org Peru electrifies zones that are not included in the National Rural Electrification Plan. In Mexico, the Electric Industry Law (2014) [88] promotes rural electrification and sets the concession area to be electrified by the public electricity company (the Federal Electricity Commission (CFE)) [89], which in turns defines the area where acciona.org Mexico establishes its potential market. In this country, there is a Universal Power Service Fund that benefits from the income surplus of the electricity market, which is used by distributors and suppliers of energy services in rural communities [88]. In Bolivia, the Political Constitution of State (CPE) defines access to electricity as a right, and the Patriotic Agenda 2015–2025 aims to supply this basic service to 100% of the population by 2025 [90,91]. The CPE establishes that the local government (governorates) must promote rural electrification, whereas the municipalities are responsible for renewable energy projects [91]. Acciona.org Mexico and ENERGETICA have faced political changes that have affected project continuity. This has demanded additional efforts to inform new authorities of project status.

Even though PV dissemination results are positive in these cases, strengthening political support is still a big challenge. Acciona.org Peru, acciona.org Mexico, and ENERGETICA agree that access to energy should be a state policy in every country that has signed a commitment to the SDGs, and consequently has the responsibility for reporting its achievements. This would reduce political constraints in Mexico and Bolivia. Thanks to the suitable policies in Peru, acciona.org Peru is working as an ESCO, while acciona.org Mexico and ENERGETICA work as private suppliers (PPPD model) of SHSs taking higher economic risks due to the lack of a fee-for-service model.

5.2. Stakeholders and Agreements

A well-articulated partnership among promoters, the public sector, funders, and communities has helped to establish a lasting commitment to implement long-term projects. Most importantly, to raise trust among partners, especially with the public sector and communities, it seems to be a plus for rural electrification that promoters have to be local companies. Acciona.org is a corporate foundation (subsidiary) of a Spanish private company ACCIONA (multinational), which sets up local foundations in every country where it has rural projects. Acciona.org Peru and acciona.org Mexico recruit local people
to lead and manage their projects, keeping a close relationship with acciona.org Spain. ENERGETICA is per se a local organization that was set up by local entrepreneurs. Furthermore, the participation of international cooperation agencies such as AECID, FONDECYT, AMEXID, and GIZ and of a multilateral development bank such as MIF-IDB is essential to audit and cover the initial investment of projects and to look after experience exchanges between regions and countries. The public sector establishes mechanisms to introduce and deliver technology, to provide subsidies to help affordability, and to support the projects so as to raise confidence in communities. Local people are more interested in being part of the projects when local governments are involved.

Local participation facilitates understanding and marketing to improve the reception of the projects, to enhance teamwork, and to generate confidence in the whole community. Local people know the culture of the community and speak the native language or dialect. Local institutions work as service providers in Mexico and Peru, and as sales channels and funders in Bolivia. Communities participate in committees for rural electrification in Mexico and Peru, and as microfranchisees in Bolivia, Peru, and Mexico. For example, in Peru, a committee consists of a group of at least three people, one of which has to be a woman. The committee works as a connection between the operator (accciona.org) and the beneficiaries, collecting fees and helping the operator on preventive maintenance. Rural electrification is promoting gender equality in Peru and Mexico, an initiative that ENERGETICA should embrace. One of the key aspects leading to the success of these projects is trust among partners, especially among local governments, promoters, and communities.

5.3. Business Models

The business models of these case studies, which can be considered successful projects, are designed according to local conditions, involving the participation and commitment of multiple stakeholders such as governments, cooperation agencies, private entities, NGOs, banking facilities, academy, and communities, guaranteeing a reliable and affordable electricity service that reaches a larger population. Furthermore, the combination of business models shows how off-grid electrification must be planned, initiated, funded, operated, and sustained. This approach ensures sustainability through the allocation of clear responsibilities, the design of suitable and proper financing mechanisms, the community training in technology and business (essential for management), the assurance of maintenance and quality. The combination of different business models joins subsidies together with innovative technologies such that access to electricity services is affordable. Table 1 shows the business models used to promote solar technology in each case study; business models, subsidies, equipment, and service details are described.

PPPD and ESCO models, which establish the roadmap to provide access to electricity, ensure the community and government participation at national, regional, and local levels in Mexico and Bolivia, and Peru, respectively. The ESCO model reveals itself as a successful option that requires the government initiative to lead and regulate off-grid electrification.

Giving financing possibilities to the end-user is a fundamental factor in successful business models for rural electrification. The fee-for-service model is a cost-effective solution when the promoter provides an electricity service that generates recurring incomes to ensure the sustainability of entrepreneurship (microfranchising) and the operator (micro-utility). This demands strong government participation and regulation mechanisms to fix a realistic tariff. While a microcredit scheme is suitable to commercialize solar systems when the population does not have savings capacity to cover the fees. In Peru, the fee-for-service model is in accordance with a national regulation that establishes that the government has to subsidize customers for a period. This subsidy is 80% of the electricity tariff (cross-subsidy) to people with low incomes. In Mexico, a subsidy was provided (50% of the cost of the SHSs—approximately $150 US) by municipalities in the first instance. However, when the promoter realized that some people could not afford to pay for the solar systems, they introduced the microcredit scheme. Thanks to an agreement with a US non-profit organization, it is possible to fund loans at the base of the pyramid. Acciona.org Mexico manages the credit facilities and assesses to provide
access to credit to their customers. In Bolivia, the subsidy of PV technology is between 24 and 50%, so the user only has to pay from $100 to 200 US for the equipment. In spite of the fact that subsidies are available, many people cannot afford to pay for any solar equipment. This is why ENERGETICA has implemented a financing mechanism to provide payment facilities that involve a credit system managed on its own. Microfinancing is a potential solution that makes renewable energy technology acquisition to end users possible. Even though in Mexico and Bolivia there are no local financial institutions showing interest in being part of energy projects in rural areas, acciona.org Mexico and ENERGETICA have adapted their business to meet market needs, taking care of their own liquidity. In addition, as some authors have concluded, a subsidy makes SHSs affordable and helps to accelerate their penetration in rural communities [46,92]. Nevertheless, according to the experiences analyzed, this is true as long as a fee-for-service scheme incorporates a cross-subsidy. When this is not possible due to policies and the commitment of government, subsidies combined with other business models such as microcredits make SHSs affordable. In all cases, further government commitment is required to maintain public subsidies when the external financing ends.

Table 1. Models for the promotion of solar technology.

| Place         | Business Model | Management | Financing                      | Sustainability Model | Technological Model | Subsidy | Equipment-Service |
|---------------|----------------|------------|--------------------------------|----------------------|---------------------|---------|-------------------|
| Bolivia       |                | PPPD       | Microcredit (managed by ENERGETICA) | Microfranchising: Direct sales (local entrepreneurs); distribution sales (municipalities) | PAYG 24–50% of SHS | SHS, electrical appliances, and productive systems, O&M |
| Around the country |                |            |                                |                      |                     |         |                   |
| Mexico        |                | PPPD       | Microcredit (international financial institution) | Microfranchising: CLC | - 50% of SHS | SHS, electrical appliances, O&M |
| Oaxaca        |                |            |                                |                      |                     |         |                   |
| Peru          |                | ESCO       | Fee-for-service                | Microfranchising: CLC | - 80% of regulated tariff | Electricity service, electrical appliances, O&M |
| Cajamarca     |                |            |                                |                      |                     |         |                   |
| Napo          |                | ESCO       | Fee-for-service                | Microfranchising: CLC | PAYG 80% of regulated tariff | Electricity service, electrical appliances, O&M |
|               |                |            |                                |                      |                     |         |                   |

Another relevant aspect is the fact that electrification is not enough to improve the economic situation of rural people. Thus, setting up microfranchises can efficiently solve problems derived from the low incomes of the population. In Peru, Mexico, and Bolivia, the promoters have implemented microfranchises as a long-term sustainability strategy. In previous experiences, microfranchises were designed only to collect fees, deliver bills, and perform metering. In the case studies, they furnish O&M and access to SHSs and more energy services via sales of electrical appliances; e.g., in Bolivia, microfranchises sell SHSs and productive devices used in the farming sector. Thanks to this model, the foundations can guarantee the money flow in the project, the technician’s revenues, and access to
more energy services. Likewise, local people receive training in O&M and management, can set up their own business, and have the opportunity to replace equipment that has reached the end of its usable life.

We have identified the design factors of microfranchisees: technology, management, economics, and culture. “Technology” entails which products should be offered, such as SHSs, electrical appliances, and productive systems, which demands the assurance of the technical quality of equipment and O&M. “Management” is related to fee collection, building local capacities, undertaking campaigns to raise confidence, and providing an effective after-sales service. “Economics” involves the assurance of money flow and the reinforcement of product sales. “Culture” implies communication with communities, commitment, confidence, and the identification of needs. Moreover, microfranchisees provide project feedback to promoters. From a business perspective, a microfranchising seeks financial sustainability in electrification projects as a way of increasing a community’s incomes through employment, productivity, and ensuring confidence in rural areas. From a social point of view, microfranchising provides access to electricity services such as lighting and communications. Particularly, in Bolivia, these services create opportunities in the agriculture, water, health, and education sectors.

Including a microfranchising within off-grid projects increases community participation. This model is mainly addressed to local entrepreneurs as a complementary economic activity in their business because it guarantees the project profitability, reducing investment needs, economic risks, and sales volume dependency. This can even drive the implementation of family microfranchises. For instance, in Bolivia, microfranchisees (generally male) train their family members (generally their wives) to manage the business when they are not at home. Promoters also involve people who do not have any business or employment and who show commitment to the project. This avoids increasing social disparities. Local governments can also be microfranchisees, e.g., municipalities in Bolivia, whose distribution system has reached 80% of total sales, since people trust in the local government, while microfranchises operated by local people have reached 20%. This model recognizes the importance of such actions as working with the local government in a framework of cooperation, regular training for microfranchisees, exchanges of experiences, and the diversification of products, which ensures economic growth for microfranchisees and microfranchising. In Peru, the fee-for-service model ensures the economic viability of microfranchisees. A technician’s revenue ranges from 800 soles ($240 US) to 2000 soles ($599 US) per month in Cajamarca. In Bolivia, microfranchisees can earn $300 US/month if they work full time.

The PAYG model has reduced the transportation costs of technicians to collect money and facilitates payment and management. In Napo, acciona.org Peru is using this technology to manage payments, to enable or disable the electricity service, and to speed up maintenance requirements and sales. ENERGETICA is starting to use the PAYG, which is limited to the payment of fees. PAYG, which is gaining force in rural communities, supports other businesses such as microfranchises and fee-for-service. These foundations started to use PAYG when they changed from conventional solar systems to others that were more innovative, including communication systems. In Cajamarca, conventional SHSs hinder the implementation of a PAYG model, whereas acciona.org Mexico is planning to introduce this model in Oaxaca.

Before planning rural projects, acciona.org and ENERGETICA have worked to understand the market, find investors, and define business models. With these inputs and analysis, they advise the government on improving regulations to make solar technology accessible to rural people. When a planned PPPD does not obtain the commitment of every partner, the project simply does not work. Both the fee-for-service and microcredits with subsidies are suitable financing models for electrification.

5.4. Payment Capacity and Management

Even though payment efficiency has been a big challenge in rural electrification [19], according to the cases analyzed, studying market characteristics allows for planning of appropriate payment
mechanisms to cover a larger population. Payment management supports money flow and rural electrification sustainability.

Before starting a project, acciona.org Mexico and Peru georeference the households and analyze the community’s incomes and expenses related to conventional energy (fuel, batteries, and candles) to define their payment capacity. For instance, in Napo, a family spent 30 soles ($8.90 US) per month on energy. Now, the electricity tariff paid by the same family is 30 soles every three months. This shows that it is possible to reduce energy costs in rural areas. Acciona.org strictly monitors payment management, which is positive for the project to increase the community’s commitment. If people cannot pay for the electricity service due to financial problems, they have a period in which their obligations are to be fulfilled. The foundation cancels the service after six months of non-payment in accordance with the current regulation. Acciona.org has a close relationship with its clients to understand their social situation. This is possible thanks to the CLCs set up in Oaxaca, Cajamarca, and Napo. They provide customer service and the sale of equipment to the clients and feedback to the promoter.

In Bolivia, a baseline study shows that the annual cost of traditional energy is between $45 and 85 US, which is 5–10% of annual incomes (A widely reference used is that the electricity is affordable when it does not exceed 5% of household expenditures in tropical climates and 10% in temperate climates where electricity may cover heating [93]). According to ENERGETICA, everyone who spends 1 BOB (14 USc)/candle/day is a potential client. Mainali and Silveira [46] conclude that only richer sections of the rural population can pay in cash for SHSs. Based on the Bolivian experience, this is true under market conditions, but it is also related to the seasonality of farm incomes and the fact that people prefer to pay in cash to avoid traveling to microfranchises. The long distance is a permanent barrier in those contexts. Microfranchisees receive a commission on the sale of equipment after paying the bill to ENERGETICA. This foundation has increased sales at harvest time, which has even helped to strengthen its business strategies. Nevertheless, environmental risks could affect the liquidity of the population, reducing the sales during this time of year. ENERGETICA has implemented a credit system with PAYG technology, which allows the payment fees for the equipment to be controlled every three or six months, and it is also a solution to solve the lack of liquidity of the population.

5.5. Technology and Quality

Finding ways to make SHSs cheaper to end-users and ensuring the acquisition of quality equipment is a priority for organizations involved in the cases studied. In the first phase of these projects, acciona.org and ENERGETICA used traditional SHSs or 2nd Generation Solar Home Systems (2G-SHSs) to deploy rural electrification. However, the failures rates of these systems affected the electricity service, which in turns affected the confidence of local communities in the projects. Thanks to the innovation of the solar market, the price reduction, and the benefits of modern SHSs, both foundations decided to renovate their stock to introduce the 3rd Generation Solar Home Systems (3G-SHSs). 3G-SHSs are more efficient, smaller, lighter, easier to use and install, cheaper, more durable, and environmentally friendly. These systems joined with technical control procedures are reducing failures rates. It has been positive in terms of investment and O&M costs. In Cajamarca, where there are still 2G-SHSs, some parts are being replaced, e.g., LEDs (light emitting diodes) are replacing fluorescent lights.

Switching from 2G-SHSs to 3G-SHSs has made it possible to characterize SHSs according to their technical, economics, and operational features in different periods: From 1995 to 2015 and from 2010 to now. Table 2 presents detailed information about the technology used in the cases analyzed as well as the main differences that we have identified [94–97]. It is worth mentioning that this technological change means a technological evolution, but not a technological revolution. This means 3G-SHSs are becoming more attractive in rural electrification due to their lower costs. For instance, in Bangladesh, the IDCOL program had introduced 2G-SHSs and 3G-SHSs. Only the population in better economic circumstances had chosen 2G-SHSs because of the higher capacity [98]. Now, IDCOL focuses on introducing 3G-SHSs [99] under a rigorous quality control process [100]. In the cases
analyzed, 3G-SHSs are the best option due to the reduction of O&M costs and failures rates. Both are more difficult to face when the off-grid electrification deploys in the most scattered communities. This shows that the rural market is demanding more affordable and reliable equipment.

Table 2. 2G-SHS vs. 3G-SHS features.

| Component  | Description | 2G-SHS (1995–2015) | 3G-SHS (2010 to Now) |
|------------|-------------|--------------------|----------------------|
| **Generation** | Technology | Monocrystalline or polycrystalline | Monocrystalline or polycrystalline |
|             | Capacity (Wp) | 50–80 | 20–50 |
|             | Supply (Wh) | 200–250 | 100 |
| **Lighting** | Technology | Fluorescent lamps | LED |
|             | Capacity (W) | 7–11 | 3 |
| **Battery** | Technology | Lead-acid | Lithium-ion |
|             | Capacity (Ah) | 100–120 | 6–10 |
| **Regulator** | | External solid-state power controllers | Microelectronics integrated into the battery box |
| **Connection** | | Splices | Plug and play technology |
| **Weight (kg)** | | 30–50 | 6 |
| **Cost (USD)** | | 1000 | 350–650 |

1 Due to the lower costs of PV technology, some equipment suppliers increase the capacity of PV regarding the future electricity needs of end-users.

- 2G-SHS installation requires specialized knowledge, which inhibits end-user installation of systems. One 2G-SHS covers at least three light points (3 h/day), one radio of 8 W (8 h/day), one TV and one DVD of 27 W (3 h/day), and a mobile phone of 6 W once a day (2 h/day). The energy losses are around 21%. The total price (one 2G-SHS and appliances) was around $1000 US in 2009 [96].

- 3G-SHSs charge electrical appliances such as compact lights, a TV with an incorporated DVD of 11 W, and a mobile phone charger of 3 W with a USB connector. The internal microelectronics allows for control of the batteries apart from offering additional services (PAYG, GPS (global positioning system), and monitoring) and operational and technical simplicity. The plug and play system ensures simple and faster installation of solar equipment, which means even end-users can install equipment on their own. The total cost ($350–650 US) includes the PV module and appliances (standard or super-efficient appliances).

The quality of 3G-SHSs is verified by laboratory tests and fieldwork. The quality control ensures the efficiency of solar systems, management of economic resources and contractual requirements for future phases of implementation. Although 3G-SHSs affect the confidence of the community due to a lack of knowledge of the benefits of smaller solar systems, training sessions have helped to overcome this barrier. In the same way, there is a challenge in adapting international standards (IEC 62257) to the national context and identifying the testing capacity of national and regional laboratories. It entails developing an off-grid electrification platform that engages the participation of national and regional stakeholders (standardization, committees, and laboratories), universities, and companies to exchange experiences globally.

In addition, the possibility of product adaptability to local market requirements is a relevant factor for the success of projects. In this way, acciona.org and ENERGETICA have agreements with manufacturing enterprises (Fosera (https://fosera.com) is the international partner of acciona.org, and PHOCOS Latin America was the local partner of ENERGETICA. PHOCOS Latin America went bankrupt, and ENERGETICA is working with other manufacturers, e.g., ZIMPERTEC (https:
Acciona.org and ENERGETICA have introduced electrical appliances suitable for 3G-SHSs without any subsidy. This supports the money flow and the technician’s revenues. ENERGETICA also offers equipment for productive uses on request due to its high cost.

5.6. Operation and Maintenance

Both maintenance and technical skills are essential for the long-term sustainability of projects [101,102]. This is why acciona.org and ENERGETICA have trained local people to guarantee the maintenance quality of the equipment. Also, they have established procedures to guide maintenance activities. These actions reduce error rates, time of interventions, and impact O&M costs positively.

In Bolivia, the maintenance is a chain process, the first people responsible for the technical support are the microfranchisees, but if it is not possible to solve the problem for them, ENERGETICA tries, followed by the manufacturer. If failures in equipment involve manufacturing defects, ENERGETICA covers the cost of repairing them. In addition, if a user requests repair work in situ, the technician transportation cost is negotiated with acciona.org to deliver work orders to local technicians. The CLC is a permanent control center for sales, stock renovation, and failures in DC (direct current) devices. It allows the failures to be solved in less than 3–4 days. In Napo, the user dismantles and brings the system to the CLC. In Mexico, the CLC is located in areas with 1000 households to provide maintenance service.

As we mentioned before, ensuring the quality of equipment is a priority for acciona.org and ENERGETICA so as to gain customer acceptance of solar technology and reduce the failure rates. Even though they have replaced 2G-SHSs with 3G-SHSs (2G-SHSs are still used in Cajamarca), reducing O&M costs, high transportation costs make the microfranchisee’s permanence non-profitable. Providing electricity even with 3G-SHSs continues to be a challenge due to the remote location of communities, especially for acciona.org Mexico and ENERGETICA. For example, a range of 300–350 failures per month of 2G-SHSs made the maintenance work profitable for ENERGETICA, justifying the technician mobilization. Nowadays, 3G-SHSs have reduced this failure rate to 3%. To reduce the mobilization costs, ENERGETICA has a technician per 1000 or 1500 solar systems. The microfranchisees work on reparations once a week in their establishments or at local fairs that are developed by the community. Maintenance is an additional service, but not the core of the business in a microfranchising. In Peru, the O&M costs do not suggest a risk to technicians’ revenues because there is a fee-for-service model that covers these expenses. These are lower with 3G-SHSs in Napo, and higher with 2G-SHSs in Cajamarca. The only access to Napo is by boat; due to this remoteness, acciona.org implemented a PAYG model to minimize O&M costs.

5.7. Local Training and Awareness Campaigns

Acciona.org and ENERGETICA have learned that the higher the local participation in the projects is, the higher the users’ confidence is. This helps project management, making it easier. The lack of local capacities has been one of the main constraints or rural electrification, which is why acciona.org and ENERGETICA take the technicians’ training seriously. Thanks to this, technicians have been able to transmit their acquired knowledge to clients and carry out the activities of O&M and management. For example, in Cajamarca, there are 12 microfranchisees to date, whose preparation has taken about six months. They have received training in technology (solar systems), which supports O&M activities as well as training in sales, taxation, and entrepreneurship, supporting project management.

As regards promotion, in Bolivia, ENERGETICA socializes the project with representatives of municipalities, leaders of farmer unions, and leaders of communities. It is a top-down process. The identification of needs is used to design bottom-up strategies to solve electricity constraints. To promote the dissemination of the projects, technicians take part in itinerant sales or radio campaigns that which help to maintain the sales level. However, it has a high cost because the population is scattered and isolated. This activity is a big challenge for acciona.org and ENERGETICA.
Finally, local people appreciate being involved in off-grid projects because this is not only about technology introduction, but also about creating an environment of confidence, where they participate as entrepreneurs of a business, and a communication channel between community and promoters.

6. Sustainability Factors for Off-Grid Electrification Based on the Lessons Learned

In spite of the diverse challenges that are facing the projects studied, there is a valuable coincidence in its implementation and management. After analyzing the lessons acquired, it is possible to highlight how important it is to build off-grid strategies based on commitment, confidence, and flexibility. This approach strengthens the “virtuous circle”, making off-grid projects sustainable. The commitment of every partner supports the success of a project. Local participation is fundamental to create confidence, but the quality of technology and good project management are also relevant. The participation of local stakeholders is a plus, raising trust in communities and even with funding partners. Moreover, management models have to be able to adapt to local requirements and changing conditions through communication with communities and monitoring performance. Here, the microfranchising is positioned as the best-proven strategy to involve communities and provide a wide range of services. Tables 3 and 4 summarizes the key factors identified that should be taken into account to deploy off-grid electrification in terms of sustainability.

| Policies | Stakeholders | Technology |
|----------|--------------|------------|
| Policies to promote off-grid electrification based on SDGs and social needs analysis | Involving multiple-stakeholders: International cooperation agencies, multilateral banks, public sector (national, regional, and local), microfinancing companies, manufacturing companies, private sector, local promoters, universities, and community | Introduction of innovative technologies based on local circumstances, e.g., 3G-SHSs |
| Policies to promote the introduction of PV technology and efficient appliances | Stakeholder commitment | Providing electricity services: Offering efficient appliances compatible with 3G-SHSs (e.g., LED technology) |
| Policies to ensure technical quality of equipment | Raising trust among partners | Assurance of SHS technical quality based on the IEC 62257 series |
| Policies to support financial issues | Raising trust between partners and communities | Assurance of O&M |

Table 3. Drivers for off-grid electrification: Policies, stakeholders, and technology.

| Economics | Social | Management |
|-----------|--------|------------|
| Local economy assessment | Networking building to take care of social needs (committees and microfranchisees) | Identification of needs |
| Financial possibilities to end-users: Subsidies (for electricity service or 3G-SHSs technology) and microfinancing | Generation of local employment through microfranchises | Including innovative technologies |

Table 4. Drivers for off-grid electrification: Economics, social, and management.
Table 4. Cont.

| Economics                        | Social                                      | Management                                      |
|----------------------------------|---------------------------------------------|-------------------------------------------------|
| Payment management and control   | Customer proximity                          | Including innovative business models             |
| (introduction of the PAYG model) | (communication)                             |                                                  |
| Setting up microfranchises       | Equality to consider the differences between communities | Local people training in technology and management (sales, taxation, and entrepreneurship) |
| Expansion of microfranchises to reduce the economic risk | Agreement with manufacturing companies | |
| Ensuring technician’s revenues   | After sales services (including assurance of O&M) | Adaptation to local circumstances |
| Affordability                    | Monitoring                                   | Flexibility                                     |

7. Discussion

In the cases analyzed, there is still a need to strengthen the political commitment to plan and coordinate the development of projects between the grid extension and off-grid initiatives, and to enable or improve policies to electrify zones for those with low incomes and few possibilities of employment. Additionally, the national government has a prevailing role in energy policies, while regional and local governments support raising trust in communities.

A multidisciplinary collaboration (PPPD or management of the ESCO model) supports the building of reliable projects based on the real needs of rural villages. Promoters should have a close relationship with their partners to provide quick responses to the community’s needs and political and market changes. Talking about financing, this is hard to overcome in spite of the flexibility of projects to adapt to the market needs for two main reasons. The first is related to the initial investment of promoters to develop the projects. The second involves microfinancing opportunities for end-users. Local public policies should incorporate financing facilities to promote off-grid electrification, attract private investment, and grant tax exemptions. Engaging local banks’ participation in rural areas is another need that ought to be solved by the government. In this way, the fee-for-service model is more advantageous than microcredits with subsidies. This is because fees are designed according to the equipment features, including associated costs to cover initial investment and O&M. Contrary to a statement of previous research [43], the fee-for-service model implemented in Peru shows that it is possible to recoup investment costs if the fee is realistic and well-designed by the national government, supported by the promoter. The microcredit scheme needs subsidies to support the lack of liquidity of the population, but it is a more expensive option for them. Microcredits granted and managed by promoters (ENERGETICA) facilitate end-users’ payment, where the economic weight in projects becomes more important. In this case, subsidies are supported by international agencies and the local government directly, making subsidies permanence more difficult when foreign assistance ends. Finally, microfranchising is a sustainability strategy not only to increase population incomes or to guarantee customer proximity to meet local needs, but also to ensure O&M activities and provide a wide range of electrical services required by the population. However, it is still necessary to strengthen women’s involvement as entrepreneurs.

The experiences acquired during the implementation of the projects are a valuable tool to innovate business models. Acciona.org and ENERGETICA have been improving the procedures and business strategies according to the monitoring results, the behavior of communities, technological response, and market and political changes. For example, the introduction of 3G-SHSs has improved the results of these case studies because they have lower prices, are more reliable, and are environmentally and
user-friendly. This technological innovation helps to bring these programs to a larger population and to facilitate management through the introduction of a PAYG model. Therefore, a continuous assessment of projects supports the improvement and update of intervention strategies. This assessment should be a mandatory requirement to ensure the commitment of private companies and to involve the improvement of policies.

Even though the biggest threat of experiences analyzed comes from the low population density in rural areas in Latin America, the good organization and flexibility of these off-grid strategies show that it is possible to leave no one behind. These strategies (a combination of business models and technology innovations) could even be a solution to facing future electrification challenges in Africa and Asia, where the most scattered communities will still lack access to electricity in the medium term. Future research could be addressed to analyze the extrapolation of these experiences in both regions.

8. Conclusions and Policy Implications

In previous experiences, providing a sustainable electricity service has been a complex task and has even been infeasible for promoters. This research offers new insights to support off-grid electrification under a sustainable approach, which means projects have to be built based on trust, commitment, and flexibility. The cases analyzed in Latin America show that a combination of ESCO (fee-for-service), PAYG, and microfranchising models with 3G-SHSs is the most suitable solution in terms of economic, social, and environmental efficiency. This model covers the technician’s revenues, investment, and O&M costs, and stimulates successful management. The combination of PPPD (with microcredits and subsidies), PAYG, and microfranchising models with 3G-SHSs supposes an economic risk of projects if microfranchises do not expand. This risk is even higher when microfranchising is the only economic activity of local people. The participation of municipalities as microfranchises supports the economic growth of this model because of the population confidence in the local government. Finally, PAYG boosts management and O&M, but it is also possible that a project that uses 2G-SHSs achieves success thanks to quality practices in management and O&M. In any case, promoters have to be capable to meet the requirements of the population and solve the structural vulnerabilities of the initiatives. Financing is the main weakness that demands more government commitment to achieving the goals of the 2030 Agenda. In other words, access to electricity must be a state policy that facilitates the participation of new actors and innovative business models and technologies. Private companies could find an opportunity to invest in rural areas, where 17 million people are still living without access to electricity. Nevertheless, governmental entities are what will lead to new investments and prioritize social needs.

Author Contributions: Conceptualization: A.A.E.-A., and M.A.E.-A.; methodology: A.A.E.-A., and M.A.E.-A.; validation: M.F., J.E., and J.G.M.; formal analysis: A.A.E.-A.; investigation: A.A.E.-A. and M.A.E.-A.; resources: M.F., J.E., and J.G.M.; data curation: M.F., J.E., and J.G.M.; writing—original draft preparation: A.A.E.-A.; writing—review and editing: A.A.E.-A., M.F., J.E., J.G.M., E.C., and M.A.E.-A.; visualization: A.A.E.-A., E.C., and M.A.E.-A.; supervision: E.C. and M.A.E.-A.; project administration: M.A.E.-A.; funding acquisition: A.A.E.-A. and M.A.E.-A.

Funding: This research was funded by the SPANISH AGENCY FOR INTERNATIONAL DEVELOPMENT COOPERATION (AECID) through the project entitled “Development of Microfranchises for Access to Clean Energy in Rural Areas,” grant number 2015/ACDE/003244.

Acknowledgments: The authors thank Paul Bertheau and Enrique García for their valuable comments.

Conflicts of Interest: The authors declare no conflict of interest.

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