sustainability

MDPI

Article

Are the Rural Electrification Efforts in the Ecuadorian Amazon Sustainable?

Sarah Feron [1,*], Harald Heinrichs [1] and Raúl R. Cordero [2]

[1] Institute for Sustainability Governance, Leuphana University Lüneburg, Scharnhorststraße 1, 21335 Lüneburg, Germany; Harald.Heinrichs@leuphana.de

[2] Departamento de Fisica, Universidad de Santiago de Chile, Ave. Bernardo O'higgins 3363, Santiago 9170022, Chile; raul.cordero@usach.cl

* Correspondence: sarah.feron@stud.leuphana.de; Tel.: +56-9-7742-6823

Academic Editor: Helmut Haberl

Received: 19 February 2016; Accepted: 30 April 2016; Published: 5 May 2016

Abstract: In this paper, we assess the sustainability of rural electrification programs in Ecuador, paying special attention to programs targeting small indigenous communities in the Amazon basin. Our assessment considers four dimensions of sustainability (institutional, economic, environmental, and socio-cultural) and is based on an exhaustive qualitative document analysis, complemented by semi-structured expert interviews. We found that disruptive changes have affected the electrification policies in Ecuador during decades of avoiding the development of strengthened institutions. Despite this major drawback, we found that there is a consensus on granting access to energy for all. This partially explains the national efforts, persistent through different administrations to fund rural electrification. However, in the case of off-grid photovoltaic solutions, these efforts have consistently neglected allocating funds for operation and maintenance, which has seriously compromised the sustainability. Moreover, although Ecuadorian officials declared to favor stand-alone photovoltaic systems in the case of indigenous communities in the Amazon, we found that environmental or socio-cultural aspects have a minor role in the selection of these systems. Progress regarding environmental awareness, social acceptance, and cultural justice, is still needed for ensuring the sustainability of rural electrification efforts in the Ecuadorian Amazon.

Keywords: Ecuadorian Amazon; rural electrification; institutions; cultural justice; off-grid photovoltaic systems; qualitative research

1. Introduction

In 2013, about 1.2 billion people (*i.e.*, 17% of the global population) did not have access to electricity [1] The lack of access to energy is mainly a rural issue (e.g., while in 2012 the global urban electrification rate reached 94%, the rural electrification rate constituted only 68% [1]).

Although it was not explicitly declared a goal, the access to energy was already considered a key factor for achieving the eight Millennium goals [2]. This is why, in 2015, affordable and clean energy was explicitly named as one (goal number seven) of the 17 new Sustainable Development goals, which are to be achieved by 2030 [3]. Furthermore, in 2011 the United Nations (UN) initiated the "Sustainable Energy for all" initiative, which focuses on three targets to be reached by 2030: (1) the provision of universal access to modern energy; (2) doubling the energy efficiency rate; and (3) doubling the share of Renewable Energy (RE) globally [4]. The emphasis given to RE can be tracked back to the Agenda 21 in Rio in 1992, which highlighted not only the need of reliable and affordable access to clean energy, but also the environmental soundness to be accomplished [5].

As compared to its Latin American neighbors, the electrification rate in Ecuador is high, having increased from 89% of the total population (79% of the rural population) in 2001, to 94.82% (89.03%

of the rural population) in 2010, and up to 96.77% (no rural figures available) in December 2013 [6,7]. These notable achievements regarding electrification have been based on the extension of the grid, which was favored by the size of Ecuador (the smallest among the Andean countries). However, the focus on on-grid expansion has begun to change in recent years as it becomes nonviable in isolated remote areas. For example, in the Northern Ecuadorian Amazon, the electrification rate ranges from 81.6% in the province of Pastaza to 88.2% in the province of Napo [7]. In addition to the major geographical challenges for the extension of the grid, the main challenge in the Ecuadorian Amazon basin (that stands for nearly 40% of the territory of the country) is that the small indigenous communities in these areas are dispersed and isolated [8], which makes the grid expansion too costly.

Although off-grid systems based on RE may have been an alternative to the national Ecuadorian grid in prior rural electrification efforts, little attention has been paid to non-conventional renewable energy (NCRE) in Ecuador. Indeed, the NCRE share in the country accounts for less than 2% of the total power generation, with photovoltaic (PV) (0.07%) and Eolic (0.32%) still playing a minor role [9]. Since 1998, the few efforts focused on small indigenous communities in the Ecuadorian Amazon basin have been based on stand-alone PV solutions. However, more recently, the Ministry of Electricity and Renewable Energy (MEER) began to promote PV-powered microgrids in remote areas [10].

In this paper, we critically analyze the current status and challenges of electrification programs in Ecuador aimed at the rural population of remote areas. Paying especial attention to programs targeting small indigenous communities in the Amazon basin, we addressed the following research question: Are the rural electrification efforts in Ecuador sustainable?

In order to answer our research question, we conducted an exhaustive document analysis [11] complemented by a qualitative research based on semi-structured interviews [12]. The interviewees included experts from different ministries, national and international agencies, energy companies (public and private), non-profit-organizations (NPOs), consultants, and researchers. Although below we describe several relevant PV-based electrification efforts in Ecuador, our research was aimed at gathering an overall picture of the rural electrification efforts in the country, rather than measure the success or failure of specific projects.

The gathered information allowed us to assess the sustainability of the rural electrification efforts in Ecuador. As detailed below, our assessment is based on a set of indicators (see our theoretical framework) corresponding to the four dimensions of sustainability considered in this paper: institutional, economic, environmental, and socio-cultural (see e.g., [13–15]).

2. Materials and Methods

2.1. Theoretical Framework

The importance of institutional sustainability is well established (see e.g., [15–17]. Institutions are a framework of formal and informal guidelines that set the rules of interaction between individuals [18]. While informal institutions include religious or moral values and traditions [19], formal institutions comprise laws, regulations, and standards meant to correct market failures and protect individual rights [20]. Failures in rural electrification have often been attributed to the lack of coherence in the legal frame (laws, regulations, and standards) [21–23], or the absence of proper standards (e.g., [24,25]). Therefore, strengthened formal institutions are considered to be essential for rural electrification [21–23,26,27]. According to Levitsky and Murillo [28], two factors determine the strength of formal institutions: their enforcement and their stability (durability).

Numerous studies have revealed project failures in rural electrification due to a lack of collaboration between local and central government entities on the one hand (see e.g., [29–31]), and a lack of collaboration between different stakeholders from the energy sector (e.g,. public agencies, NPOs, and private companies) on the other hand (see, e.g., [32,33]). These studies underline the importance of openness to participation in the decision-making process by considering the role of informal institutions [22,26]. Decentralization has also been stressed for facilitating participative

decision-making, improving in turn the accountability of authorities [34], as well as the adaptability (*i.e.*, the ability to meet the changing needs of the population in remote areas) [30,35–38].

Ensuring the funding or affordability of energy solutions is a major issue since rural households of developing countries like Ecuador are generally significantly poorer than urban households. The economic sustainability of rural electrification solutions requires ensuring the funding or affordability of the systems (i.e. the initial investments and the operation and maintenance (O and M)) (see, e.g., [23,38–40]). In this context, it is important to provide a cost-effective solution for electrification [23,38].

The security of supply (or reliability) of the provided solution also needs to be addressed. Although RE may help to increase the reliability of supply (due to the diversification of energy matrix; [23,39,41]), reliability in rural areas demands for local access to spare parts, which entails the know-how to exert maintenance [42]. Moreover, as a higher access to energy is usually correlated with higher income [38], these solutions are expected to contribute to the income-generating opportunities for inhabitants of remote areas [43–45]. In this case, electrification programs need to be coupled with complementary infrastructure, including training and education [46].

Empowered individuals have strong influence on policy makers [47]. Therefore, ensuring environmental sustainability depends to a significant extent on people supporting the adoption and enforcement of policies aimed at environmental protection. The support is linked with understanding and awareness [48].

Environmental sustainability also entails the prevention of negative environmental impacts [49]. RE can generate electricity with low or very low net CO_2 emissions over their lifecycle [48]. In addition to this positive long-term effect, the adoption of RE technologies in the Amazon may have direct short-term environmental impacts in terms of reducing deforestation, which may also result in a loss of biodiversity [23,38,39,50]. Although the positive impact of PV-based solutions is appealing, ensuring recycling and proper disposal of PV modules and batteries after the end of their service life needs to be ensured in order to avoid indirect environmental impacts [33].

Socio-cultural sustainability embraces notions of social justice, since ensuring the accessibility (*i.e.*, the access to electricity) may improve the life conditions of the rural population in terms of more education (longer study hours due to the availability of electric light) and higher productivity (use of machines) [23,35,37,51,52]. These notions of social justice drive the principle of equity/disparity used to distribute the limited available resources as well as to decide who is provided with electricity [38,39] and the amount of energy to be provided to each person [35,39,53].

Socio-cultural sustainability also requires social acceptance (which implies a participatory and inclusive approach in which the local community is engaged to increase their accountability for a technology; [37,54,55]); as well as accuracy (which comprises the selection of the technology appropriate to the local consumer demands; [23,42]).

The importance of culture (traditions, values, identities, and cultural diversity) for sustainability has been stressed elsewhere (e.g., [26,35,53,56]). In this regard, cultural justice refers to justice through participation, as well as mutual learning and knowledge sharing [57]. The cultural justice in rural electrification can be evaluated according to the ability shown to integrate the technology into the existing social structures [23,50,51,58].

Based on this review, we have defined a set of indicators (see Table 1) that were, in turn, used to qualitatively evaluate the sustainability of the rural electrification efforts in Ecuador.

Table 1. Indicators of sustainability used in this study.

Institutional	Economic	Environmental	Social/Cultural
• Stability (Durability) • Regulation and Standards • Decentralization and Openness to participation • Adaptability (ability to meet future needs)	• Cost effectiveness • Reliability • Funding (initial investment; operation and maintenance) • Contribution to income of users	• Environmental awareness • Environmental impact	• Accessibility (disparity, equity) • Social Acceptance • Accuracy • Cultural Justice

2.2. Methodology

A qualitative document analysis was conducted; document analysis is used when the history of events is relevant to the research question [11]. It included public documentations such as the current constitution; the "National Plan for Good Living" (PNBV by its Spanish acronym); electrification laws and regulations published by the energy regulator; energy roadmaps (prior and current versions); academic publications on rural electrification projects; online newspaper articles on the social effects of energy projects; rural electrification project descriptions and their outcomes from international organizations; and scientific papers on topics related to the PNBV, as well the fields of study, such as decentralization, government relations with indigenous communities, and political institutions. Special attention was paid to prior efforts that tackled rural electrification programs in Ecuador from the perspective of the indigenous communities (see for example references [59–62].

In addition to the document analysis, we conducted semi-structured interviews with stakeholders. According to the approach broadly used for the assessment of sustainability (see, for example, [63–66]), the stakeholders included experts from different ministries, national and international agencies, energy companies (public and private), non-profit-organizations (NPOs), consultants, and researchers (see Table 2 for details). The selection of initial interview partners was grounded on literature review that we conducted before empirical research started. After receiving information from the initially-identified interviewees, we selected new relevant interview partners according to both the theoretical sampling methodology [11] and the snowball principle [11]. Once we had reached data saturation, as no additional information could be obtained from further interviews, the empirical interview process was closed (for details on this methodology, see [11].

A total of 22 interviews were conducted in three series: the first interview series (12 interviews) was held in December 2014 in Quito (Ecuador). Based on the recommendations from the first group of interviewees, we interviewed further experts (5) in April 2015 (also in Quito). Finally, for completion of data collection, we conducted five additional interviews via Skype®(Microsoft Corporation, Washington, DC, USA) in May 2015, mainly with international partners. Most of the interviews were held in Spanish, except one interview that was held in English and one in German.

While interviews with officials of the central government gave insights into the legal framework as well as into strategic plans, interviews with representatives of electricity distribution companies (EDCs) provided information on specific rural electrification projects. Interviews with academics allowed us a better understanding of the political and social circumstances, while interviews with international and local NPOs gave important insights into the consequences on the local population of policies and specific rural electrification programs. Indeed, representatives of NPOs, closely working with the communities, exposed several complaints from indigenous communities regarding the electrification policy of the central government.

Interview questions were clustered into four dimensions (institutional, economic, environmental, and socio-cultural) considered in this paper and addressed each of the indicators in Table 1. Questions on the institutional dimension (e.g., "What has been the role of this institution for rural electrification in the past and the present?"; "How is the rural electrification process put into practice?"; "How are the community members imbedded in the rural electrification projects?"; "Who and how is the compliance with the regulation assured?") were focused on the regulatory framework and its compliance, as well as the interaction between key stakeholders. Questions on the economic dimension (e.g., "Who is paying for the initial investment/O and M costs?"; "What has the economic impact been on the user (e.g., energy for productive uses)?"; "What are the technical minimum requirements for the systems?") addressed the funding of the systems over their lifetime, their reliability, as well as the economic potential of energy for rural areas. Questions on the environmental dimension ("How is battery disposal handled in rural electrification?"; "How would you describe the awareness on environmental issues on a political and social basis?") focused on the environmental awareness (formal and informal). Finally, questions on the socio-cultural dimension ("To what extend (and how) are projects adjusted to local circumstances?"; "Have you found different behaviors related to the ethnical background?";

"Do you provide different technological solutions to different communities? If so, what are the criteria these decisions are based on?"; "Do you remember any cases where PV systems were rejected by a community?) aimed to address socio-cultural aspects of policies and electrification programs, as well as their social acceptance and accuracy. Although the questions were previously defined, the semi-structured interviews allowed us to dive much deeper into specific topics by asking additional questions according to the background and expertise of the interview partners.

The interviews lasted between 28 and 108 minutes, and all of them but one (as one interviewee asked to stop the recorder fearing political retaliations) were fully recorded. Two additional statements were given by email. A representative from a German Bank for Development refused the interview fearing to fuel diplomatic turbulence between Germany and Ecuador at that time.

The information gathered by the document analysis and the semi-structured interviews allowed us to assess the sustainability of the rural electrification efforts in Ecuador. The assessment of the information was based on coding. By using the MAXQDA11®software [67], the codes were clustered according to a set of indicators (see Table 1) corresponding to the four dimensions of sustainability considered in this paper: institutional, economic, environmental, and socio-cultural. Our assessments are presented below.

Table 2. Interview Partners.

Area	Sub-Area	Division (if applicable)
Government Institutions Energy Sector	Ministry of Electricity and RE (MEER)	Division of Renewable Energy
		Division of Energy Distribution
	Agency for Regulation and Electricity Control (ARCONEL, by its Spanish acronym)	Division of Planning
		Division of Technical Regulation
		Division of Environmental Management
	National Institute for Renewable Energy and Energy Efficiency	Research Line on Solar Energy
Government Institutions Non- Energy Sector	Coordinating Ministry of Strategic Sectors (MICSE)	Sub-secretary Coordinating Ministry
	National Planning and Development Secretary (SENPLADES by its Spanish acronyms)	General Sub-secretary for Planning of Good Living
	Ministry of Environment	Third Communication on Climate Change Mitigation
Academics and Research Institutes	Universities/Research Centers	Public Policies
		Sociologist
		Electric Engineer
International Agencies	United Nations Development Program (UNDP)	Energy Division
	Inter-American Institute for the Cooperation in Agriculture (IICA by its Spanish acronyms)	Division of renewable energies
NPOs	Ecuadorian Foundation for the Proper Technology (FEDETA)	
	Rural Development Organization (naming undesired)	Local solar energy initiative
	Cooperation for the Investigation on Energy	
Energy Companies	Electricity Distribution Companies (EDCs)	RE Unit
	Private RE Companies	RE Companies
Independent Energy Consultant (previously hired at EDCs)	Energy	Rural Energy

3. Ecuador

3.1. General Background

Ecuador is a former Spanish colony of about 283,500 km^2 bordered by Colombia on the north, Peru on the east and south, and the Pacific Ocean to the west. The Andes act as a transect from north to south dividing the country into three geographic regions: the coastal lowlands (located between the Andes and the Pacific coastline and characterized by its tropical climate), the Andean highlands (mostly temperate and relatively dry), and the Amazon basin (on the eastern side of the Andes and characterized by a rainforest climate).

Most of the inhabitants of the country (nowadays, about 15.8 million people) traditionally lived in the coastal lowlands and the Andean highland. In 2015, 63.7% of the total population of the country was urban [68]. By the mid-1960s, the Amazon basin of about 120,000 km^2 was basically disconnected from the rest of the country, which favored the conservation of the Amazon rainforest. This area was traditionally inhabited by small and dispersed indigenous communities. However, during the last decades the central government favored the colonization of the region, which was further accelerated by the discovering of oil in the early 1970s. To date, still less than 5% of the total population of the country inhabits this area that stands for nearly 40% of the total territory of the country.

Although Ecuador's economy was traditionally based on agriculture, during the last decades the country has been highly dependent on oil revenues that, in 2013, accounted for 56.5% of its incomes from exports [69]. Mostly driven by oil revenues, between 2007 and 2014, on average GDP grew by 4.3% per year, while the poverty ratio declined from 38% to 23% during that period [70].

The government of the country is organized at different levels: municipalities or cantons (often including towns, small cities, and also rural areas), provinces (which include several cantons) and, more recently, political regions (which include several provinces). Ecuador is a presidential republic and representative democracy. Officials are elected by popular vote at different levels: majors in municipalities or cantons, prefects in provinces, and the president of the country (which controls the national government and designates officials in charge of the political regions [71]). Despite this formal decentralization, oil revenues are controlled by the national government, and there is a partial redistribution of these funds to municipal and provincial governments. The representatives (congressmen) are elected by popular vote to the National Assembly (unicameral congress) that acts as the legislative branch. The current President, Rafael Correa, was elected in January 2007 for the first time, and reelected in 2013. Since 2008, the national government has been reorganized, currently accounting for 21 Ministries, six Coordinating Ministries, and 11 State Secretaries [72]. In 2013, Ecuador ranked 79th on the Democracy Index (compiled by the Economist Intelligence Unit, EIU).

3.2. Electrification in Ecuador

Generation and distribution of electricity began in Ecuador during the first half of the 20th century as private initiatives, later supported by local governments (municipalities) of major cities in the country. This is why municipalities still hold some shares of EDCs serving major cities in the country (see e.g., [73–75]). These early initiatives were focused on the major urban nucleus and only in the early 1960s did the national government assume a regulation role by creating the Ecuadorian Institute of Electrification (INECEL, by its Spanish acronym). Since 1961 to 1999, INECEL centralized the sector's planning, regulation, tariffs, construction, and operation processes, leading to high electrification growth rates [76]. INECEL bought most of the shares of existing EDCs, and created new public companies for generation (including important hydroelectric projects), transmission, and distribution (aimed at areas beyond major cities) [77,78].

In the 1990s, a liberal administration tried to open the electric sector to private investors [79]. Aimed at the privatization of the public EDCs, this administration decreed the substitution of INECEL by the Agency for Regulation and Electricity Control (CONELEC, by its Spanish acronyms). CONELEC assumed the role of strategic planning, control and supervision of the EDCs, as well as

the tariff regulator [80], while INECEL's assets were transferred to the "Solidarity Fund" ("Fondo de Solidaridad"). The latter was an agency created in 1993 and controlled by the National Modernization Council (CONAM, by its Spanish acronym) that led the privatization processes in Ecuador [81]. The "Solidarity Fund" became the majority shareholder of six generation companies, one transmission company, and 20 EDCs [10]. Yet, the planned privatization of the EDCs was never accomplished.

In 2009, the Correa Administration eliminated the "Solidarity Fund", transferring the assets of the six generation companies to a new public consortium: the Ecuadorian Electric Corporation (CELEC E.P. by its Spanish acronym). Assess of the EDCs were transferred to a new ministry: the Ministry of Electricity and Renewable Energy (MEER by its Spanish acronym) that assumed the role of designing policies on generation, transmission, and distribution [76].

In 2015, the Correa Administration ordered the merging of the existing EDCs to form a single company, and reorganized the functions of the MEER and CONELEC (which slightly changed its name and its Spanish acronym to ARCONEL), giving more power to MEER. MEER assumed the role of strategic planning, while ARCONEL kept the role of control and supervision of the EDCs, as well as a tariff regulator [80].

Currently, the share of NCRE in Ecuador accounts for less than 2% of the total power generation, with PV (0.07%) and Eolic (0.32%) playing still a minor role [82]. The country mainly relies on hydro and thermal power plants that account for 46% and 49% of the total power generation, respectively [82]. The relative importance of hydropower plants will sharply increase in the upcoming years, as the government commissioned the construction of several major power plants, accounting for a total power capacity of about 2.5 GW, which stands for an increment of nearly 50% of the current power capacity (5.3 GW) [83].

Tariffs in the on-grid sector are highly regulated; all grid-connected residential users in Ecuador are subjected to the same electricity tariff (US$ 1.4 fixed costs plus US$ 0.08 per kwh consumed), which is adjusted annually by ARCONEL [84]. However, households that consume less than 130 kwh/month (in the Amazon basin and the coastal lowlands) and 110 kwh/month (in the Andean highlands) are subjected to the so-called "dignity tariff" (enacted by Constitutional Mandate No.15 in 2008), which is half of the regular tariff. On the other hand, the off-grid sector is still mostly unregulated and there is neither a tariff regulation nor are there service standards.

3.3. Rural Electrification

As compared to its Latin American neighbors, the electrification rate in Ecuador is high, having increased from 89% of the total population (79% of the rural population) in 2001, to 94.82% (89.03% of the rural population) in 2010, and up to 96.77% (no rural data available) in December 2013 [6,7].

These notable achievements in rural electrification were fueled by the "Fund for Rural and Urban-marginal Electrification" (FERUM by its Spanish acronym). From 1998 until 2008, FERUM received resources from a 10% tax charged to the tariff paid by on-grid commercial and industrial consumers around the country [85].

In 2008, the Correa administration cancelled this tax, and funds for FERUM have thereinafter directly been disbursed from the national budget. Although the funds for FERUM increased in the first years (from US$46 million in 2007 to US$126 million, in 2008), promises of funding FERUM by US$120 million were not fulfilled in 2009 and in 2011 [6]. More recently, in 2012/2013, FERUM received about US$ 55 million (US$40 million by the Inter American Development Bank (IADB) and about USD$15 million by the national government). A new contract (known as FERUM II) was signed with the IADB in 2014 for a credit of US$30 million [86].

So far, most of the FERUM investments have been focused on the expansion of the grid to rural areas. From 1998 to 2009, only 1.86% of FERUM was invested in off-grid RE solutions, including stand-alone PV systems [87]. However, the focus on the grid expansion has begun to change in recent years as it becomes nonviable in remote areas. Especially the provinces of Pastaza and Napo in the Northern Ecuadorian Amazon and the province of Esmeraldas in the Northern Ecuadorian

coastal lowlands present major geographical challenges for the extension of the grid. Moreover, some communities in these areas are dispersed and isolated [8], which makes the grid expansion too costly.

Until 2009, few efforts targeted these remote and isolated areas by providing stand-alone PV solutions. Before disappearing, the CONAM and the "Solidarity Fund" installed off-grid PV systems in the Ecuadorian Amazon basin [88]. International initiatives in collaboration with MEER, such as the Euro-Solar program (EUROSOLAR, NA), and the PROMEC program [88] were also relevant efforts, targeting communities in the Amazon basin and the northern coastal lowlands [89]. Yet, estimations indicate that only about 10% of the off-grid PV systems installed until 2009 are still in use [90].

In 2009, ARCONEL proposed to the EDCs to form special units focused on rural electrification based on off-grid RE solutions. Some companies, following this proposal, thereinafter deployed stand-alone PV systems funded by FERUM. For example, the EDC "Empresa Electrica Quito (EEQ)" formed a RE unit and has installed 370 stand-alone PV systems (funded by FERUM) in rural areas surrounding Quito (the capital of the country of nearly two millions inhabitants). EEQ has the responsibility of providing electricity to Quito, but also to the surrounding rural population (that includes non-indigenous farmers separated from the grid by dozen of kilometers). EEQ has installed systems of 390 watts peak (Wp), which translates into approximately 45.81 kwh per month (roughly twice those provided by the EDC CentroSur) [91]. EEQ set a monthly fix price of US$5. The company subsidizes the remaining US$14.4 to cover the total O and M costs of US$19.4 per month [91].

Another EDC, "CentroSur", also formed a RE unit and installed, since 2010, approximately 2900 stand-alone PV systems of 150 Wp in about 70 communities in the Amazon basin. CentroSur is the EDC in charge of providing electricity to Cuenca (the third most populated city in Ecuador with nearly half a million inhabitants), but also to a significant part of the Southern Ecuadorian Amazon basin (inhabited by small indigenous communities—each with a population of less than 60—often highly dispersed). CentroSur estimates that the minimum energy generated by their PV solutions is 19 kwh per month, which is charged by applying the "dignity tariff" [88]. Montero and Cajamarca [60] estimate that this tariff only covers about 15% of the related operational costs of the EDC. The rest of the operational costs are normally absorbed by the EDC, which is facilitated by the size of the company and the incomes from providing the service to a significant urban population.

Nowadays, rather than stand-alone solutions, MEER is promoting PV-powered microgrids of up to 10 megawatts peak (MWp) in remote areas. These microgrids should be funded by FERUM (through the FERUM II contract) and are meant to generate energy not only for households, but also for schools, public lightning, and small health centers.

4. Results

4.1. Institutional Sustainability

4.1.1. Stability

Institutional sustainability requires strengthened formal institutions, whose strength is determined by their enforcement and their stability (durability). Both have always been problematic in Ecuador.

As described above, the Correa administration has introduced profound reforms that included the energy sector [92]. However, institutional changes did not begin with the Correa administration. In fact, Ecuador has undergone frequent institutional changes in its short history as a free nation. Since 1938, the country has adopted seven different constitutions: in 1938, 1945, 1946, 1967, 1978, 1998, and 2008. The last of these constitutions was promoted by President Rafael Correa after his election in 2006.

Disruptive changes can also be observed in RE policies. For example, in 2011, ARCONEL introduced a very high Feed-In-Tariff (FIT) of 40 cents per kWh to foster on-grid NCRE; an even higher tariff of 44 cents per kWh was introduced in Galapagos Islands (which are also Ecuadorian territory). Despite the fact that it did not reach the goal of 300 MWp, the FIT program was abandoned.

Rural electrification efforts by off-grid PV systems have been affected by these frequent institutional changes as well. In 2004, the CONAM, decided to run a program to install 620 stand-alone

PV systems. The systems were acquired and installed by the "Solidarity Fund" in remote areas in the Ecuadorian Amazon basin. In order to ensure the maintenance of the systems, they were supposed to be transferred to the EDCs. However, the transfer of the system to the EDCs did not occur and the "Solidarity Fund" was eliminated in 2009. According to an EDC representative, due to the lack of a legal transfer, the PV systems did not have an owner and were eventually abandoned, as they were not maintained by anyone.

Several interviewees considered the continuing changes in the institutional framework and the changes in authorities to be a significant issue in Ecuador. According to a representative of the UNDP "*one of the big issues of any project is the rotation of authorities in the different Ministries. [. . .] So, often the planning of the projects is affected by these authority changes. And this really affects the projects a lot, and especially, it affects the transmission of all the generated information*".

4.1.2. Regulations and Standards

The National Planning and Development Secretary (SENPLADES, by its Spanish acronym) was founded in 2004 as a planning entity that originated from a merger of the CONAM with the National Secretary of Development of Millennium Goals [93]. It is a branch of the Presidency and is the ultimate decision-maker on the project approvals of all sectors. SENPLADES generated the "National Plan for Good Living PNBV 2009–2013", and more recently, the PNBV 2013–2017 [93].

Allegedly, based on the 2008 Constitution, the PNBV aims to provide a roadmap for developing the country. However, several interviewees have questioned if the PNBV was conceived according to the reality of the country's situation and if its effective execution is possible. According to a social science researcher.

" . . . they [SENPLADES] are writing what is the policy or the dream of Good Living. [. . . .] So you got persons [. . . .] who are directly from the middle upper class, especially middle class, who have a wonderful vision, full stop. From there on it is disconnected from reality." Furthermore, according to a political science researcher, objectives in the PNBV are expressed as mere intentions without any quantifiable indicators.

A professor of electrical engineering argued that another reason why PNBV objectives are hardly achievable is that "many of these things are in the constitution, but from the constitution it needs to be passed on to laws, and from there to regulations". However, at different government levels, some public agencies have not produced the regulations needed to deliver the vision expressed in the PNBV. Reasons are manifold, but some interviewees pointed to the lack of consensus on some of the PNBV objectives. According to a social science researcher, there is a gap "between the political decision and the technical criteria, and hence the applicability of the policy".

The lack of coherence between the constitution and the regulations has affected the rural electrification in Ecuador. According to a representative of ARCONEL, although the 2008 constitution declares that energy is a basic right, it is not anchored in the law, such that the lack of provision of service is not penalized. An energy consultant added: *"in fact, one of the managers [of an EDC] who is a very good friend of mine, said 'Listen, I already have enough with the grids. Don't put me any more activities, because I don't even get along with what I have. It is irresponsible to compromise to attend more people when I can't attend the current ones well'"*.

Constitutional rights regarding energy have also lacked enforcement in Ecuador. This lack of enforcement has inhibited the development of strengthened and sustainable formal institutions which, in turn, may avoid further efforts on improving regulations or setting new standards.

4.1.3. Decentralization and Openness to Participation

In addition to a decentralization process (understood as redistribution of the funds to elected local governments), the Correa administration adopted a "deconcentration" approach (understood as the delocalization of the central government aimed at the efficient provision of services). Indeed, several services have undergone delocalization/deconcentration in recent years. However, the energy

sector, in particular the distribution of electricity, takes the reverse strategy, being subject to a process of recentralization.

Law 418 issued in 2015 stipulates that the 11 EDCs in the country will be merged to one single company, whose ownership will be transferred to the central government by the end of 2016. This decision was mainly motivated by the prospect of economies of scale. The interviewees partly welcomed the initiative, since it may facilitate the compensation of eventual losses of one EDC by other EDCs. Indeed, losses are frequent in the case of EDCs serving rural areas, while they are less frequent in the case of companies serving urban populations. Moreover, EDCs show considerable differences in their efficiency, and pay different attention to rural electrification. One single EDC could phase out these differences. The same is true for technical and quality standards, as there are currently differences between the standards adopted by different EDCs.

Recentralization may lead to short-term benefits to the Ecuadorian energy sector (by facilitating the adoption of coherent technical and quality standards of service). However, some interviewees pointed to the loss of adaptability (*i.e.*, the ability to meet the changing needs of the rural population in remote areas of the country). The central government planning may further restrict local participation, while empowering its own position. According to a representative of a NPO: *"On top is the Ministry of Electricity. In theory, with the new electricity law, the [. . .] national energy operator, the one which would basically be the generation, transmission, and distribution, would all be below this organism. So, basically this is a very high concentration of power in the electricity sector."* and *"the EDC, in this case [referring to an example] the CentroSur, does not have the independence from the MEER to take decisions in the area, in the local sector."*

4.2. Economic Sustainability

4.2.1. Cost Effectiveness and Reliability

In the case of the remote areas (inhabited by small communities—each with a population less than 60 and often very dispersed), Ecuadorian officials appear to recognize that off-grid RE systems are a cost-effective solution (since grid expansion is too costly in the Northern Ecuadorian Amazon as well as in the province of Esmeraldas, in the Northern Ecuadorian coastal lowlands). This may explain why, in 2009, ARCONEL proposed to the EDCs to form RE units focused on rural electrification based on off-grid RE solutions. As described above, following ARCONEL's advice, some companies (such as EEQ and Centro Sur) established RE units and have deployed stand-alone PV systems funded by FERUM in rural areas of the country.

The cost-effectiveness of off-grid PV solutions in remote areas is also favored by the geographical location of Ecuador. Indeed, the adoption of solar energy technologies has the potential to yield long-term benefits for the country in terms of reliability (through reliance on an inexhaustible and import-independent resource). However, assuring a reliable energy supply further demands for local access to spare parts, which entails not only the know-how, but also funding for O and M. Yet, missing spare parts and a lack of know-how of the communities on how to do small maintenance repairs has been one of the reasons for the damage of PV systems from the FERUM 2008–2010 program [94]; in the case of CentroSur, on the other hand, despite the fact that costs are not covered by the government, the communities all have a stock of spare parts and receive training (all users get trained on basic maintenance, and a technical operator is trained in-depth) on how to maintain the systems [88]. As explained below, O and M funding is still an open issue in Ecuador, which may compromise the reliability of off-grid PV solutions in remote areas.

4.2.2. Initial Investment

Economic sustainability of rural electrification efforts requires ensuring the affordability of the systems and their O and M. In Ecuador, policy intervention is inevitable because rural populations are poor and cannot afford the initial investment by themselves.

The initial investment (either for grid extension or for off-grid PV solutions) is provided by FERUM. The high rate of rural electrification reached in Ecuador in recent decades is a consequence of FERUM that funded initial investments associated with rural electrification efforts. Although FERUM is still the main source of resources for initial investments aimed at rural electrification, it is no longer funded by on-grid commercial and industrial consumers, but by the central government. In other words, the budget of FERUM depends on political priorities of the central government. The change in the funding mechanism for FERUM has resulted in great variability of funds aimed at rural electrification.

These changes in the funding system of FERUM were sharply criticized by interviewees who were also skeptical on the perspectives of FERUM. According to a NPO representative, as *"lean periods that may come next year because of a lack of oil revenues, what are you going to do? Cut the budget."*

4.2.3. Operation and Maintenance

There are no public funds specifically allocated to O and M of rural electrification programs. In the case of grid-connected users, the costs of O and M are covered by the tariff (also in rural areas). However, in the case of off-grid PV solutions, these costs are significantly greater than what poor inhabitants in remote areas can afford. Although, in the latter case, the IADB has suggested MEER to allocate funds for O and M, the interviewees from MEER and from ARCONEL confirmed that, up to now, it is not clear how to fund the O and M of the off-grid rural electrification programs. The costs of O and M of rural solutions could be included in the tariff of urban users or be covered by FERUM. However, no solution has been implemented yet.

As FERUM only funds the initial investments, the O and M of off-grid systems must currently be assumed by EDCs. However, according to the interviewees, companies are reluctant to assume these costs (especially in the case of remote areas), since it generates a financial gap for EDCs. Although this gap is supposed to be covered by the Ministry of Finance, according to an interviewed consultant (and confirmed by a representative of an EDC), the reimbursement to EDCs for O and M expenses is not met in practice.

The need of allocating funds aimed at O and M is well known by the Ecuadorian officials. However, a representative of MEER declared that the country is still searching for a model to ensure the economic sustainability of rural off-grid electrification.

4.2.4. Contribution to Income of Users

As a higher access to energy is usually correlated with higher income, for energy solutions to be sustainable they are expected to contribute to income-generating opportunities for inhabitants of remote areas. This idea seems to drive the new policy adopted by MEER that promotes PV-powered microgrids of up to 10 (MWp) for remote areas. A pilot project based on microgrids at Zancudococha (Orellana Province) has benefitted 29 families [10]; the new microgrids will be funded by FERUM (through the FERUM II contract) and are meant to generate energy not only for households, but also for schools, public lighting, and small health centers. However, for the user's productive outcome to be increased, the electrification programs need to be coupled with complementary infrastructure including training and education which, according to the interviewees, is currently not the case.

Moreover, several projects based on productive uses have been implemented in Ecuador by NPOs. These projects range from handcrafts, to corn dryers powered by PV energy, solar boats for transportation, and energy for milk collection centers. All of these solutions are only pilot projects so far. A representative of a NPO involved in the development and implementation of these solutions stressed that *"in order to be sustainable, it needs to originate right there. From the profitability of the proper system, which need to be sufficiently profitable to be attractive."* Similarly, another NPO representative agreed on the importance of *" . . . not creating a project from outside and imposing it on the community so much, but rather talk about what is solar energy capable of, and what would be helpful to them."*.

4.3. Environmental Sustainability

4.3.1. Environmental Awareness

Interviewees considered especially the middle and upper class in Ecuador to be aware of the need for environmental protection. Indeed, the country was one of the first Latin American countries in creating a Ministry of Environment (in 1996) [95]. Moreover, the concept of environmental protection was included in the 2008 Constitution. The 2008 Constitution also states the need of consulting the communities affected by any major economic activity (such as oil drilling or mining). However, these rules are usually not complied in practice, which may indicate that environmental awareness is not widespread in Ecuador.

A representative of a NPO explained that communities in the Amazon basin, where most of the oil drilling takes place, are mostly opposed to these activities since "*they know that their lives economically, as well as socially, but economically, that they depend on the health of the forests.*" Despite the opposition of some communities, drilling in the Amazon basin and major mining in the Andean highlands are currently flourishing in the country. Indeed, recently the Correa administration authorized oil drilling in the Yasuni National Park, located in the Amazon basin and considered to be one of the most biologically-diverse forests in the world [96]. This authorization was issued despite the fact that the area was a protected National Park hosting uncontacted indigenous communities [97].

The high dependence of the country on oil revenues accounted for 56.5% of its incomes from exports in 2013 [69], and appears to be driving decisions of the central government. Notwithstanding what is written in the constitution, environmental issues seem to be having a minor role in policy-making.

4.3.2. Environmental Impacts

In general terms, the adoption of solar energy technologies yields long-term benefits in terms of pollution abatement and climate change mitigation. In the Amazon basin, which hosts the greatest biodiversity on Earth, the benefits are particularly clear in the short term; the adoption of solar energy technologies for electrification in these areas may contribute to protect the biodiversity, reduce deforestation, moderate land degradation, and avoid noise (that may disturb uncontacted indigenous communities inhabiting some areas in the Amazon basin; [98,99]). Despite these benefits, rural electrification policies in Ecuador continue to favor grid expansion. Off-grid solutions have been adopted only in areas that present major geographical challenges for the extension of the grid, or that are inhabited by dispersed and isolated communities.

Regarding the prevention of negative environmental impacts, environmental considerations seem to rank behind economic or political motivations of electrification efforts. One example has been in San Lorenzo (a town in the province of Esmeraldas, in the Northern Ecuadorian coastal lowlands), where the grid extension was only possible by clearing part of the mangrove forest. The alternative would have been a minigrid, but as stated by an NPO manager, " . . . *because on Saturday I [the president during his TV-aired weekly "report of activities"] say 'they will put it [the grid] in this part [in San Lorenzo].' So everybody [the public agencies] ran and in two months they cleared the mangrove forest and put the things.*"

Even in those cases within which off-grid solutions have been adopted, potential negative environmental impacts have not been taken into account. In the particular case of stand-alone PV systems, the major issue is the battery disposal. Although some EDCs collect the batteries after replacement, there is no regulation on what to do with the old batteries. According to a senior official of the MEER, "*the whole amount of batteries is extremely heavy. So it sums up. So, the battery is sometimes buried, or they are really taken out to be processed here in the urban regions. There are companies that take care of that, but the costs are not yet made transparent. So, we are still in the discussions*". Although, in the main cities of the country, there are companies that buy the old batteries and, thus, in theory facilitate a cleaner disposal, it is not clear what is currently occurring with the batteries of stand-alone PV systems after replacement.

4.4. Socio-Cultural Sustainability

4.4.1. Accessibility (Disparity/Equity)

Based on the interviews, we found especially the middle and upper class in Ecuador to have a notion of social justice concerning distribution of economic resources (which includes the access to electricity). This may partially explain the notable achievements in rural electrification of the country as compared to its Latin American neighbors. The rural electrification rate in Ecuador reached 89.03% in 2010 [6,7] and the 2008 constitution states that electricity is a basic right.

Despite the apparent consensus regarding the accessibility (access to electricity) for everybody, different redistribution approaches coexist in the country. These approaches are relevant when deciding who is provided with electricity, and the amount of energy to be provided to each person. The most recent approach adopted by the current administration is nowadays promoting PV-powered microgrids of up to 10 MWp for remote areas, rather than the stand-alone solutions. A microgrid can have a positive socio-economic impact in terms of productivity by delivering significantly more energy per inhabitant than stand-alone solutions.

However, several interviewees criticized this microgrid policy because it leads to a disparity of resources, which may be unfair. According to a representative of a private company, the microgrid is *" . . . a project which they have and want to take out quickly, because it is a good image for them, because it is a big system and it will look very nicely on the picture [. . .]. We are providing the solution to 20 families, and that's fine, but what happens to the rest?"* Regardless of the motivation of MEER, the issue is that microgrids are significantly more expensive, such that few communities receive a complete solution, while others have to wait until new funds are available.

These critics favor policies based on the principle of equity, which claims that all citizens should be secured a minimum standard. Hence, the EDCs should provide a minimum level of energy for everybody (including rural areas). Although it is not clear what this minimum would be, the interviewees have some suggestions. For example, according to a representative of a private company, *"they [the government] should put a real goal, and say 'I can eliminate the darkness', right? I won't give them a TV, nor a fridge [. . .] But I do take them out of the darkness, I will give them light. And that could be done. They could do so very rapidly. In six years we could leave the country completely free from matches."*.

4.4.2. Social Acceptance and Accuracy

Social acceptance requires a participatory and inclusive approach in which the local community is engaged. Efforts to promote social acceptance are necessary, because often political differences between indigenous leaders and the government have led to the rejection of electrification programs in Ecuador [88]. Although social acceptance of electricity appears to be still an issue in remote areas of the country, some EDCs have addressed the topic. For example, CentroSur has carried out significant efforts aimed at getting its consumers involved in the Amazon basin (often small and isolates communities). The RE unit of this EDC reaches the community and gets them involved by creating an Electrification Committee (formed by the heads of each beneficiary household) and a Steering Committee (formed by member of the community that act as the local representative of the EDC). Another elected local official is in charge of collecting the monthly payments and presents the monthly reports and accounting to the EDC. This engagement strategy is actually aimed at gaining the social acceptance of the technology, and at least in the case of CentroSur, has proven to be appropriate. Indeed, this engagement strategy may explain the success of CentroSur; according to Urdiales [88], more the 95% of the stand-alone systems installed by this EDC are still operating.

Although they argue that it was determined according to the consumption habits of the local population, CentroSur provides to its consumers in the Amazon basin stand-alone PV systems of 150 Watts peak (Wp). The lack of accuracy (the capability of meeting local consumer demand) of this flat solution has been criticized since it was not defined according to gender-specific or community-specific requirements [94]. The same type of criticism applies for the microgrids promoted by MEER since, for

example, in Esmeraldas, Leid [62] reported that they were oversized for the electricity consumption of the area. The sophistication of microgrids may also be inaccurate for rural population if the system is expected to be locally managed [62].

4.4.3. Cultural Justice

The 2008 Constitution in Ecuador as well as the PNBV emphasize that Ecuador is a plurinational and intercultural State, with all ethnic groups having rights. Yet, the culture of small indigenous communities is often not considered in the execution of public policies. Referring to the situation of small isolated indigenous communities in the Amazon basin, a representative of a NPO provided an example: "*they [government] are building them [indigenous] a house of 40 meters, of 50 meters, with bricks, with cement, with these, and stairs. [But] they don't live with stairs [. . .] they start to close down the lower part, because they don't want to live downstairs. Or they put the animals downstairs*".

The microgrid policy from MEER has also been mentioned as an example of the disengagement between public policies and culture of indigenous communities. For instance, although in the Amazon basin an EDC discarded microgrids for semi-nomad indigenous communities, this technology was ultimately imposed by MEER. According to a NPO representative, "*the argument of the MEER is that [. . .] you couldn't say that you don't like pizza, if you haven't been given pizza. So I will give you pizza, and let's see if you like it*".

The major issue is not necessary the lack of awareness of the cultural particularities of small indigenous communities, but the lack of respect for them. According to a representative of a NPO, "*so I told them [the MEER] 'this [nomadism] is part of their culture as an identification term of their behavior.' So they said 'change their culture'.*"

5. Discussion

Institutional sustainability requires durable and strengthened formal institutions. We found that disruptive changes have affected the electrification policies in Ecuador during decades of avoiding the development of strengthened institutions. New ministries, regulators, and EDCs have been created and later disappeared, often after changes in the central government administration. This lack of stability or durability in formal institutions has, in turn, prevented further efforts on enforcing regulations, ensuring the coherence of the legal frame, and setting better standards. The absence of strengthened and sustainable formal institutions is a major drawback in Ecuador that, by inhibiting law enforcement, also compromises the environmental and socio-cultural sustainability of rural electrification efforts, particularly in the Ecuadorian Amazon.

Despite the frequent changes in policies and in the institutional framework, we found that, in Ecuador, there is an apparent consensus on granting access to energy for all. This partially explains the steady national efforts aimed at funding rural electrification. Favored by its size, the notable achievements of the country regarding electrification have been based on the extension of the grid. Since 1998, efforts targeting small indigenous communities in the Ecuadorian Amazon basin also included off-grid PV systems. Although this type of solution may be particularly suitable for semi-nomad indigenous communities in the Amazon Basin (which hosts the greatest biodiversity on Earth), we found that environmental and socio-cultural aspects appear to have a minor role in explaining the choice for RE solutions. Indeed, rural electrification policies in Ecuador continue to favor grid expansion. Off-grid solutions have been adopted only in areas within which grid expansion is too costly. Although throughout different administrations, Ecuadorian officials declared to favor off-grid PV systems for rural populations, they have consistently avoided allocating funds aimed at the O and M of the systems compromising the sustainability of the systems. Granting funds specifically to O and M is required for ensuring the economic sustainability of off-grid PV solutions in Ecuador.

Environmental sustainability entails the prevention of negative environmental impacts. Although Ecuador was one of the first Latin-American countries in creating a Ministry of Environment (in 1996), the environmental regulation are usually not complied with in practice, which may be a consequence

of the lack of strengthened and sustainable institutions, but also of the absence of widespread environmental awareness of civil society. We found that environmental impact seems to rank behind the economic and political motivation in Ecuador, such that environmental issues seem to still play a minor role in policy-making. Even in those cases within which stand-alone PV systems have been adopted, potential negative environmental impacts (for example, the battery disposal) are not taken into account. Improvements regarding the impact assessment, but also in environmental awareness and understanding, are required for ensuring the environmental sustainability of rural electrification efforts.

The whole legal framework emphasizes that Ecuador is a plurinational and intercultural State, with all ethnic groups having full rights. Yet, the culture and opinion of small indigenous communities are often not considered in public policies. The proposal aimed at providing energy to semi-nomad indigenous communities in the Amazon deploying microgrids is a clear example. Although their rights are explicitly recognized by the constitution, once again, the lack of strengthened and sustainable formal institutions frustrates the enforcement of rights, laws, and regulations. The lack of inclusive approaches in the policy-making also indicates that, despite the awareness of their cultural particularities, there is no widespread respect for small indigenous communities in the country. Progress regarding social acceptance, accuracy, and cultural justice is urgently needed for ensuring the socio-cultural sustainability of rural electrification efforts in the Ecuadorian Amazon.

6. Conclusions and Recommendations

In this paper, we assess the sustainability of rural electrification programs in Ecuador, paying special attention to programs targeting small indigenous communities in the Amazon basin. Our assessment was based on a set of indicators (Table 1) corresponding to the four dimensions of sustainability considered in this paper: institutional, economic, environmental, and socio-cultural.

Disruptive changes in electrification policies in Ecuador are too frequent. This lack of stability in the institutional framework needs to be addressed if the country aims to build up strengthened and sustainable formal institutions. Since these frequent disruptive changes have often occurred after political changes, it is advisable for the central administration to promote a broader political compromise aimed at building up strengthened and sustainable formal institutions.

Furthermore, the enforcement of the constitutional rights regarding energy is still weak in Ecuador and the coherence of the legal frame regarding rural electrification is currently feeble. Since the off-grid sector remains mostly unregulated, the MEER should consider reviewing the current legal frame (including regulations and standards), paying particular attention to the consistency with the constitutional rights. Moreover, ARCONEL should set technical and service standards that are binding for all EDCs. Sponsored by ARCONEL, it is advisable for the EDCs to also define billing models, which may differ from one community to the other.

Ecuador exhibits an incomplete decentralization, since decision-making rests on the central government, not only regarding policies, but also concerning specific solutions (minigrids, stand-alone systems, *etc.*). Therefore, ARCONEL should study the possibility of granting the faculties to the existing RE units to decide on specific solution among the possible alternatives (minigrids, stand-alone systems, *etc.*) and the power capacity of the systems. Granting these faculties to RE units (which are normally in closer contact with the communities) will also address the likely loss of adaptability (*i.e.*, the ability to meet the changing needs) expected as a consequence of the ongoing administrative recentralization process (all EDCs are merging on a single EDC). In order to address the alleged weak openness to participation of locally-elected authorities or community representatives, it is advisable for ARCONEL to enforce a consulting mechanism between the existing RE units, locally-elected authorities, and native community representatives.

Although off-grid RE systems appear to be a cost-effective solution in rural areas of Ecuador, few EDCs have conducted detailed cost analyses of off-grid solutions. Therefore, sponsored by ARCONEL, the EDCs ought to carry out such detailed cost analyses for installation cost (per Wp) of off-grid RE

solutions, the cost of O and M, recycling and proper disposal, as well as the spending capacity of the inhabitants of remote areas. These analyses are also useful for defining billing models.

Moreover, the FERUM funds the initial investment, but its annual budget depends on political priorities. O and M costs are covered neither by users, nor the existing funding mechanism (*i.e.*, FERUM). Currently, these costs are borne by EDCs, which makes them reluctant to deploy off-grid RE systems. Thus, it is recommendable for the central administration to restore the prior model based on cross-subsidies (from users connected to the grid). A scheme based on cross-subsidies would also address the uncertainty related to the funds allocated to the FERUM, whose annual budget would no longer depend on political priorities. The MEER should, thereby, ensure that this cross- subsidy will cover O and M costs of off-grid systems used to power low-income inhabitants of rural communities.

Several NPOs have installed PV-powered prototypes of productive systems (e.g., handicraft, corn dryers, solar boats, milk collection centers). A government-sponsored program including microgrids (for households, schools, and health centers) has also been initiated recently, aiming to contribute to the income of users. However, no program exists for complementary infrastructure (training and education, telecommunication, and transport). The MEER should, therefore, consider strengthening transdisciplinary relations with other sectors, as well as identifying and replicating successful pilot projects (in collaboration with NPOs).

Environmental protection is anchored in the Ecuadorian constitution, but rules are often not complied with in practice, which may indicate that environmental awareness is not widespread. In this regard, the MEER and the EDCs ought to include environmental experts in the design and implementation of programs in sensitive zones, such as the Amazon. Moreover, environmental impacts (positive or negative) are currently not included in the evaluation of small-scale electrification projects. Therefore, the MEER and ARCONEL may want to consider including environmental impacts (positive or negative) in the evaluation of small-scale electrification projects. In case of off-grid PV projects, it is also recommendable for the RE units to ensure recycling and proper disposal of PV modules and batteries after the end of their service life. ARCONEL should, therefore, explicitly regulate the battery disposal.

In Ecuador there is consensus regarding accessibility to electricity for everybody, but disagreements persist on who is provided with electricity first and the amount of energy to be provided to each person. Recent programs based on microgrids provide sufficient power to households, but will favor a limited number of people leaving thousands waiting for solutions. In this context, the MEER may want to consider promoting a policy aimed at getting rid of dangerous energy sources, like matches/candles, by granting access to electricity with a minimum capacity to all citizens first. In this regard, pre-electrification via pico-solar PV systems could be an option.

Additionally, few EDCs, through their RE units, apply a participatory and inclusive approach aimed at gaining social acceptance of the technology. Following the example of the successful program applied by CentroSur, it is advisable for ARCONEL to enforce a participatory and inclusive approach, particularly important in the case of indigenous communities.

As far as the EDCs are concerned, they apply one-size PV solutions that do not necessarily fit all needs and that have not been determined based on gender-specific and community-specific requirements. In order to improve the accuracy of their solutions, they should take gender-and community-specific requirements in their project designs into account.

In general terms, cultural justice criteria and the opinion of small indigenous communities are not considered in public policies (e.g., microgrids for semi-nomad indigenous communities in the Amazon). In this regard, the MEER may want to consider including sociologists or social experts in the design of programs for indigenous communities.

Even if not comprehensive or sufficient, these recommendations may be the first step in further improving the sustainability of rural electrification programs in Ecuador. As the qualitative approach can do justice to the complexity of such energy policies in the national context, additional qualitative approaches to evaluate the sustainability of off-grid PV systems in different countries would be insightful; these studies could then be used for an intercomparison between countries.

Acknowledgments: The support of CORFO (Preis 14BPC4–28651 & 15BP–45364), CONICYT-BMBF (Preis PCCI20130041), CONICYT-ANILLO ACT1410, FONDECYT (Preis 1151034), is gratefully acknowledged.

Author Contributions: The first author conceptualized and structured the paper. The first author was solely responsible for data collection (interviews) and analysis. The whole paper was jointly drafted and developed by the authors to bring to the current state.

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

Abbreviations

The following abbreviations are used in this manuscript:

ARCONEL	Agency for Regulation and Electricity Control
CELEC	Ecuadorian Electric Corporation
CONELEC	Agency for Regulation and Electricity Control
CONAM	National Modernization Council
EDC	Electricity Distribution Company
EIU	Economist Intelligence Unit
EEQ	Electric Compnay Quito
FEDETA	Ecuadorian Foundation of Appropriate Technology
FERUM	Fund for Rural and Urban-marginal Electrification
IADB	Inter American Development Bank
IICA	Inter-American Institute for the Cooperation in Agriculture
INECEL	Ecuadorian Institute of Electrification
MEER	Ministry of Electricity and Renewable Energy
MICSE	Coordinating Ministry of Strategic Sectors
MWp	Mega Watts peak
NCRE	Non-conventional renewable energy
NPO	Non-profit-organization
O&M	Operation and maintenance
PNBV	National Plan for Good Living
PV	Photovoltaic
RE	Renewable Energy
SENPLADES	National Planning and Development Secretary
UN	United Nations
UNDP	United Nations Development Program
Wp	Watts peak

References

1. International Energy Agency (IEA). *World Energy Outlook. Electricity Access Database*; International Energy Agency: Paris, France, 2015.
2. Organisation for Economic Co-operation and Development (OECD) and International Energy Agency IEA. Energy Poverty. How to make modern energy access universal? Special early excerpt of the World Energy Outlook 2010 for the UN General Assembly on the Millennium Development Goals. 2010. Available online: http://www.se4all.org/wp-content/uploads/2013/09/Special_Excerpt_of_WEO_2010.pdf (accessed on 13 December 2015).
3. United Nations. Transforming Our World: The 2030 Agenda for Sustainable Development. 2015. Available online: https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed on 7 April 2016).
4. United Nations. Sustainable Energy for All. A Framework for Action, The Secretary-General's High-Level Group on Sustainable Energy for All. 2012. Available online: http://www.un.org/wcm/webdav/site/sustainableenergyforall/shared/Documents/SE%20for%20All%20-%20Framework%20for%20Action%20FINAL.pdf (accessed on 23 August 2015).

5. Earth Summit. *Agenda 21: The United Nations Programme of Action from Rio*; United Nations: New York, NY, USA, 1992.
6. CONELEC. *Plan Maestro de Electrificación 2012–2021*; CONELEC: Deland, FL, USA, 2012.
7. CONELEC. Cobertura De Servicio Eléctrico A Diciembre De 2013. Available online: http://www.conelec.gob.ec/contenido.php?cd=10275&l=1 (accessed on 18 June 2015).
8. Ten, M. *Revisión de los Resultados de la Operación 2608/OC-EC: Electrificación Rural y Urbano-Marginal del Ecuador*; Programa de Electrificación Rural y Urbano-Marginal (FERUM) (IADB): Washington, DC, USA, 2013. (In Spanish)
9. CONELEC. Centrales Renovables No Convencionales (NA). Available online: http://www.conelec.gob.ec/images/documentos/doc_10238_CENTRALES_RENOVABLES_NO_CONVENCIONAL.pdf (accessed on 18 June 2015).
10. Ministerio de Electricidad y Energias Renovables (MEER). *Informe—Rendición de Cuentas*; Ministerio de Electricidad y Energias Renovables (MEER): Quito, Ecuador, 2014. (In Spanish)
11. Ritchie, J., Lewis, J., Nicholls, C.M., Ormston, R., Eds.; *Qualitative Research Practice: A Guide for Social Science Students and Researchers*; Sage: New York, NY, USA, 2013.
12. Gläser, J.; Laudel, G. *Experteninterviews und Qualitative Inhaltsanalyse*; Springer: Berlin, Germany, 2010.
13. Burford, G.; Hoover, E.; Velasco, I.; Janoušková, S.; Jimenez, A.; Piggot, G.; Harder, M.K. Bringing the "missing pillar" into sustainable development goals: Towards intersubjective values-based indicators. *Sustainability* **2013**, *5*, 3035–3059. [CrossRef]
14. Derakhshan, F. On Sustainability in Local Energy Planning. *Int. J. Sustain. Dev.* **2011**, *8*, 80–96.
15. Spangenberg, J.H.; Pfahl, S.; Deller, K. Towards indicators for institutional sustainability: Lessons from an analysis of Agenda 21. *Ecol. Indic.* **2002**, *2*, 61–77. [CrossRef]
16. Ciegis, R.; Ramanauskiene, J.; Martinkus, B. The concept of sustainable development and its use for sustainability scenarios. *Eng. Econ.* **2015**, *62*, 28–37.
17. Platje, J. The level of institutional capital and challenges in sustainable development. *Econ. Environ. Stud.* **2011**, *11*, 99–116.
18. North, D.C. *Institutionen, Institutioneller Wandel und Wirtschaftsleistung*; Mohr Siebeck: Tübingen, Germany, 1992; Volume 76, p. 4.
19. Pejovich, S. The effects of the interaction of formal and informal institutions on social stability and economic development. *J. Mark. Moral.* **2012**, *2*, 164–181.
20. Reiche, K.; Tenenbaum, B.; de Mästle, C.T. *Electrification and Regulation: Principles and a Model Law*; The World Bank: Washington, DC, USA, 2006.
21. Reddy, B.S. Measuring and Evaluating Energy Security and Sustainability: A Case Study of India. Available online: http://www.igidr.ac.in/pdf/publication/WP-2015-08.pdf (assessed on 16 December 2015).
22. Sharma, T.; Balachandra, P. Benchmarking sustainability of Indian electricity system: An indicator approach. *Appl. Energy* **2015**, *142*, 206–220. [CrossRef]
23. Wimmler, C.; Hejazi, G.; de Oliveira Fernandes, E.; Moreira, C.; Connors, S. Multi-Criteria Decision Support Methods for Renewable Energy Systems on Islands. *J. Clean Energy Technol.* **2015**, *3*, 185–195. [CrossRef]
24. García, V.G.; Bartolomé, M.M. Rural electrification systems based on renewable energy: The social dimensions of an innovative technology. *Technol. Soc.* **2010**, *32*, 303–311. [CrossRef]
25. The World Bank. Policy and Governance Framework for Off-grid Rural Electrification with Renewable Energy Sources (TF090884). 2008. Available online: https://openknowledge.worldbank.org/bitstream/handle/10986/7954/683390ESW0WHIT0lectrification0Final.txt?sequence=2 (accessed on 24 August 2015).
26. Ilskog, E.; Kjellström, B. And then they lived sustainably ever after?—Assessment of rural electrification cases by means of indicators. *Energy Policy* **2008**, *36*, 2674–2684. [CrossRef]
27. Vera, I.A.; Langlois, L.M.; Rogner, H.H.; Jalal, A.I.; Toth, F.L. Indicators for sustainable energy development: An initiative by the International Atomic Energy Agency. In *Natural Resources Forum*; Blackwell Publishing Ltd.: Hoboken, NJ, USA, 2005; Volume 29, pp. 274–283.
28. Levitsky, S.; Murillo, M.V. Variation in Institutional Strength. *Annu. Rev. Polit. Sci.* **2009**, *12*, 115–133. [CrossRef]
29. Laufer, D.; Schäfer, M. The implementation of Solar Home Systems as a poverty reduction strategy—A case study in Sri Lanka. *Energy Sustain. Dev.* **2011**, *15*, 330–336. [CrossRef]

30. Lyndrup, M.; Jensen, T.Y.H.W. Illuminating the Potential for a Rural Energy Service Company-Meeting the Off-Grid Electrification Challenge in Mozambique. Ph.D. Thesis, Roskilde University, Roskilde, Denmark, 2012.
31. Wlokas, H.L. *A Review of the Solar Home System Concession Programme in South Africa*; Energy Research Centre, University of Cape Town: Cape Town, South Africa, 2011.
32. Friebe, C.A.; von Flotow, P.; Täube, F.A. Exploring the link between products and services in low-income markets—Evidence from solar home systems. *Energy Policy* **2013**, *52*, 760–769. [CrossRef]
33. Polack, A. Drivers and barriers of renewable energy in the electrification of Vanuatu. Ph.D. Thesis, Murdoch University, Murdoch, Australia, 2010.
34. Machado, F.V. Decentralization and Accountability: The Curse of Local Underdevelopment. 2013. Available online: http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=37809480 (accessed on 29 November 2013).
35. Axelsson, R.; Angelstam, P.; Degerman, E.; Teitelbaum, S.; Andersson, K.; Elbakidze, M.; Drotz, M.K. Social and cultural sustainability: Criteria, indicators, verifier variables for measurement and maps for visualization to support planning. *Ambio* **2013**, *42*, 215–228. [CrossRef] [PubMed]
36. Pansera, M. Renewable energy for rural areas of Bolivia. *Renew. Sustain. Energy Rev.* **2012**, *16*, 6694–6704. [CrossRef]
37. Retnanestri, M. The I3A framework-Enhancing the sustainability of off-grid photovoltaic energy service delivery in Indonesia. Ph.D. Thesis, University of New South Wales, Sydney, Australia, 2007.
38. Bhattacharyya, S.C. Energy access programmes and sustainable development: A critical review and analysis. *Energy Sustain. Dev.* **2012**, *16*, 260–271. [CrossRef]
39. Mainali, B.; Pachauri, S.; Rao, N.D.; Silveira, S. Assessing rural energy sustainability in developing countries. *Energy Sustain. Dev.* **2014**, *19*, 15–28. [CrossRef]
40. Rosen, M.A. Energy sustainability: A pragmatic approach and illustrations. *Sustainability* **2009**, *1*, 55–80. [CrossRef]
41. International Atomic Energy Agency (IAEA); United Nations Dfrtment of Economic and Social Affairs (UNDESA); International Energy Agency (IEA); Eurostat, European Environment Agency (EEA). *Energy Indicators for Sustainable Development: Methodologies and Guidelines*; International Atomic Energy Agency (IAEA): Vienna, Austria, 2005.
42. Dunmade, I. Indicators of sustainability: Assessing the suitability of a foreign technology for a developing economy. *Technol. Soc.* **2002**, *24*, 461–471. [CrossRef]
43. Van Campen, B.; Guidi, D.; Best, G. Solar photovoltaics for sustainable agriculture and rural development. In *Rural Development*; FAO Publication: Rome, Italy, 2000.
44. Khandker, S.R.; Barnes, D.F.; Samad, H.A. Welfare impacts of rural electrification: A panel data analysis from Vietnam. *Econ. Dev. Cult. Chang.* **2013**, *61*, 659–692. [CrossRef]
45. Kirubi, C.; Jacobson, A.; Kammen, D.M.; Mills, A. Community-based electric micro-grids can contribute to rural development: Evidence from Kenya. *World Dev.* **2009**, *37*, 1208–1221. [CrossRef]
46. Cook, P. Infrastructure, rural electrification and development. *Energy Sustain. Dev.* **2011**, *15*, 304–313. [CrossRef]
47. O'Faircheallaigh, C. Public participation and environmental impact assessment: Purposes, implications, and lessons for public policy making. *Environ. Impact Assess. Rev.* **2010**, *30*, 19–27. [CrossRef]
48. International Energy Agency (IEA). *Energy Technology Perspectives*; International Energy Agency: Paris, France, 2010.
49. Pope, J.; Annandale, D.; Morrison-Saunders, A. Conceptualising sustainability assessment. *Environ. Impact Assess. Rev.* **2004**, *24*, 595–616. [CrossRef]
50. Prandecki, K. Theoretical Aspects of Sustainable Energy. *Energy Environ. Eng.* **2014**, *2*, 83–90.
51. Ilskog, E. Rural electrification sustainability indicators—manual for field workers. Available online: http://swepub.kb.se/bib/swepub:oai:DiVA.org:kth-9132?tab2=abs&language=en (accessed on 27 June 2014).
52. Kolk, A.; van den Buuse, D. In search of viable business models for development: sustainable energy in developing countries. *Corp. Gov. Int. J. Bus. Soc.* **2012**, *12*, 551–567.
53. Ribeiro, F.; Ferreira, P.; Araújo, M. The inclusion of social aspects in power planning. *Renew. Sustain. Energy Rev.* **2011**, *15*, 4361–4369. [CrossRef]

54. Chaurey, A.; Kandpal, T.C. Assessment and evaluation of PV based decentralized rural electrification: An overview. *Renew. Sustain. Energy Rev.* **2010**, *14*, 2266–2278. [CrossRef]
55. Frame, D.; Tembo, K.; Dolan, M.J.; Strachan, S.M.; Ault, G.W. A community based approach for sustainable off-grid PV systems in developing countries. In Proceedings of the 2011 IEEE Power and Energy Society General Meeting, San Diego, CA, USA, 24–29 July 2011; pp. 1–7.
56. Nurse, K. Culture as the fourth pillar of sustainable development. *Small States Econ. Rev. Basic Stat.* **2006**, *11*, 28–40.
57. Fenner, R.A.; Ainger, C.M.; Cruickshank, H.J.; Guthrie, P.M. Widening engineering horizons: addressing the complexity of sustainable development. *Proc. ICE Eng. Sustain.* **2006**, *159*, 145–154. [CrossRef]
58. Demirtas, O. Evaluating the best renewable energy technology for sustainable energy planning. *Int. J. Energy Econ. Policy* **2013**, *3*, 23–33.
59. Mendieta Vicuña, D.; Escribano Pizarro, J. Electricidad, Desarrollo Rural y Buen Vivir, III Simposio Internacional Historia de la electrificación. Estrategias y cambios en el territorio y la sociedad. 2015. International Conference, Mexico City, Mexico. Available online: http://www.ub.edu/geocrit/iii-mexico/mendietaescribano.pdf (accessed on 27 May 2015). (In Spanish)
60. Montero Banegas, M.; Cajamarca Huayllazaca, E. Análisis Socio-económico de las Comunidades Aisladas en la Provincia de Morona Santiago Beneficiadas del Servicio Eléctrico Mediante la Instalación de Sistemas Fotovoltaicos, en el Período 2009–2011. Available online: http://dspace.ucuenca.edu.ec/bitstream/123456789/1027/1/teco723.pdf (accessed on 12 June 2015). (In Spanish)
61. Zhumi, M.; Gerardo, L. Diagnóstico de la Implementación de los Sistemas Fotovoltaicos Correspondientes a la Primera Etapa del Proyecto Yantsa ii Etsari. 2012. Available online: http://dspace.ucuenca.edu.ec/bitstream/123456789/689/1/te321.pdf (accessed on 17 March 2015). (In Spanish)
62. Leid, L.H. Llegó La Luz: A Case study of the Impacts of Solar Photovoltaic electricity in Las Balsas, Ecuador. Ph.D. Thesis, University of Texas, Austin, TX, USA, 2014. Available online: https://tdl-ir.tdl.org/tdl-ir/handle/2152/26125 (accessed on 31 March 2015).
63. Bernhardt, J. The Effectiveness of Science-Policy Interactions: Case Studies on Climate Change Mitigation and Sustainable Development in Pan-European Forest Research and Politics. Ph.D. Thesis, University of Hamburg, Hamburg, Germany. Available online: http://ediss.sub.uni-hamburg.de/volltexte/2015/7160/ (accessed on 24 March 2015).
64. Heinrichs, H.; Laws, N. "Sustainability State" in the Making? Institutionalization of Sustainability in German Federal Policy Making. *Sustainability* **2014**, *6*, 2623–2641. [CrossRef]
65. Nguyen-Trinh, H.A.; Ha-Duong, M. Perspective of CO_2 capture & storage (CCS) development in Vietnam: Results from expert interviews. *Int. J. Greenh. Gas Control* **2015**, *37*, 220–227.
66. Hugé, J.; Mukherjee, N.; Fertel, C.; Waaub, J.P.; Block, T.; Waas, T.; Dahdouh-Guebas, F. Conceptualizing the effectiveness of sustainability assessment in development cooperation. *Sustainability* **2015**, *7*, 5735–5751. [CrossRef]
67. MAXQDA. Software for qualitative data analysis, 1989–2016, VERBI Software–Consult–Sozialforschung GmbH, Berlin, Germany. Available online: http://www.maxqda.com/ (assessed on 11 December 2015).
68. Instituto Nacional de Estadística y Censos (INEC) (NA). MUJERES Y HOMBRES del Ecuador en Cifras III. Editorial Ecuador. Instituto Nacional de Estadística y Censos: Quito, Ecuador. Available online: http://www.ecuadorencifras.gob.ec/wp-content/descargas/Libros/Socioeconomico/Mujeres_y_Hombres_del_Ecuador_en_Cifras_III.pdf (accessed on 4 April 2015). (In Spanish)
69. Ministerio Coordinador de Sectores Estrategicos (MICSE) (2014). Políticas Energéticas en Ecuador. Available online: http://www.nist.gov/iaao/upload/3-_Presentacion_Politica_Energia__v2-pptx_DARWIN_COSTA.pdf (accessed on 24 August 2015).
70. The World Bank (NA). World Development Indicators. Available online: http://databank.worldbank.org/data//reports.aspx?source=2&country=ECU&series=&period= (accessed on 21 February 2015).
71. Secretaría Nacional de Planificación y Desarrollo (SENPLADES). *Plan Nacional para el Buen Vivir 2013–2017*; Secretaría Nacional de Planificación y Desarrollo: Quito, Ecuador; Available online: http://www.buenvivir.gob.ec/versiones-plan-nacional (accessed on 13 August 2014). (In Spanish)
72. Presidencia de Ecuador (NA). Gabinete de la Revolución Ciudadana. Available online: http://www.presidencia.gob.ec/gabinete-de-la-revolucion-ciudadana/ (accessed on 3 July 2015).

73. Empresa Eléctrica Ambato EEASE (NA). 55 Años En La Historia De Empresa Eléctrica Ambato Regional Centro Norte S.A. Available online: http://www.eeasa.com.ec/index.php?id=2&id1=6 (accessed on 11 December 2015). (In Spanish)
74. CENTROSUR (NA). Trayectoria de la Centrosur Al Servicio de la Región. Available online: http://www.centrosur.com.ec/?q=node/10 (accessed on 11 December 2015). (In Spanish)
75. Azogues (NA). Reseña Histórica. Available online: http://www.elepcosa.com/eec/index.php/la-empresa/2014--11--08--14--13--09 (accessed on 12 December 2015).
76. Ministerio de Electricidad y Energias Renovables (MEER). Plan Estratégico Institucional 2014–2017. Available online: http://www.energia.gob.ec/wp-content/uploads/downloads/2014/09/PLAN-ESTRATÉGICO-2.pdf (accessed on 17 October 2014). (In Spanish)
77. Mena Pachano, A. La Investigación y Desarrollo de Energías Renovables en el Ecuador. Análisis Crítico. Available online: http://www.energia.org.ec/cie/wp-content/uploads/2014/01/Investigacion-energi%C2%ADas-renovables-Ecuador.pdf (accessed on 12 December 2014). (In Spanish)
78. Congreso Nacional. *Ley De Regimen Del Sector Electrico. Registro Oficial Suplemento 43 de 10-oct-1996*; Congreso Nacional: Buenos Aires, Argentine, 2011. (In Spanish)
79. Haanyika, C.M. Rural Electrification Policy and Institutions in a Reforming Power Sector. Available online: http://www.un.org/esa/sustdev/sdissues/energy/op/parliamentarian_forum/haanyika_policy_institutions_re.pdf (assessed on 15 November 2013).
80. Asamblea Nacional. *Ley Orgánica del Servicio Público de Energía Eléctrica*; Asamblea Nacional: Caracas, Venezuela, 2015. (In Spanish)
81. Congreso Nacional. *Ley de Modernizacion del estado. Ley 50, Registro Oficial 349 de 31 de Diciembre de 1993*; Congreso Nacional: Buenos Aires, Argentine, 1993. (In Spanish)
82. Agencia de Regulación y Control de Electricidad (ARCONEL). *Estadística del Sector Eléctrico Ecuatoriano 2014*; Agencia de Regulación y Control de Electricidad (ARCONEL): Quito, Ecuador, 2014. (In Spanish)
83. Ministerio de Electricidad y Energias Renovables (MEER). Available online: http://www.energia.gob.ec/coca-codo-sinclair/# (accessed on 28 August 2015).
84. CONELEC (2014). Cargos Tarifarios. Available online: http://www.conelec.gob.ec/documentos.php?cd=3073&l=1 (accessed on 14 August 2015).
85. Asamblea Constituyente. Mandato Constituyente No. 15. Montecristi, Ecuador. 2008. Available online: http://www.trabajo.gob.ec/wp-content/uploads/downloads/2012/08/Mandato-Constituyente-No.-2.pdf (accessed on 4 June 2015).
86. Inter American Development Bank (IADB) (2014). CONTRATO DE PRÉSTAMO No. 3087/OC-EC. Programa de Electrificación Rural y Urbano-Marginal del Ecuador II. Available online: http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=38805074 (accessed on 16 August 2015).
87. CONELEC. *Plan Maestro de Electrificación 2009–2020*; CONELEC: Deland, FL, USA, 2009; p. 417.
88. Urdiales Flores, L.E. Procedimiento Para la Electrificación en Zonas Aisladas: Caso Cantón Taisha, Morona Santiago. Master's Thesis, Universidad de Cuenca, Cuenca, Ecuador, 2015. Available online: http://dspace.ucuenca.edu.ec/handle/123456789/21428 (accessed on 5 May 2015). (In Spanish)
89. Ten, M.; Neira, M.; Navarro, G.; Cordero, M. *Experiencias De Modelos De Gestión Off-Grid, En Ecuador e Internacionalmente*; FEDETA: Quito, Ecuador, 2015. (In Spanish)
90. Inter American Development Bank (IADB). Soluciones Sostenibles De Energias Renovables Fuera De Red Para Comunidades Aisladas En Ecuador. 2013. Available online: http://idbdocs.org/wsdocs/getdocument.aspx?docnum=37911288 (accessed on 7 June 2015). (In Spanish)
91. Balseca, M. *Programa De Energizacion Rural "Luz Para El Sumak Kawsay"*; Ecuacier: Riobamba, Ecuador, 2015. (In Spanish)
92. Pino, B.A.; Dolcetti, M. Revolución ciudadana, buen vivir y cooperación en Ecuador (2007–2013). *Relac. Int.* **2014**, *23*, 177–199. (In Spanish)
93. Secretaría Nacional de Planificación y Desarrollo (SENPLADES) (NA). Reseña Histórica. Available online: http://www.planificacion.gob.ec/resena-historica/ (accessed on 4 June 2015). (In Spanish)
94. Fundación Ecuatoriana De Tecnología Apropiada (FEDETA). *Modelo de Gestión para Sistemas Energéticos Aislados—Articulación Energética Territorial para Poblaciones Indígenas de la Región Amazónica Ecuatoriana*; FEDETA: Quito, Ecuador, 2014. (In Spanish)

95. Ambiente (NA). Subsecretarías y Direcciones. http://www.ambiente.gob.ec/subsecretarias-y-direcciones-2/ (accessed on 23 June 2015). (In Spanish)
96. Bass, M.S.; Finer, M.; Jenkins, C.N.; Kreft, H.; Cisneros-Heredia, D.F.; McCracken, S.F.; Di Fiore, A. Global conservation significance of Ecuador's Yasuní National Park. *PLoS ONE* **2010**, *5*, e8767. [CrossRef] [PubMed]
97. Fileccia, C.M.; Caravaggio, N.; Conte, E. Buen Vivir: Sumak Kawsay and reality. In Proceedings of the 25th annual EAEPE Conference, Paris, France, 7–9 November 2013; Available online: https://www.academia.edu/15369034/Buen_Vivir_between_Sumak_Kawsay_and_reality (accessed on 22 March 2015).
98. Finer, M.; Jenkins, C.N.; Pimm, S.L.; Keane, B.; Ross, C. Oil and gas projects in the western Amazon: Threats to wilderness, biodiversity, and indigenous peoples. *PLoS ONE* **2008**, *3*, e2932. [CrossRef] [PubMed]
99. Orta-Martínez, M.; Finer, M. Oil frontiers and indigenous resistance in the Peruvian Amazon. *Ecol. Econ.* **2010**, *70*, 207–218. [CrossRef]