The gendered politics of rural electrification: Education, indigenous communities, and impacts for the Venezuelan Guajira

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Abstract

Rural electrification has often been promoted to improve women's access to education. However, no studies have been conducted to measure the actual impact of electrification on equitable access to education, qualitatively and quantitatively. This is particularly true when studying rural and indigenous communities in developing countries. The objective of this study is to comprehensively evaluate the impact of electrification on schooling for men and women in La Guajira (Venezuela). Their traditional indigenous rural communities were recently electrified with Renewable Energy Technologies (RET). The study focuses on eight communities that have never had electricity and whose location far from urban settlements limits other social relationships. During a week of total immersion in the fieldwork, the impact on 285 men and 273 women was analyzed through 43 household surveys. The results show that access to primary, secondary, and higher education has increased significantly thanks to coordinated education and electricity policies. School offers similar opportunities for both genders, but a higher percentage of indigenous women take advantage of the opportunity to study beyond the primary level.

Keywords

Rural electrification; gender; education; Venezuela; indigenous communities

1. INTRODUCTION

Between 2000 and 2016, the number of people living without access to electricity was reduced from 1.70 to 1.16 billion, thanks to rural electrification programs partially based on renewable energy technologies (RET-based) and off-grid systems [1]. However, in 2017, people without electricity services still represented 17% of the world population. [2]. Among this population, women suffer gender inequalities related to lack of electricity [3]. Access to modern and sustainable energy services is an important factor for improving women's living conditions in rural communities [4][5]. For instance, locally provided electricity reduces the adverse impacts of traditional energy sources on women's health and working hours [6][7].

In particular, different studies show the link between gender, energy and education, because women spend more time on unpaid care [8], domestic and agricultural work when living in unelectrified rural settlements [9][10]. This situation usually leads to women giving up opportunities to participate in literacy and education [11]. Thus, the benefits of rural electrification are particularly important for women's education, especially in developing countries [12] [13]. In South African rural settlements, educated and working women benefit more from the productivity gains of electrification as they increase their earnings compared to men [12] [14]. In China, a similar study led to analogous conclusions [15]. Therefore, equitable access to education in both genders is an important initial factor, leading to equal conditions in the productive sector and a more egalitarian society [16]. If the women conditions as consequence of energy access are not considered, modern energy services can be ineffective as drivers of sustainable development [17] [18].

In the region of the case study, Latin America, gender gaps translate into income gaps and are reflected in a higher prevalence of poverty among women [19]. On average, there are 118.2 women poor, for every 100 men in the same condition [20]. Previous studies show that, in rural areas, there is a direct relationship between electrification, energy sources, education and development [21], from the most unequal countries such as Mexico and Brazil to the Andean region (Colombian, Bolivia, Ecuador, Perú and Venezuela), where notable improvements has been found. In Andean countries, increases in the rural electrification index from 53.65% in 1995 to 91.13% in 2018 have helped reducing gender inequalities [22] [23]. For instance, in Bolivia women represent 63% of population having higher education and research positions; while in Venezuela the value is 56% [20]. In addition, women's involvement in the development and management of rural electrification projects, has also proved suitable to reduce gender gaps and is progressively becoming part of rural development programs [19].

Historically, the link between energy and gender has been poorly investigated because of the empirical evidence and difficulty for achieving quantitative analyses, which discourages researchers from technical branches of exact sciences [24]. In order to analyze the rural electrification precisely, data concerning the social dimension of

sustainability must be collected and discussed [25]. In this respect, no publicly available o documented studies have been found that perform gender and educational analyses based on surveys and information from field work in electrified communities [8] [26]. In general, very few studies have been published on empirical evaluations of access to electricity [24][19][27], particularly for small-scale applications [28][29]. Thus, more quantitative studies based on appropriate ex-post analysis of benefited communities are still needed [30]. In particular, in Venezuela the sustainability of RET-based microgrids for rural communities has been studied through technical visits and using a formative evaluation [23][31]. However, no analysis has been made regarding access to education according to gender.

In this context, the objective of this study is to make a gender comparison regarding education access before and after RET-based electrification, based on the Venezuelan experiences in La Guajira (Zulia State). The work focuses on 8 communities, electrified from 2008 to 2013 using hybrid wind-diesel-solar microgrids installed by the Program *Sembrando Luz* (Sowing Light) of the *Fundación para el Desarrollo del Sistema Eléctrico – Fundelec* (Foundation for the Development of the Electric System) under supervision of the Ministry of Electric Energy of the Bolivarian Republic of Venezuela. Indeed, the post-electrification impact in the rural communities after a medium to long term is considered (i.e. more than three years after the electrification project starts and before it accomplishes the 25 years' lifetime). During a week of total immersion in field work, 43 house-surveys were carried out to evaluate the impact of electrification on 285 men and 273 women. The results quantify, for the first time, the benefits of electrification in improving women's education. The quantitative data, together with qualitative information, is analyzed to identify the key aspects that have allowed such an improvement in indigenous Wayuu population.

The rest of the paper is organized as follows. In Section 2, the studied communities, the electrification projects, and the data gathering methods are provided. The evaluation methodology is described in Section 3. In Section 4, results are discussed regarding how electricity has improved education levels in men and women. Finally, the main conclusions are summarized in Section 5.

2. CASE STUDIES

In last years, Venezuela has been facing a severe energy crisis due to the centralization of the oil industry and its hegemonic role in the economy, including the electricity industry [32]. The recurring electricity failures and the collapse of the generation system based on thermoelectric and hydroelectric plants have shown the need to advance the pilot programs for the development of renewable energy in a decentralized manner at regional, municipal and community levels [33]. In this context, the regions with the greatest potential in renewable energy (wind and solar) are those of the Venezuelan north-west, and especially the coasts of Falcón and Zulia states (La Guajira). The projects with

renewable energies at the community level are part of this strategy of progressive migration to a new energy matrix in the country, which has focused mainly on these two states, and in which the Guajira region holds the greatest potential for a sustainable change in the future.

This work analyzes the electrification impact on impact of electricity access (and education policy) on men and women in La Guajira. The rural electrification index in Zulia increased from 92.49% to 94.53% during the 2008-2013 period. However, geographic conditions and the accelerated growth of indigenous housing, 63% in the mentioned period [34], hindered full electrification. Under these circumstances, non-electrified houses in rural settlements were only reduced by 28%, while in urban areas the reduction was 53%. Another characteristic that impedes rural electrification is the high dispersion of housing and the low population density, 33.49 inhabitants/km^2.

Among the rural electrification systems implemented by the national government in Zulia state (839 houses), 49.94% are supplied by autonomous photovoltaic systems for very scattered houses, 28.61% by isolated diesel networks for larger communities and 21.45% by hybrid microgrids, which are the focus of this research. In particular, 8 communities are studied: Punta Manglar, Poloos, Wososopo, Taparo, Macuirrapa, Cúsia, Iramacira and Castillete (Figure 1). The inhabitants are ethnic Wayuu natives who have previously never had electricity and whose location [35], far from urban settlements, limits other social intercourse for the purpose of the study. These commonly called *traditional indigenous rural communities* remained under ancient cultural and economic conditions prior to electrification [36].

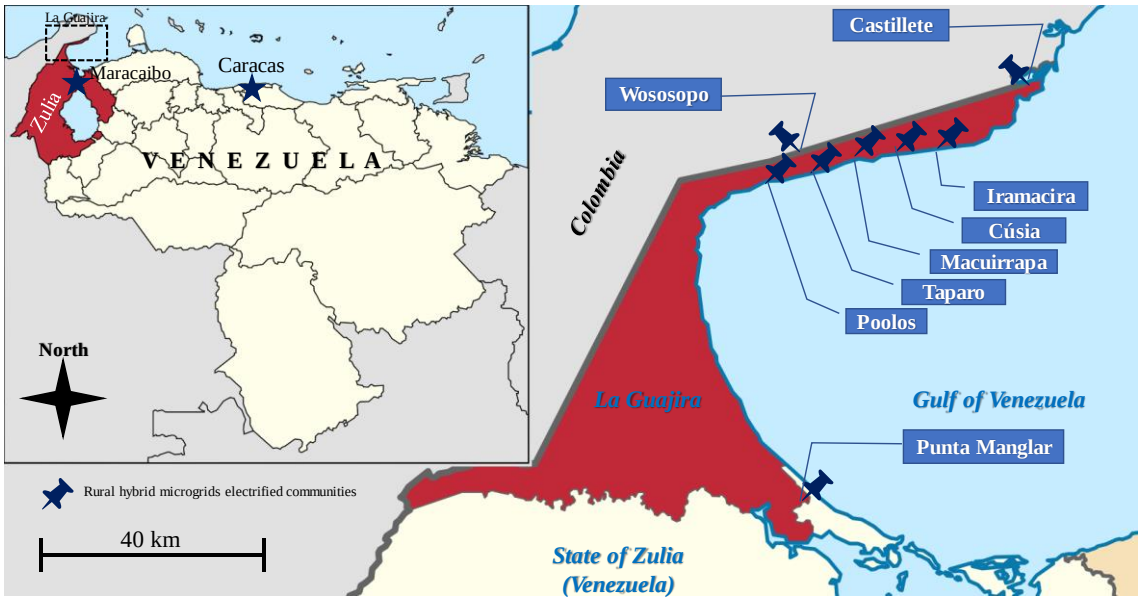

Figure 1. Wayuu communities electrified during 2008-2013 in La Guajira, Venezuela

The hybrid microgrids were designed to provide 2 kWh/day per house [37]. This value represents around 730 kWh/year per house and 122-182 kWh/year per capita, considering 6-4 inhabitants per house, respectively. The estimated demand exceeds the minimum

threshold established by the United Nations to meet the basic needs of population considering standard global conditions (100 kWh/year per capita) [38], and is consistent with Rojas-Zerpa and Yusta [39]. Four types of hybrid microgrids are installed, according to the approximate number of houses in the community to be electrified: 10, 20, 30 and 40. These sizes imply nominal capacities of 9, 14, 19 and 23 kW using a combination of small wind turbines, solar photovoltaic panels, a diesel backup system and battery storage. In addition, a demand of 3.8 kWh/day for schools and health centers was considered during the design of microgrids [33]. Figure 2 shows the hybrid microgrid installed in the community of Cúsia and its school.

Figure 2. Hybrid microgrid and school in the community of Cúsia

The education of Wayuu children is determined by genders, roles and socioeconomic activities. Therefore, they are educated for the foreseen future work. Additionally, education is based on population beliefs and customs. In addition, the traditional matriarchy inside Wayuu communities was not represented in the external relationships of the communities with the Venezuelan political society. Only through education of women have they been able to assume the representation of their communities in Venezuelan political institutions.

It is important to highlight that the Wayuu people have dual nationality (Colombian and Venezuelan) because their territory extends over both countries. Most of them are involved in goat farming and fishing, in addition to binational commerce [40]. The growing trade (Colombian-Venezuelan) and the development needs in the Guajira region have led the Wayuu to increasingly want access to higher levels of education, in order to develop more economically profitable activities [41]. Since the 1980s, bilingual Spanish-Wayuunaiki (name of the Wayú or Guajiro language) has been taught in La Guajira; and Wayú is now spoken by about 400,000 people [42].

Moreover, the education among Wayuu people in La Guajira is a strategic policy in order to obtain qualified workers for the development of the north-western power grid, proposed by the Venezuelan Government within sustainable energy transition plans [33]. La Guajira has enormous oil and gas resources: 656 million barrels of oil and 5.7 trillion cubic feet of gas planned to be exploded in the next ten years. Hence, technicians and engineers will be needed, and preferably from the local population, according to Venezuelan law [43]. In addition, 35% of the Zulia territory, particularly La Guajira, have economically favorable conditions for photovoltaic solar energy. Regarding wind energy, the estimates are 8% of the Zulia territory, all in La Guajira [32]. Therefore, the government plans to develop 10 GW of on-shore and off-shore wind farms in these territories, so there will be a huge need of technicians from the local population [44] [45].

3. METHODOLOGY

The electrification of the 8 studied communities took place around 2010, and since then the population has assumed responsibility for operating the systems [23][31] . The communities were visited and evaluated in 2016, after some 6 years of operation. During the fieldwork, 43 random house-surveys were performed, out of the 163 houses in the 8 communities visited, evaluating the impact of electrification on 285 men and 273 women. On the one hand, community and individual electricity consumption was examined to identify the suitability of systems in satisfying users' electricity demand. On the other hand, the education level was consulted, distinguishing by age and gender. This information was complemented by databases from the National Institute of Statistics [34], to obtain a reference of the situation in rural Venezuela.

This article is limited to educational conditions in Wayuu communities in the upper Guajira region of Venezuela, particularly in 8 communities out of the total 12 that exist in that territory. It should be noted that, considering the social, economic and political context of Venezuela, the quantitative and qualitative results have been analyzed jointly. In this work, both analyses are carried out in parallel since the quantitative data in no way could be conclusive if they are not associated to a context in an analytical manner. Indeed, this has provided the opportunity to develop a comprehensive assessment that has been developed to give integrated answers to the preliminary approaches and questions of this research.

The methodology for impact evaluation of rural electrification on education in the studied communities consists of two parts: a technical analysis of microgrids to evaluate demand fulfillment and appropriate energy generation (Section 3.1) and a social analysis of the impact of electrification on education in both genders (Section 3.3).

3.1. Technical assessment method

The technical evaluation aims to discover whether electrification with hybrid microgrids has been effective in satisfying the energy needs of the population or has limited the growth of electricity demand. For this purpose, load surveys were carried out in the visited houses, through which the average electricity demand in each community was determined. On the other hand, simulations of the hybrid microgrids of each community were carried out using HOMER v2.67 [46] , with the purpose of estimating the electricity production compared with demand. Hence, the technical evaluation is based on both surveys and simulations to obtain the following results:

- **Annual generation** refers to the energy that wind-solar-diesel microgrids can provide considering the availability of resources at each community location. Generally, part of this energy is not leveraged because of the disconnection of wind turbines or photovoltaic modules when electricity demand is covered and batteries are charged.

- **Annual consumption** refers to the estimated consumption of houses and schools in each community. It is determined from the load surveys carried out at each house and the estimated consumption of schools according to the Venezuelan Ministry of Energy.

3.2. Education access assessment method

The social analysis aims to identify the impact of electrification on equitable access to education between men and women. More specifically, people were asked their opinions regarding the influence of electricity on their lives, their working conditions and the possibility of reaching higher levels of education. The data collected with surveys is organized according to age group and education level.

Age groups

Three main population groups are distinguished, each one divided into sub-groups:

- **Minor population (<19)**: the population of up to19 years of age who, according to the Venezuelan system, are expected to attend basic (from 7 to 12 years) or secondary (from 13 to 18 years) education. Before basic education, nursery school takes care of small children when parents are away; this is not considered in the education system.

- **Economically active population (19-65)**: the population aged from 19 to 65 who can work. Three sub-groups are differentiated:
  - **19-24**, population available to work but still at typical higher studies age.
  - **25-45**, population available to work and generally with children to care for.
  - **46-65**, population available to work but relatively close to retirement.

- **Retired population (>65)**: the retirement age in Venezuela is 65 [34], so this population is no longer expected to be economically active.

Education level

Three main education levels are distinguished:

- **Basic**, typically including the 7 to 12-year-old population. At this level, reading and writing skills are learnt together with the bases of mathematics, language, history and other general disciplines. Note that the population without even basic education are illiterate.

- **Secondary**, typically the 13 to 18-year-old population. At this level, general disciplines are consolidated and advanced knowledge (physics, chemistry, etc.) is introduced. Logically, this level requires having previously received basic education.

- **Higher**, usually comprising the 19 to 24-year-old population. At this level, advanced disciplines are consolidated, focusing on the knowledge area studied. This generally involves studying at universities or through programs promoted by the government, as explained in the next section. Logically, this level requires having previously attended secondary education.

It must be noted that, when analyzing the education level reached by the population, minors have only been able to attend basic and/or secondary but that does not mean they will not attend higher studies. Therefore, they are not included in the higher education comparison of results. Figure 3 shows a fraction of the surveys applied in the Macuirrapa community. In this part of the survey, data about the age, education level, labor activity and gender of the people in each of the houses visited are taken.

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3. ASPECTOS SOCIOECONÓMICOS

3.1 Nivel educativo y actividades productivas

3.1.1 Genero		3.1.2 Edad	3.1.3 Nivel de formación educativa	3.1.4 Actividad Productiva (Agricola, Ganadera, Estudios)	3.1.5 ¿Trabaja / estudia dentro o fuera de la comunidad?
F(X)	M( )	23	Bachiller	Ama de casa	—
F( )	M(X)	50	Primaria	Pescador/Pesca	chavez
F(X)	M( )	9	Van a la escuela local	Estudian	—
F(X)	M( )	7	11	11	—
F(X)	M( )	5	11	11	—
F( )	M( )				
F( )	M( )				
F( )	M( )				

3.1.6 En los casos de personas que trabajen y/o estudien fuera de la comunidad describir: lugar, medio de transporte, etc:

Figure 3. Part of the surveys applied to Macuirrapa: (1) gender, (2) age, (3) education level, (4) productive activity and (5) employment

4. Results Discussion

In this section, two different aspects are analyzed in order to reach a conclusion regarding the impact of electrification on men and women education in traditional indigenous communities. First, Section 4.1 describes the findings related to the technical aspects, i.e. the balance between generation and demand in the microgrids. Then, Section 4.2 discusses the results related to impact of electricity access on men and women education, analyzed according to age groups and education level.

4.1. Technical assessment

During the surveys, the load censuses allowed the average electricity consumption per house and other consumption such as that of basic and secondary schools to be estimated. Additionally, the analysis of installed systems, using HOMER v2.67, determines the annual average electricity generation at each visited microgrid. Simulations based on a self-load census, carried out from the surveys, are used. This method is considered more

accurate than using general data provided by the state, for the date of installation of the microgrids, not updated. Table 1 shows the results of the technical assessment.

Table 1. Technical aspects of the rural communities visited

Community	Size of the microgrid [houses]	Electrified houses	Annual generation [kWh]	Annual consumption [kWh]	Houses consumption [kWh/day)	Other consumption [kWh/day]
Punta Manglar	20	16	42315	13439	2.250	3.8(1)
Poloos	30	24	35104	9680	1.066	3.8(1)
Wososopo	30	26	43507	6103	1.964	3.8(1)
Taparo	20	15	33447	10768	1.073	-
Macuirrapa	30	26	48834	22053	2.290	3.8(1)
Cúsia	40	36	72293	24426	1.837	7.6(2)
Iramacira	20	14	34885	6103	1.084	-
Castilletes	10	6	40091	6534	2.996	-

(1) Basic school daily average consumption; (2) Basic and secondary schools daily average consumption

As observed, the annual generation in all the communities is significantly higher than the annual consumption. Therefore, user needs are amply covered by electricity from the microgrids and power cuts are infrequent. In this sense, none of the 43 surveyed houses reported limitations in electricity consumption due to a lack of generation capacity. It must be noted that small differences in consumption between houses were identified, mainly due to different electricity usages, economic income, the number of family members or daily activities, among others. In other words, the technical design of the hybrid microgrids is consistent with the real consumption of the rural population in these indigenous communities [9][10].

The demand fulfillment was also confirmed by users. According to the surveys, 44.4% of economically active women (19-65 y.o.) believe that electricity has improved their working conditions at home. Some of them even claim that the power supply has allowed them to use home appliances that have reduced their daily working hours in domestic tasks. Moreover, 48.1% consider that electricity has enabled access to information for women and children, through television and radio, which has been an important incentive for achieving increasingly higher levels of education.

4.2. Education access assessment

In this section, the results from the 43 surveys are discussed regarding the impact of electrification on education levels for men and women in the studied communities. For this purpose, the base line used is Regnault [47], who carried out a socioeconomic evaluation of education levels for both genders in the Wayuu indigenous population in La Guajira in 2006, i.e. a few years before the electrification projects were implemented. Table 2 compares the percentage of male, female and total population having reached basic, secondary and higher education in 2006 [47] with that of 2016 (according to the applied surveys). Note that the percentages are cumulative from lower to higher levels;

for instance, basic education includes the population who, at least, have attended basic studies but maybe also secondary and higher.

Table 2. Education level comparison by gender between 2006 and 2016

Education level	Before electrification (2006)			After electrification (2016)		
	Male	Female	Total	Male	Female	Total
Basic	56.1%	45.8%	51.0%	88.2%	89.5%	88.9%
Secondary	9.5%	8.1%	8.7%	56.9%	61.2%	59.3%
Higher	1.2%	1.6%	1.3%	10.9%	19.8%	16.8%

As observed, the results show a significant and general improvement in education from 2006 to 2016 at all levels: people with basic education have increased from 51.0% to 88.9%; with secondary from 8.7% to 59.3%; and higher from 1.3% to 16.8%. The increases are bigger at the lower education levels (basic 37.9 points, secondary 50.6 points), but even in higher education the increment is significant (15.5 points). Illiteracy reduction and basic education are based on the Venezuelan government's video and TV assisted program called *"Misión Robinson"*, which is based on the Cuban method *"Yo si puedo"* [48]. Electricity is a necessary condition for their implementation, using TV monitors, video assistance and internet.

When analyzing results by gender, it can be observed that since electrification women's education has improved significantly more than men's. Indeed, percentages in 2006 were globally lower for women but became notably higher in 2016, only 10 years later. In particular, regarding basic education, female education was 10.3 points lower than men's in 2006 (45.8% vs. 56.1%), but it reached men's level in 2016 (89.5% vs. 88.2%). As overcoming basic education and illiteracy is a key indicator for achieving education improvements in societies [49], these results are examined in detail, distinguishing by age groups (Figure 4). Results show that almost all the young population has basic education (percentages over 90% for both genders). Indeed, among women under 19 years, the school attendance achieved in these communities is close to the Venezuelan average, 95.35% [34]. In contrast, differences between men and women's education persist among the population over 46 years (7.8 points difference), and particularly elders above 65, where the gender differences are significant (53.8% for men vs. 42.9% for women). Nevertheless, the significant improvements in basic education among younger women will presumably lead to percentages of older women with basic education similar to those of men in the near future.

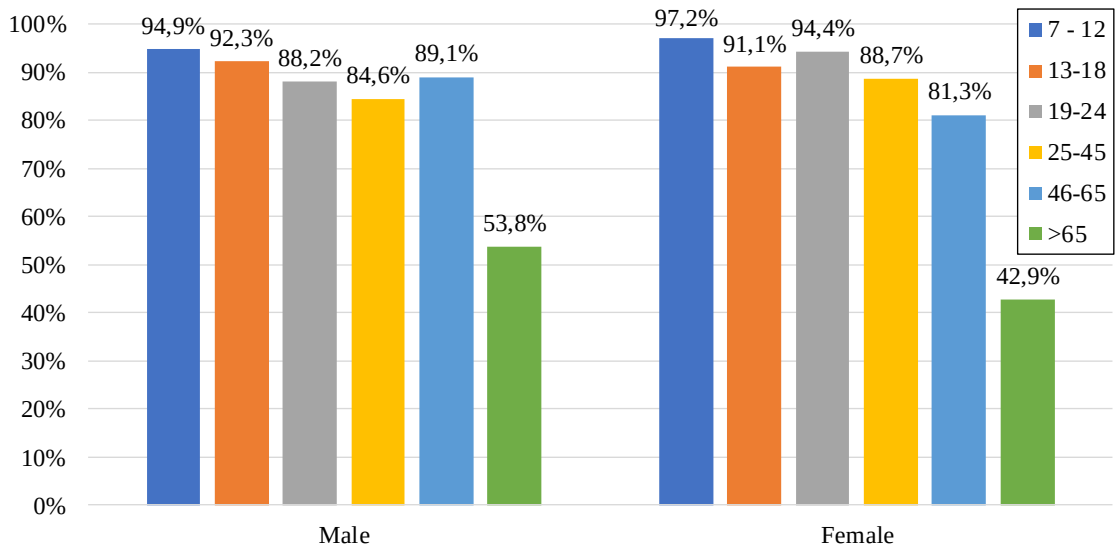

Figure 4. Basic education level by age groups and gender in 2016

Regarding secondary education (Table 2), women's improvement has been greater than men's, from 1.4 points behind (8.1% vs. 9.5%) in 2006 to 4.3 points ahead (61.2% vs. 56.9%) in 2016. Among men, there is a tendency not to pursue secondary education, mainly because outside economic duties (fishing, binational trade, etc.) limit their opportunities. In contrast, among women there is a tendency to continue basic education once finished. Indeed, it can be seen from the surveys that young women have not left their traditional duties, mainly food processing and transporting water from domestic/community tanks to houses, which takes them about 4 hours per day (Figure 5). However, improvements in the secondary school conditions in Cúsia enable young women to attend daily, while electric light bulbs give them more time at night for studying and achieving education beyond the basic level. The community of Cúsia is the main center of activity in the region and there are transportation routes by which the population can easily access the village, particularly the secondary school, from their own communities.

Finally, the difference regarding higher education is much more significant: the percentage of men increases from 1.2% to 10.9% and the percentage of women from 1.6% to 19.8%. In particular, the surveys show a greater attendance to higher education among the young (age groups 19-24 and 25-45) and elderly women (over 65 years). The impact of electrification at this level is mainly motivated by the institutional alignment between electricity and the national program "*Misión Sucre*" [50]. This program promotes the "*aldeas universitarias*" (rural village universities) where small groups, including all the active population, meet a teacher to receive higher studies according to an open university scheme (Figure 6). In this regard, electrification allows information technologies to be used by the communities in order to access information and advanced knowledge for studying.

Figure 5. Girls filling containers with water from the domestic water storage tank

Figure 6. Wayuu women in electrified rural village university in La Guajira [51]

The social organization of the Wayuu culture has historically been based on women [52]: at a community level, organizing the clan to regulate politico-economic activities and, at a domestic level, being the main authority within households. The pre-electrification situation represented a barrier for the free development of women as local leaders. Once the communities became electrified, both genders have had similar opportunities for taking advantage of electricity, but diverse behaviors are observed. On the one hand, electrification has given women the education tools to improve their leadership, expanding their influence and insertion within Venezuela. Women can now participate in

political and institutional national committees and promote projects in their communities to help the local population. On the other hand, men remain in charge of fishing or grazing goats and, consequently, have a lower implication in solving daily domestic and community problems [40].

5. CONCLUSIONS

This is the first study conducted in Venezuela regarding the impact of electrification on the indigenous rural communities in terms of impact of electricity access (and education policy) on men and women education. The work is based on surveys and field data collected in 2016, in 8 communities that had never had electricity before the studied electrification process (implemented around 2010) and where traditional ethnic-cultural aspects remain. Previous data from 2006 in indigenous communities from Venezuela enables a valid comparison to be made regarding the real impact of electrification.

Results show that basic studies are now widely accessed thanks to the complementarity of electricity and the program "*Misión Robinson*", based on TV and video assisted education. Gender differences have disappeared in lower age groups but are still high among the elderly. Secondary studies have significantly increased, especially among young women, using light at night-time for studying to balance the time invested in domestic duties. Finally, most men delay or decline access to higher education, while women take greater advantage thanks to the institutional alignment between electrification and the program "*aldeas universitarias*". Electrification has served to establish more stable villages and introduce a bilingual educational model with advanced technological means. However, electricity itself provides limited benefits; while accompanied by parallel educational programs, it can lead to achieving significant benefits on the education level of the indigenous populations.

This research has clearly demonstrated, with concrete data, that electrification has had a noticeable impact on access to education in the Wayuu indigenous communities of Venezuela. Both genders have had similar opportunities due to electricity, but women have taken greater advantage by studying at night, reducing their domestic workload and accessing information, reinforcing their position as community and domestic leaders. These results are invaluable for Venezuela and policy makers in other developing countries when addressing rural electrification. It is well-known that poverty is strongly related to gender inequalities and electricity access has been found to be a powerful force for changing this situation.

Finally, the energy crisis in many developing countries, such as Venezuela, is caused by an extreme centralization of electrical systems. Therefore, decentralization through solar power generation is an important step towards a more robust and reliable system that can have a positive impact on communities' sustainable development. This is valid both for Venezuela and the rest of Andean and developing countries.

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