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Women, equality, and energy access: Emerging lessons for last-mile rural electrification in Brazil

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ABSTRACT

The inaccessibility to clean and affordable energy, as well as large gender inequalities are two of the greatest challenges faced by rural areas of the Global South. However, the gender approach is still very lacking in energy access literature. This work aims to bridge this gap, by answering two questions: "How do gender inequalities limit women's access to energy benefits, and how can this be counteracted to ensure equal benefit from energy access for both genders?" and "To what extent do energy access initiatives reduce or increase the gender gap and how can these initiatives be improved to correct gender inequalities?". To respond to these questions, field research has been carried out in 19 remote traditional communities in the semi-arid region of Bahia (Brazil), where a last-mile rural electrification program was launched a decade ago. The collection of mixed empirical evidence permitted a multi-criteria analysis of the impact of energy at the residential, community and productive levels. The results highlighted that, to benefit both genders equally, there is a need for higher energy capacities, capable of running household electrical appliances and electrifying community services where women play a fundamental role. In addition, the incorporation of energy affordability mechanisms for women and the continuous local provision of gender-sensitive services are transformative vectors in reversing gender inequalities through energy access initiatives.

1. Introduction

According to the most recently published data [1], in 2020 17 % of the world's rural population was without access to electricity and 52 % lacked access to clean cooking mechanisms. During the last decade, international efforts have focused on solving the power shortage and have dealt with the problems of last-mile electrification. Renewable-based off-grid systems have proven to be particularly advantageous in enabling both remote access to rural energy and climate change mitigation. In particular, 28 million Solar Home Systems (SHS) have been installed up to 2019 [1].

Women tend to be primarily responsible for household chores, especially in low- and middle-income rural areas, and therefore more exposed to polluting energy sources in the absence of clean domestic energy. International organizations [1] agree that accelerating access to energy is essential in reducing both poverty and gender inequalities. In fact, energy plays a transformative role in rural people's development and in changing the living conditions of Global South women, since it makes several daily activities at the home, community or work level more effective. Access to energy has the potential to save time and effort, improve comfort and reduce exposure to polluting energy sources such as biomass, kerosene or oil [2]. Electrified households, when they do not have electric stoves, are more likely to use modern biomass stoves or alternative fuels for cooking [3]. Access to energy improves health care and develops human capital by means of better access to information, communication and education [2]. In addition, energy is a driver of change in reducing gender inequalities, expanding labour market opportunities, improving maternal health and safety in communities and even transforming social gender norms [4]. In this sense, Fujii & Shonchoy [5] identified a causal relationship between access to television and the reduction of women's fertility in Bangladesh. López-González et al. [6] discovered that the electrification of rural schools in

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indigenous Venezuelan communities increased women's participation in primary school. Similarly, two studies applied in Brazil show evidence that girls with access to electricity are more likely to complete primary education [7] and that women with a washing machine have more productive opportunities than those without [2].

However, social norms and gender inequalities can prejudice women's benefit from rural electrification initiatives. Almeshqab and Ustun [8] noted that the stakeholder consultation procedure in the design of Senegal's off-grid projects focused on interviewing heads of households. Due to the male prevalence in this role, preferred community spaces for men (mosques) were electrified rather than women's priorities (health centres). Berger [9] identifies the lack of gender-sensitive training as one of the main causes of failure of the PV-based off-grid systems installed in rural health posts in Ethiopia. Despite the fact that the majority of health workers are women and, therefore, are in charge of operating the systems, the project did not adapt the training format to the target audience. Gill-Wiehl et al. [10] analyse the energy gender justice of off-grid rural electrification in Tanzania. They identified that while women and men have an equal benefit from energy usage, access is not equitable and women are limited in terms of energy management. A similar idea is discussed concerning rural electrification in Nepal, Kenya and India [11]. Winther et al. highlight that, given that men have greater decision-making power within households, domestic appliance purchases and the spatial location of light points tend to benefit men rather than women. This and several other studies have also found that female-headed households have, on average, less access to energy than male-headed households since they face greater affordability concerns [1,11]. Finally, Pueyo & Maestre [12] address the productive use of energy by women through an extensive bibliographic review of grid and off-grid projects applied in the global south. They suggest that women's existing labour opportunities are less energy intensive and thus gender-neutral interventions are less beneficial for the female workers.

Therefore, the literature highlights that initiatives that do not explicitly address the gender inequalities may have a reduced benefit on women and may even increase gender gaps [2,3]. Numerous authors suggest paying greater attention to the prevailing gender norms where the initiatives operate [12] and indicate the need for comprehensive energy interventions that also consider political instruments and economic tools [13,14]. A very limited number of works assess the gender impact of off-grid energy interventions practically, despite their relevance for achieving universal access to energy. A full understanding of the interrelationships between gender inequality and access to energy requires the real experience of rural women from the global south. In particular, more literature is required to transform these experiences into clear policy recommendations, so that promoters of rural electrification can build initiatives that avoid trade-offs and leverage synergies.

In 2003 the Luz Para Todos program (LpT), one of the world's largest rural electrification programs, was implemented in Brazil. This allowed >16 million people to gain energy access through a massive grid extension. As electricity coverage was completed, the program focused on the most remote and excluded regions of the country. The Amazon region received special attention through another specialized program called "Mais Luz na Amazonia", which is outside the scope of this study. Considering the magnitude of its territory, diversity of climates, extensive natural heritage and the presence of a wide variety of native and traditional populations, Brazil became a pioneer in facing the challenges of last-mile electrification. To date, >24,000 solar home systems (SHS), have been installed throughout the country. The LPT program was launched with the purpose of social inclusion [15], but did not explicitly address women's energy needs; to date, no studies have evaluated the last-mile program's impact from a gender perspective. Meanwhile, Brazilian rural women face great gender inequalities such as the excessive burden of family and domestic responsibilities, lack of work recognition and reduced access to basic health, educational and professional opportunities. In addition, women's safety is particularly relevant in Brazil, the country with the highest absolute number of gender-based aggressions in Latin America and the Caribbean [16].

The objective of this article is to fill the literature gap and present recommendations to effectively align the efforts of future rural electrification initiatives with the reduction of gender inequalities. More precisely, this work seeks to analyse the interrelationship between access to energy and gender equality, in order to avoid trade-offs and take advantage of synergies. To do so, the following research questions have been addressed: (RQ1) "How do gender inequalities limit women's access to energy benefits, and how can this be counteracted to ensure equal benefit from energy access for both genders?" and (RQ2) "To what extent do energy access initiatives reduce or increase the gender gap and how can these initiatives be improved to correct gender inequalities?". To answer these questions, the connection between the LpT program and the gender and energy access contexts is measured in 19 communities of the semi-arid region of northern Bahia, where most of the SHS were installed. This territory, particularly vulnerable to climate change due to frequent droughts, is inhabited by traditional *Fundo de Pasto* communities. These postcolonial rural populations combine extractive activities from the local vegetation (Caatinga) with agricultural and livestock activities carried out in collective areas. Family farming is significantly present, where women play a fundamental role linked to food security [17]. Through extensive fieldwork and interviews with the most relevant stakeholders, mixed empirical evidence is collected and 8 ad-hoc indicators are assessed, which allows, from a gender perspective, the impact and limitation of access to energy for women at residential, community and productive levels to be defined.

The organization of the article is as follows. Section 2 presents the case study and characterizes both energy access and gender inequality contexts. The assessment model and data gathering, transcription and analysis methods are described in Section 3. The results are presented later, in Section 4. Section 5 combines the discussion, the answer to the research questions and 4 direct recommendations to improve the gender equality of future interventions. Finally, Section 6 summarizes the main conclusions of the work.

2. Case study description — Bahian women in context

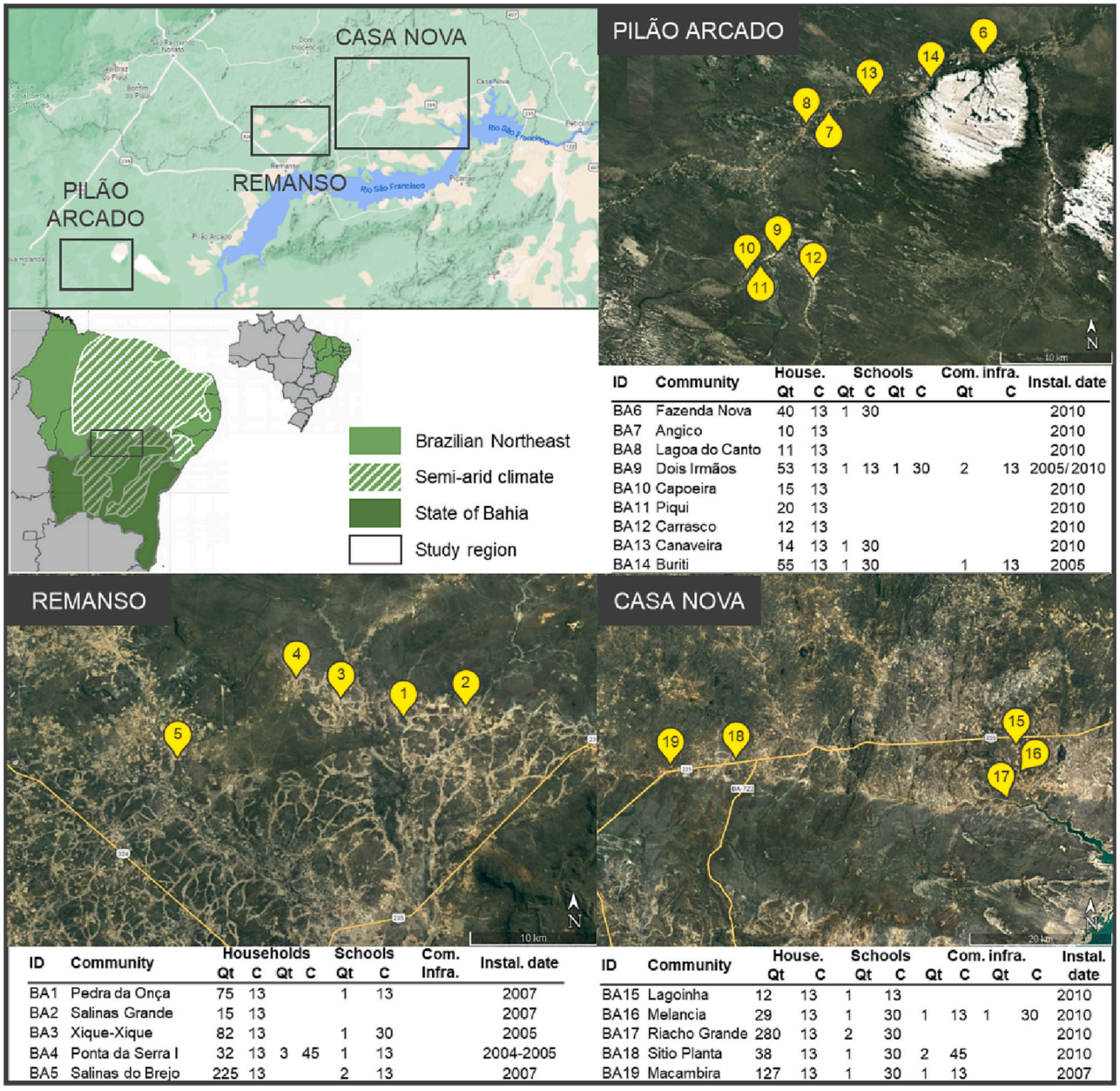
Section 2.1 contextualises the last-mile LpT program's design, implementation and management characteristics in the state of Bahia. Then, the territory's gender context is shown in Section 2.2, supported by the most accurate national and regional statistics.

2.1. The energy access context

Due to its great electrification deficit, the Brazilian Northeast benefited the most from the LpT program. 20,891 systems were installed in the state of Bahia, and particularly in the north of the state, around the Sobradinho hydroelectric dam on the São Francisco River. This region is marked by a semi-arid climate and the significant presence of traditional populations called *Fundo de Pasto* communities. The municipalities of Casa Nova, Remanso and Pilão Arcado accounted for 5605 systems in 2014, of which 4948 systems were still registered in 2020 [18]. Fig. 1 shows the location and characteristics of the 1172 systems visited.

The implementation and management of the LpT program in Bahia is run by the Coelba company, along with periodically renewed subcontracted companies (performed by the Redimax company in 2021). The monthly residential tariff is calculated according to the systems' wattage and to Coelba's electricity price. Since most of the beneficiaries are low-income families, there is an additional tariff discount, called the social energy tariff (TSE), associated with an economic aid called Bolsa Família (BF). The electricity bills of the community spaces are generally borne by the municipalities.

Most of the residential systems are able to generate 13 kWh/month. The greatest benefit generated by these systems is the use of electric light and the consequent reduction of polluting sources. In addition, the



ID	Community	House. Qt	House. C	Schools Qt	Schools C	Schools Qt	Schools C	Com. infra. Qt	Com. infra. C	Instal. date
BA6	Fazenda Nova	40	13	1	30					2010
BA7	Angico	10	13							2010
BA8	Lagoa do Canto	11	13							2010
BA9	Dois Irmãos	53	13	1	13	1	30	2	13	2005/2010
BA10	Capoeira	15	13							2010
BA11	Piqui	20	13							2010
BA12	Carrasco	12	13							2010
BA13	Canaveira	14	13	1	30					2010
BA14	Buriti	55	13	1	30			1	13	2005

ID	Community	Households Qt	Households C	Households Qt	Households C	Schools Qt	Schools C	Com. Infra.	Instal. date
BA1	Pedra da Onça	75	13			1	13		2007
BA2	Salinas Grande	15	13						2007
BA3	Xique-Xique	82	13			1	30		2005
BA4	Ponta da Serra I	32	13	3	45	1	13		2004-2005
BA5	Salinas do Brejo	225	13			2	13		2007

ID	Community	House. Qt	House. C	Schools Qt	Schools C	Com. infra. Qt	Com. infra. C	Instal. date
BA15	Lagoinha	12	13	1	13			2010
BA16	Melancia	29	13	1	30	1	13	2010
BA17	Riacho Grande	280	13	2	30			2010
BA18	Sitio Planta	38	13	1	30	2	45	2010
BA19	Macambira	127	13	1	30	1	13	2007

Fig. 1. Location, quantity (Qt), capacity (C, in kWh/month) and installation date of the 19 field-assessed communities of Pilão Arcado, Remanso and Casa Nova municipalities.

system also allows the use of low consumption appliances (e.g., small fans) and the use of information and communication technologies (ICTs) (e.g., radio, TV and phone) in communities where coverage allows it [19]. The traditional way of cooking in rural areas consists of wood or charcoal stoves, with the increasing adoption of LPG. To promote the transition to clean cooking mechanisms, the Brazilian government launched a gas aid, included in the BF program. Its objective is to subsidise a large part of the cost of a monthly bottle of liquified petroleum gas (LPG) for low-income families [20].

In schools, electricity is used to run ICT and audio-visual equipment and to light evening or night classes of literacy and school reintegration for youths and adults (EJA) [21]. Since 2014, rural schools have been undergoing a process of nucleation, that is, centralization of primary education in larger schools in rural areas and secondary education in cities [22]. According to the 2020 census, only 64 % of rural schools were active in Bahia before the pandemic. Since then, as a result of COVID-19, all active schools have been operating remotely, distributing teaching material physically or online in communities where access to energy and internet allows.

Furthermore, 8 community systems have been implemented in 2 community associations (BA19 & BA16), 1 honey production centre (BA16), 1 cassava flour and fruit processing centre (BA16), 3 bars (BA4 & BA18) and 2 churches (BA4 & BA9). In some communities, schools (e.g., BA16) or the residences of the community leaders are also used for associative purposes. The main productive activities of the communities revolve around family farming and raising free animals (mainly goats and cattle, which feed on the local vegetation) on collectively owned land [17]. Most residences use fuel generators, either to grind food (for human or animal consumption) or pump water and irrigate crops. The latter is of utmost importance due to the high prevalence of drought in the region.

2.2. The gender equality context

According to national statistics, Bahian women over the age of 14 spend an average of 20.9 h/week caring for people (children, the elderly and the sick) and/or housework (cooking, cleaning, laundry), which corresponds to 2.1 times the time spent by men [23]. In the Northeast, moreover, many households have neither daily running water [24] nor clean fuel for cooking [25], which often overloads women. In rural contexts, added to all these activities, is their prominent role in agriculture, food collection and processing. In this sense, a recent study of two *Fundo de Pasto* communities in the semi-arid region of Bahia [17] has highlighted that, on average, women spend 17 h a day on mainly domestic tasks, childcare and backyard agricultural activities. Men spend between 5 and 6 h less on their daily routine, mainly in external service and agricultural activities both in the field and in the backyard. Care tasks also represent a great proportion of women's time, which is maximized due to the scarcity of nearby basic services. For example, recent studies have shown the impacts of the nucleation of rural schools (presented in the previous section) on the time allocated by women to childcare [26]. This burden of time and effort, often unpaid, reduces women's leisure or rest time. This state of deprivation, in which people lack enough resting time due to an overload of time-intensive activities, is called "time poverty" [27]. Women's time poverty is considered one of the main obstacles for gender equality [28].

In 2019, a study [29] identified aggressions (31.2 %) and medical complications in pregnancy, childbirth and the puerperium (6.9 %) as being among the main causes of mortality for women between 20 and 29 years old in Brazil. Prenatal and childbirth care are thus important strategies to prevent or reduce the risk of women and children's mortality [30]. The Brazilian state recommends a minimum of 6 prenatal sessions, half of which are performed in the last trimester of pregnancy [31]. According to regional statistical data [32], in the municipalities of Casa Nova, Remanso and Pilão Arcado, the number of women with inadequate prenatal care was 34 % in 2003 and 20 % in 2020. Adolescent motherhood (10–19 years old) is also high and represents 29 % and 24 % of births in the three municipalities in 2003 and 2020 respectively. Pregnancy and domestic workload are among the main reasons for girls dropping out of school. In fact, despite a higher male dropout rate nationwide, girls between 15 and 19 years old represent 50.9 % of out-of-school youth [33]. However, access to education for girls and young people has improved considerably in recent years in rural areas of Bahia: while literacy, primary and secondary classes had a higher proportion of men in 2003 [34], in 2020 girls predominated in classrooms at all levels [35].

Despite reaching higher educational levels, there is still a pronounced gender gap in access to job opportunities. North-eastern women (ages 25–49) without children are 18.7 % less likely to work than men, while for women with young children (< 3 years) the gap is 36.5 % [36]. In addition, employed women (> 14 years) receive on average 86.5 % of the male salary [37] and are paid only 78.3 % of men's wages in agriculture, forestry, hunting and fishing [38]. The lack of recognition of work activities and equal pay conditions reduces women's access to rural pensions. Although pensions have received gender attention in Brazil, through a rural women workers' documentation program and various age and contribution criteria that favour women [39], there are still gender gaps in rural retirement pension approvals [40]. In addition, social security reforms [41] have critically affected the progress made for women.

Women and men also occupy different decision-making roles both at household and societal level. In the rural areas of the Brazilian north-east, the percentage of households headed by women increased from 19.3 % in 2003 to 30.2 % in 2015 [42]. The household head is defined in Brazil as the person responsible for the home and for the family, and considered as such by the other members of the family nucleus [42]. Thus, it is common for decisions about household expenses to be made by this person. However, it is important to note that most female-headed families (such as female single-parent families) are often still driven by obligation rather than empowerment [42]. Leadership roles within society, on the other hand, are usually measured considering women's participation in decision-making positions or business leadership. In this sense, females occupy only 37.4 % of the managerial jobs [43].

3. Methodology

This section presents the methodology considered for assessing the gender impacts of the LpT program in Bahia. To do this, first the evaluation model and the indicators used are developed (Section 3.1). Next, the complete data gathering, transcription and analysis process and the methodological considerations for mainstreaming gender are presented (Section 3.2).

3.1. Assessment model and indicators

As gender analysis is context dependent [44], this study considers the interrelationship between the gender equality context and that of access to energy within the LpT program framework. On the one hand, existing gender inequalities may limit the benefit of energy interventions for women. In this sense, RQ1 seeks to identify solutions to guarantee energy benefits for both genders. RQ2, for its part, studies the extent to which energy access initiatives increase or reduce the gender gap and how to promote initiatives that, in addition to electrification, seek to correct gender inequalities. Fig. 2 outlines the structure of the investigation.

The interrelations between the contexts of gender equality and energy access (presented in detail in Section 3), are analysed at residential, community and productive levels through 8 ad-hoc indicators. The gender equality indicators evaluate the local gender reality and the changes produced by the LpT program (I1, I2, I4, I6.2 and I7). The energy access indicators measure the differentiated impact and limitations of rural electrification on women and men (I1-I3, I5, I6.1 and I8). Note that some indicators pertain to both groups. These indicators have been carefully selected through an extensive literature review, considering that they were systemic, consistent, independent, measurable and comparable, and validated by expert academics in the area as well as local and regional professionals (described in Section 3.2). The details of each indicator are presented below:

- **Health and safety (I1):** assesses the impacts of energy access in antenatal health care and improvements on emergency resolution. These energy needs are of high gender importance, since aggressions and pregnancy complications remain among the leading causes of women's death in the global south.
- **Education (I2):** evaluates the proportion of women and men in evening classes. Energy allows new educational opportunities through the incorporation of new methods and more teaching shifts.
- **ICTs (I3):** presents the energy access improvements on ICTs, such as mobile phone and internet usage. ICTs may present gender gaps due to differences in women's and men's digital literacy and ICTs ownership.
- **Time poverty (I4):** evaluates which of the two spouses assumes each of the household responsibilities. Since electricity reduces the time spent on housework, mechanising some processes, this indicator allows a differentiated understanding of how access to energy impacts the time burden of women and men.
- **Clean lighting and cooking (I5):** measure the share of lighting and cooking methods used by households. Although access to electricity promotes the use of cleaner sources [45], women and men may benefit differently depending on the distribution of housework.
- **Energy poverty (I6)**: measures the repressed energy needs and the access to social assistance mechanisms. This allows for a gendered analysis of energy poverty, by identifying constraints on priority energy uses and energy affordability.

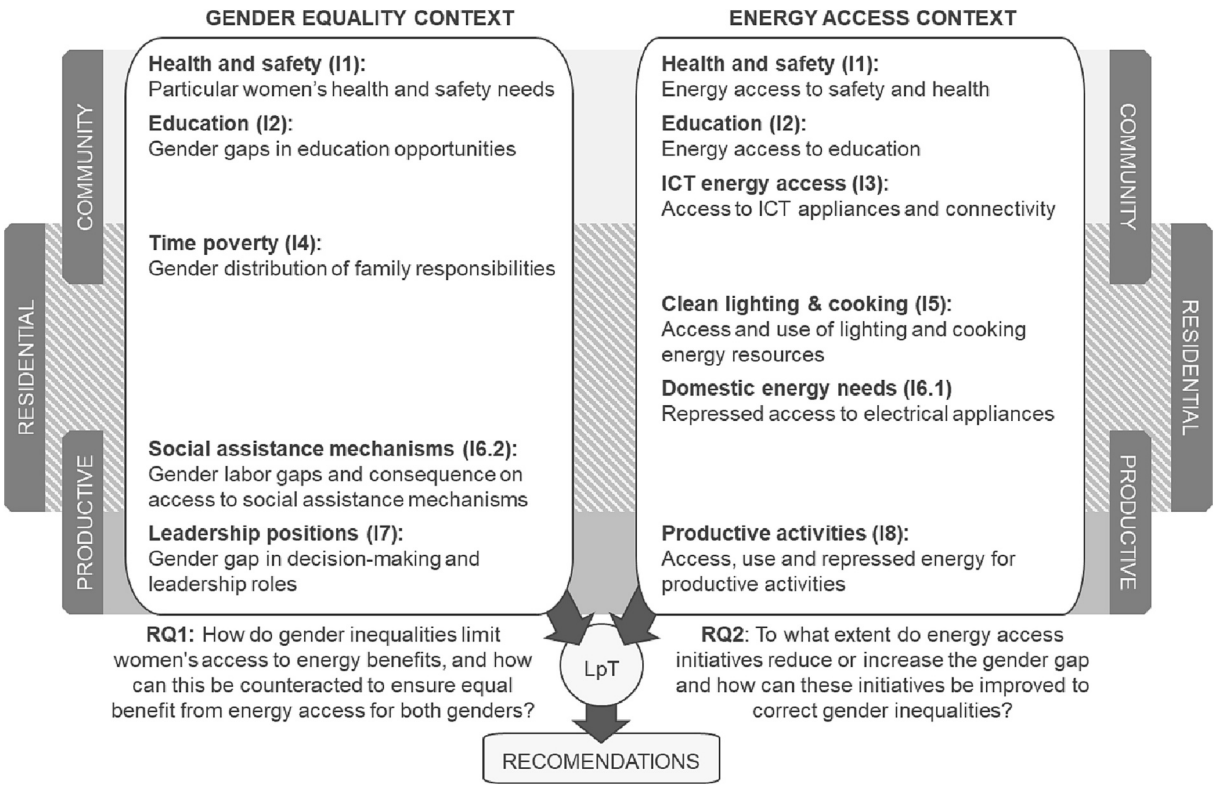


Fig. 2. Assessment of the interrelations between the gender equality context and the energy access context at residential, community and productive levels.

- **Leadership (I7):** measures the proportion of women and men interviewed with leadership roles as community leaders or in associations' committees. Electrification of associative space favours the socio-economic development of the community and may have differentiated gender implications.
- **Productive activities (I8):** assesses the improvements and limitations of access to energy for productive purposes. Despite productive development being one of the main objectives of rural electrification initiatives, women and men may perceive differentiated results due to gender labour gaps.

3.2. Data gathering, transcription and analysis procedures

The field-assessment has been carried out in the municipalities Casa Nova, Remanso and Pilão Arcado from July to September 2021. The 19 communities visited encompass 24 % of the LpT systems of Bahia [18]. Quantitative and qualitative data has been collected and assessed. While the former allows energy access to be objectively measured, the latter has proven to be very useful in analysing smaller data samples and avoiding gender biases. In fact, there is growing interest in the literature in incorporating qualitative evidence to better include relevant contextual conditions in gender analysis [46]. Mixed empirical analyses are widely applied by scholar [47,48] and international organizations [49] in contexts of energy access and gender equity. Since the communities visited are the most accessible of the three municipalities, there may be different progressions towards gender equality compared to the more remote ones.

A total of 44 structured interviews were conducted with beneficiaries. A proportional representation of women (57 %) and men (43 %) was considered, allowing the collection of sex-disaggregated data. Because all the people interviewed are cisgender, this research does not address transgender or non-binary identities. To ensure ethical considerations regarding interviewees' freedom of expression, gender discussions have been developed in non-mixed groups. The main discussions dealt with the perceived use, improvement and limitations of energy in the residential, community and productive spheres. The variation in the distribution of household responsibilities as a result of electrification and the access to affordability mechanisms were also addressed. In addition, 19 structured interviews with community leaders were conducted, in order to collect general data on the installed systems (number, year, technical characteristics, type of application and current status), the population (socioeconomic profile, number of families) and the existing community infrastructure (nearby schools and hospitals, access to drinking water and sanitation).

Semi-structured interviews have been conducted with promoters of rural electrification and local institutions, to obtain a more comprehensive analysis. A face-to-face meeting was held with the manager of the LpT electrification plan from the state distribution company Coelba and with the manager of the current maintenance company, Redimax. To facilitate the field work, consultations were also carried out with government organizations, such as the reference centre for social assistance (CRAS – in Portuguese: *Centro de Referencia de Asistencia Social*) of Casa Nova and Remanso, the Secretary of Agriculture of the municipality of Remanso, and the Secretary of Education of Pilão Arcado. Non-governmental organizations, such as SASOP (Advisory Service to Rural Popular Organizations - in Portuguese: *Serviço de Assessoria a Organizações Populares Rurais*) and SAJUC (Social and Environmental Assistance Service in Countryside and City - in Portuguese: *Serviço de Assistência Socioambiental no Campo e Cidade*) have also supported field activities.

Data from the face-to-face interviews has been recorded by the corresponding author through questionnaires and additional field notes. This has ensured the precise level of detail required to interpret data [50]. Pictures and GPS coordinates have also been gathered in order to support further analysis. Qualitative data has been documented, exploited and interpreted according to Akinyode and Khan [51]. First, all the information gathered from both individual and community interviews has been transcribed and logged into a spreadsheet. Qualitative responses have been stored in Portuguese in order to maintain a greater level of detail. Secondly, each answer has been analysed individually

and restructured into legible and understandable anecdotes. In some cases, additional in-depth information has been included near the anecdotes (i.e., narrative of the interviews, field observations, etc). Thirdly, the data has undergone a coding process. To do so, data has been managed and sorted into relevant and manageable pieces of statements, transformed into an extensive list of codes. This list has been analysed from a gender perspective, separating and disaggregating data from both genders to identify similarities and differences among them. Through the constant comparative method, the most relevant codes have been identified and the list shortened. The interpretation of these codes has led to the identification of themes. First, explicit themes corresponding to simpler findings were identified; then more implicit themes were outlined, allowing more complex conceptual insights to be extracted. The codes and themes have been critically reviewed through an iterative process, to ensure that the most salient ideas were captured.

4. Results

This section presents the results of the field study. The evaluation of the previously presented sub-indicators is summarized in Table 1. A detailed description is presented in the Appendix, including field observations and quotes from the people interviewed. After that, the impact of energy access on rural Bahian women is presented at residential (4.1), community (4.2), and productive (4.3) level. As a complement, Fig. 3 presents several images featuring Bahian women. Some daily activities are shown in the top picture, such as the pumping of water for residential and productive backyard usage (BA5) or a rural woman taking care of the home and family, near an exterior light powered by the SHS (BA8). The lower set shows women assuming key functions in the communities, such as the president of the community association showing the cassava flour and fruit production centre (BA16) or the technician of the local SASOP organization presenting the school (BA18).

4.1. Residential analysis

According to the interviews, women are 100 % responsible for the household chores (cleaning the house, cooking and washing clothes) and family care (I4.1). In 12 % of the cases they receive support from their partners. This overload of activities is responsible for women's time poverty and can represent, in some *Fundo de Pasto* communities, between 5 and 6 h per day more than those invested by their partners (see Section 3.2). Residential SHS allow the use of light (I5.1). However, the reduced power of the inverters (300 W) makes it unfeasible to use washing machines or electric irons (> 1000 W) [61], which is one of the women's main repressed energy demands (I6.1). This need is appreciated by men (8 %), who also request appliances to reduce the domestic workload of their wives.

Although 100 % of households use low-consumption lamps and 39 % rechargeable lanterns, the reduced energy availability of the SHS means

Table 1
Results of the indicators and sub-indicators, assessment type and data source.

Indicator		Sub-indicator		Type	Assessment	Women	Men	Source
I1.	Health & Safety	I1.1.	Average distance travelled during pregnancy for antenatal health care	Community	km (hospital/ on-grid health centre /PV-powered health centre)	453/ 413/ 300	–	Interviews and Google Earth
		I1.2.	Users' perception of emergency improvements	Community	% (health/ dangerous animals/security)	56 %/ 33 %/ 11 %	33 %/ 67 %/ 0 %	Interviews
I2.	Education	I.2.1.	User's participation in EJA	Community	% (20–29 years old/average)	59 %/ 45 %	41 %/ 55 %	Local stats [35]
I3.	ICT	I3.1.	ICTs access	Community	% (mobile phone owners/ internet users)	55.5 %/44.8 %	47.2 %/ 38.2 %	Regional stats [52,53]
		I3.2.	Users' mentions of ICTs improvements types	Community	% (phone access/ TV access/ internet access)	100 %/ 83 %/ 35 %	100 %/ 83 %/ 28 %	Interviews
I4.	Time poverty	I4.1.	Person in charge of household responsibilities	Community & Residential	% (household care/ family care/ water gathering/ wood gathering/ agriculture tasks/ bill payments)	100 %/100 %/ 100 %/53 %/ 50 %/ 70 %	12 %/ 16 %/ 0 %/ 82 %/ 50 %/ 80 %	Interviews
I5.	Clean lighting & cooking	I5.1.	Current lighting mechanism	Residential	% (efficient lamps/lanterns/ oil or kerosene lamp/candles/ bonfire)	100 %/ 39 %/ 32 %/ 29 %/ 26 %		Interviews
		I5.2.	Current cooking mechanism	Residential	% (firewood and charcoal/ LPG)	97 %/ 84 %		Interviews
I6.	Energy poverty	I6.1.	Users' mentions of domestic repressed energy demand	Residential	% (food refrigeration/washing machine/electric iron/ bigger TV/construction tools)	80 %/ 45 %/ 15 %/ 0 %/ 0 %	67 %/ 8 %/ 8 %/ 25 %/ 33 %	Interviews
		I6.2.	Social assistance mechanisms' main recipient	Residential & Productive	Social assistance mechanism name (% eligible person in receipt)*	RET (67 %), BF, TSE, SAFRA	RET (100 %), SAFRA, DEFESO	Interviews and national data [54–60]
I7.	Leadership	I7.1.	Participation in community leadership positions	Productive	% (community leaders/ associations' committees)	12 %/ 16 %	37 %/ 11 %	Interviews
I8.	Productive activities	I8.1.	Users' mentions of current productive activities' improvements	Productive	% (extending working hours/ ICT/ construction tools)	67 %/ 11 %/ 0 %	22 %/ 44 %/ 22 %	Interviews
		I8.2.	Users' mentions of repressed energy needs for economic activities	Productive	% (food refrigeration/blender & water pump)	22 %/ 11 %	11 %/ 56 %	Interviews

* RET = retirement pension; BF=Bolsa Familia, TSE = Social Energy Tarif, SAFRA guarantee, DEFESO insurance).

Fig. 3. Portrait of rural Bahian women. Two residential systems (13 kWh/month), powering the rainwater tank pump (BA5) and an external light point (BA8), and two community systems (30 kWh/month) installed in a production centre (BA16) and a school (BA18) are presented.

these lighting sources must be complemented. In this regard, 32 % of the households maintain the use of kerosene lamps and/or diesel, 29 % that of candles and 26 % bonfires (I5.1). Given that women spend more hours at home, performing domestic tasks, they are most exposed to the residual use of these polluting lighting mechanisms. Likewise, the LpT program has allowed low-income families to increase their purchasing power [62] and switch to cheaper, cleaner and more efficient fuels (according to the energy ladder model [45]. 84 % of the households use LPG for cooking (I5.2), but the high LPG prices force 97 % of families to continue using firewood or charcoal as their main energy source for cooking. LPG is commonly used by women to run the oven or to save time in the morning coffee preparation. Only one single-parent women-headed household uses it as her primary energy source.

Water and firewood collection, traditionally assigned to women, has undergone some transformations in recent decades (I4.1). All the visited communities have benefited from a rainwater cistern program, launched in parallel with the LpT program. This advance was considered a turning point in the quality of life of the women interviewed, allowing a significant reduction in the effort and time invested in collecting water. Some women (Fig. 3 - BA5) have managed to fully mechanize this task, using a small pumping system (1/4 CV - 180 W) [63] connected to the SHS. Firewood collection has also been reduced through access to clean lighting and cooking sources, but is still necessary given the high price of LPG. However, a change in gender roles is observed and it is being assumed more by men, who go weekly or monthly in groups using some type of animal transport (cart or donkey). When no means of transportation is mentioned, harvesting continues to be done by women. Despite the male predominance, paying the SHS bill is increasingly a shared activity, performed by the person who goes to the city. Since women receive the BF social assistance program (I6.2) in the city, they also assume this responsibility. Both partners participate in agricultural labour, carrying out different tasks. In family farming households, men work the fields and women the productive backyards. Women heads of households or those with spouses engaged in other paid work usually take charge of all agricultural activities (Section 2.2). In both cases, women play a key role in ensuring family food security, but their efforts are not recognized economically [17]. When the family finances allow it, diesel or gasoline generators are used to pump water or grind food to facilitate agricultural tasks (Section 2.1).

4.2. Community analysis

Most of the communities visited lack adequate basic community infrastructure, and particularly nearby health services. People must travel to the neighbouring grid-connected communities or to the city's municipal hospital for care. This increases the time poverty of women, who are primarily responsible for caring for children, the elderly, the sick or disabled (I4.1). In addition, the distance to health centres and the bad transportation conditions -on roads mainly of sand or beaten earth and often in collective vans- makes attendance to the six recommended pre-natal consultations [31] difficult. These are a requirement to access the corresponding economic benefit of BF [64]. It should be noted that half of these are carried out in the third semester of pregnancy, where the health of the foetus and the mother is more delicate. Consequently,

in the communities from Remanso, the women interviewed have shown a preference to travel 300 km for prenatal attention in a nearby PV-powered regular health centre than to go to the city hospital (I1.1).

Despite the limited infrastructure, the majority of the communities have schools (see Fig. 1). Due to the nucleation process of rural schools [22], only 2 thirds are active, either teaching primary classes or EJA courses in night classes [21] (Section 2.1). During the visits, and due to COVID-19, these schools were operating remotely (physical or online homework distribution). According to local statistical data [35] the EJA classes held in solar-powered rural schools in Bahia have a higher participation of women in the age group of 20 to 29 years (I2.1), surpassing that of men.

Furthermore, since the arrival of the LpT program, half of the communities visited have obtained telephone coverage and access to the Internet. This is due to an increase in 4G coverage and the installation of private rural internet antennae (rural Wi-Fi). Users agree that access to telephone and television are the main improvements in ICT (I3.2) and 7 % more women than men also identified improvements in internet access. These data present a similar pattern to the statistical analysis of the Brazilian rural Northeast [52,53], where women are 8.3 % more likely than men to have a personal mobile phone and 6.6 % more likely to have used internet in the last 3 months (I3.1). Some authors [65] attribute the success of female adoption of ICTs to the digitization of institutional services, such as the BF benefit. In addition, telephone and light have improved health emergency resolution and protection from dangerous wild animals (I1.2). Furthermore, the majority of interviewed households use outdoor lighting, which is a security concern only mentioned by women.

4.3. Productive analysis

The majority of beneficiaries interviewed consider themselves rural workers. However, rural women's activities are often invisible and less recognized economically [66]. The financial exclusion of women limits family purchasing power and women's role in decision-making about household expenses, including those related to electricity consumption [11]. This lack of labour recognition makes it difficult for some of the older women interviewed to access retirement pensions (I6.2). To reduce this gender gap, the women-centred social assistance program BF was implemented in Brazil (see Section 2.1), received by 68 % of the interviewed families. The gas subsidy (for LPG purchase) and the TSE discount (for SHS affordability), are also included in the BF program and, consequently, are discounted or transferred to women. Although the lowest income families receive TSE, none mentioned the benefit of gas. Additionally, many families face economic difficulties when coping with periods of drought by using generators to pump water. The SAFRA guarantee aid has the function of reducing this risk and covering possible crop losses. Similarly, the DEFESO insurance aid subsidises some interviewed families during the fishing closed seasons. While the former received gender-sensitive attention through the creation of a specific line of aid aimed explicitly at the female public [58], the latter continues to predominantly favour males. The main barriers are the lack of recognition of women's fishing activities and the lack of proper documentation.

The productive inclusion of women is also hampered by the excessive burden of domestic work and care [2]. In fact, the main productive benefit observed by women refers to how light (I8.1) has helped extend their working day. Women would like to have more energy (I8.2) to use refrigerators to store and commercialize processed food products (22 %). Men prefer agricultural equipment, such as blenders and water pumps (56 %) to increase their productivity. A repetition of the labour profiles inherited from traditional gender roles is observed in both genders, as well as a more diversified business vision on the part of men.

All the communities visited operate around a community association or community leaders (I7.1), who advocate for the labour rights of men and women. The associative work is carried out in spaces electrified by the LpT program (in community associations, schools or the residences of the community leaders). Access to electricity enables evening meetings and running administrative equipment such as computers and printers. It is observed that 25 % fewer women interviewed are community leaders, while 5 % more women are present in community association committees. Local organizations (SASOP, SAJUC, Pro-Semiárido), for their part, work to raise awareness of women's role in family farming and promote their sustainable productive development. In fact, two of the three productive spaces electrified through LpT integrate women into the paid agri-food value chain (honey and a cassava flour and fruit production centres – BA16). Another, larger, women-led enterprise is processing local fruits using solar panels and gasoline generators (BA4). Local organizations also include women in more technical positions within the organizations and the communities (Fig. 3 – BA18).

5. Bridging energy access and gender gaps

This section analyses the results of the field study. The findings of this study are discussed and compared with current literature (Section 5.1). Then, the answer to the research questions and the main recommendations are presented (Section 5.2). It is worth mentioning that the actions of the LpT program presented and the results obtained are exclusive to the studied regions and that there are no elements to say that it happened in the same way in other regions of the country.

5.1. Discussion

According to Multi-TIER framework [67], low-capacity SHS (TIER2) guarantees clean lighting. However, this work empirically demonstrates that these capacities are not sufficient to ensure the complete elimination of polluting lighting mechanisms. This is particularly detrimental to women, who are primarily responsible for household chores. Neither is women's time poverty reduced, since these systems do not allow the operation of household appliances such as washing machines or electric irons. These findings help strengthen the scarce literature on the topic [2].

Although electrification of community services is known to benefit women and men differently [8], this work provides new evidence. In this sense, the presence of nearby electrified health centres is essential to guarantee the health of pregnant women and avoid obstetric violence resulting from displacements in poor conditions. Since women are the main caregivers, the lack of nearby health centres also impacts their time poverty. Likewise, the less education provided in educational centres, the more provided in homes, where women are mainly responsible for caring for children. Evidence of how EJA courses create new educational opportunities for women in grid-connected communities has been discussed [68]. But this data has never been analysed in PV-powered off-grid schools. Brazil is an exemplary case study of how the combined action of gender-centred subsidies and the digitization of institutional services has contributed to reducing the gender digital divide [69]. The field-collected evidence and regional statistics presented in this work show similar findings in last-mile communities with internet connectivity (4G or rural Wi-Fi).

It has been confirmed that the improvement in living standards obtained from rural electrification accompanies the change to a more efficient cooking mechanism (i.e., efficient cookstoves). However, this does not guarantee the exclusive use of clean resources by women, who are mainly responsible. In fact, the shared use of LPG and biomass is common throughout the Brazilian Northeast [25]. In line with some authors [10,11], the results highlight that the management of cooking energy-related expenses is biased by gender roles (i.e., men prefer to use firewood or coal to save money, while women prioritize LPG to save time). Brazilian data demonstrates that LPG consumption is tied to the existence of an affordability mechanism aimed at women (gas aid), and that better results are obtained when the subsidy is exclusively

attributed to its purchase [70]. The feminization of energy poverty is a concern in Brazil, particularly in rural areas [71]. The literature calls for more energy policies to address it by including gender-centred actions [72]. It also highlights the usefulness of comprehensive energy initiatives that include economic and institutional tools [13,14]. In this work, the TSE (included in the BF aimed at women) has performed a double action: reducing energy affordability gender gaps [1,11] and increasing women's agency in household spending decisions.

Various coordinated actions and rural development policies have favoured women's labour inclusion in the Brazilian northeast. For instance, rainwater cisterns or SAFRA insurance have increased women's productive autonomy by reducing their time poverty and facilitating their access to agricultural assets. These initiatives have also promoted the local capacity to build community organizations and improve territorial articulation [73]. The Bahian experience shows increasing women's participation in leadership roles in electrified community associations, favouring gender-sensitive actions. At the productive level, the main use of energy by women is the extension of the working day, which contributes to increasing their time poverty. In this context, local organizations (SASOP, SAJUC) have redirected the productive interests of women (related to food processing) towards increasing their business vision, to successfully develop productive, sustainable and locally appropriate activities. Financial mechanisms and women's community associations are also identified as drivers for women's empowerment in other countries of the global south [74].

5.2. Answers to the research questions and recommendations

The Bahian field study highlights the synergies and trade-offs between energy access and gender equality. Two recommendations are drawn (A1.1 & A1.2) addressing RQ1 and two others (A2.1 & A2.2) responding to RQ2. These interrelations and the proposed recommendations are summarized in Fig. 4.

Higher SHS capacities (A1.1) dimensioned for domestic appliances reduce women's energy poverty, which contributes to clean lighting and alleviates women's time poverty. The electrification of community services (A1.2) equipped for women's needs, also contributes to significant improvements in ICT access and usage, education, health and safety, and alleviates women's time poverty related to care responsibilities. Women-centred social assistance financial mechanisms (A2.1) increase women's and families' energy affordability and thus foster clean cooking adoption and energy poverty reduction. Finally, the provision of gender-sensitive local services (A2.2) plays a transformative role, raising women's participation in leadership roles, as well as their productive recognition. The reduction of time poverty, labour recognition and the productive tools provided by local organizations foster the inclusion of women in paid work.

5.2.1. RQ1. How do gender inequalities limit women's access to energy benefits, and how can this be counteracted to ensure equal benefit from energy access for both genders?

A1.1. Install higher SHS capacities, dimensioned for domestic appliances.

Low capacity SHS (13 kWh/month), does not allow for refrigerating food or using electrical appliances such as washing machines and electric irons. Since women are primarily responsible for domestic tasks, their time poverty is not alleviated. Consequently, women's productive use of energy is limited. Furthermore, the reduced energy availability imposes energy rationing and the need to schedule electrical appliance usage. For example, electric lighting is often used at night, when it benefits the whole family. As women spend more time at home, they are most exposed to the residual use of polluting methods (kerosene and oil lamps) in times of scarcity.

Recommendation: In order to prevent energy rationing from affecting women more, systems with greater capacity are required. To guarantee that clean energy access meets women's needs, these systems must be explicitly sized for the energy loads of the household chores.

A1.2. Prioritize the electrification of community services equipped to meet women's needs.

The lack of equipped schools and hospitals means greater dedication by women to the care of children, the elderly and the sick. The presence of these electrified community services, on the contrary, improves women's health and well-being, by reducing pregnancy complications or improving community safety. Night or remote school reinsertion classes have created new educational opportunities for women who dropped out of school due to pregnancy or domestic workload. Similarly, the combination of telephone coverage and internet connectivity improvements with institutional digitization strategies have favoured the reduction of the gender digital divide.

Recommendation: Energy access initiatives should prioritize the electrification of community infrastructure that benefits women by incorporating equipment tailored to their specific needs. Some examples include health centres with prenatal health assistance, schools with educational activities adapted to women's preferences (night classes, online courses), public lighting and rural internet antennas that allow ICT usage.

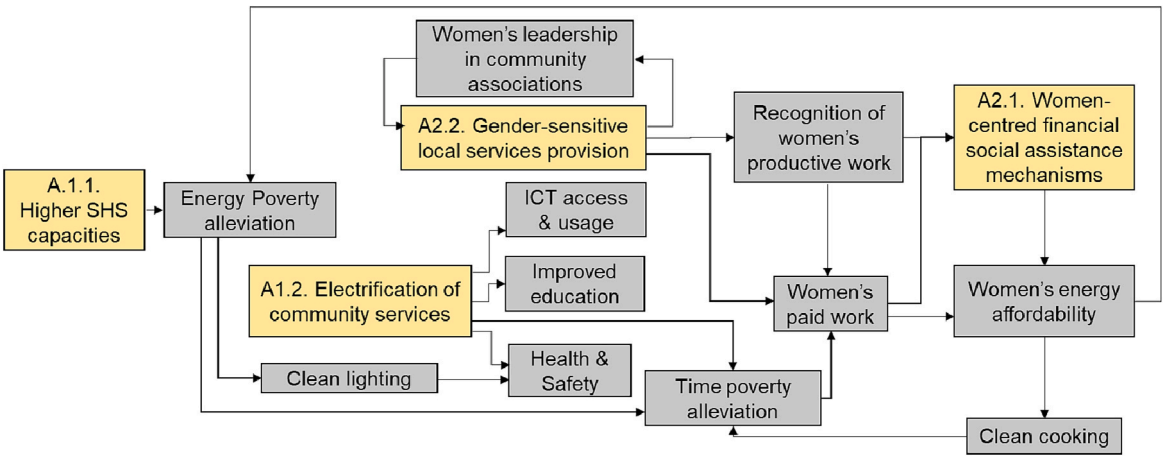


Fig. 4. Recommendations (yellow boxes) to foster gender equality and benefit women from access to energy (grey boxes). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

5.2.2. RQ2. To what extent do energy access initiatives reduce or increase the gender gap and how can these initiatives be improved to correct gender inequalities?

A2.1. Women-centred financial social assistance mechanisms.

In most cases, only men contribute to the family income since women are attributed non-paid and time-intensive activities. Family purchasing power is thus limited and hinders the affordability of larger systems. The purchase of household appliances that favour women (i.e., LPG, washing machines, electric irons) is often not prioritised in the household spending decisions. The economic remuneration of women plays, therefore, a decisive role both in family accessibility to larger systems and in changing the power dynamics within households. However, the gender labour gap also affects women's access to retirement pensions and agricultural benefits. In this sense, women-focused social assistance programs (BF, SAFRA) have become an effective way of increasing women's financial inclusion. The importance of the careful design of such initiatives should be emphasised. For example, LPG affordability mechanism failed to promote clean cooking, since it did not accompany the gas price rise and was easily usable for other purposes.

Recommendation: To ensure households' access to larger power systems, rural electrification initiatives must explicitly address affordability for women. To this end, it is recommended that public policies with specific women-targeted financial social assistance mechanisms (i.e., for productive activities support, adoption of clean cooking technologies) be actively promoted.

A2.2. Promote gender-responsible local services provision.

The presence of an electrified community associative space has motivated women to assume leadership roles. Community associations play a fundamental role promoting family farming, through advocacy, advisory services and access to productive assets. Greater female participation in decision-making positions fosters gender sensitivity in the inputs provided. However, the reduced productive experience of women limits their business vision and hinders their professional development. For instance, men manage to perform a broader range of productive opportunities with less energy capacity. In this sense, local organizations have promoted sustainable productive activities aligned with rural women's interests, such as food processing centres. Financing, training and monitoring through continuous technical advice led to effective strategies for the sustainable empowerment of women.

Recommendation: Comprehensive energy initiatives are suggested, combining the electrification of productive and associative spaces and their articulation with gender-responsible local organizations. These initiatives should promote women's financial and productive inclusion through tailored rural advice and business development support (capacity building & funding).

6. Conclusion

A significant proportion of rural women still lack access to clean and affordable energy. Although access to energy has the capacity to reduce poverty and inequalities, the few studies on the topic highlight the limitations of gender-neutral interventions. Since guaranteeing a similar benefit from these initiatives is already challenging, transforming gender roles requires even greater efforts. Some studies argue that current energy initiatives may hinder, rather than promote, progress towards gender equality. Therefore, more studies are needed to align efforts of future energy access and gender equality interventions in the Global South.

For this reason, the purpose of this article is to analyse the synergies and trade-off between gender equality and access to energy in a practical case study. The significant lessons learned and recommendations outlined aim to promote more sustainable and gender-responsive interventions. To this end, the interrelationships between energy access and gender equality is evaluated under the Luz Para Todos (LpT) last-mile rural electrification program. 19 communities are field-assessed, comprising a quarter of the Solar Home Systems (SHS) implemented through the program. Hence, the context of energy access and gender equality are presented in detail. Therefore, two sets of questions arise: (RQ1) "How do gender inequalities limit women's access to energy benefits, and how can this be counteracted to ensure equal benefit from energy access for both genders?" and (RQ2) "To what extent do energy access initiatives reduce or increase the gender gap and how can these initiatives be improved to correct gender inequalities?". To answer these questions, empirical mixed evidence has been collected through structured and semi-structured interviews with beneficiaries, community leaders and the most relevant stakeholders. Field work was performed during the second half of 2021, ensuring equal participation of women and men. Women and energy interplay have been assessed at residential, community and productive level considering 8 ad-hoc indicators.

The results present the residential implications of energy access, such as changes in lighting, cooking and distribution of domestic, care and agricultural responsibilities. Subsequently, the differentiated impact on women of electrified community services such as access to ICT, education, health and safety is analysed. Then, the economic emancipation of women is discussed, concerning existing energy affordability mechanisms and the impact of electrified and associative spaces. Finally, the main findings are discussed and validated through a literature analysis and 4 transformative recommendations are drawn.

To ensure **equal access to energy**, energy initiatives must address:

1) Energy sufficiency at the residential level, sized for the use of household appliances.
2) The electrification of community services used directly and indirectly by women and equipped to meet their needs.

To **reduce gender inequalities**, energy initiatives should promote:

3) Women-centred financial social assistance mechanisms at institutional level, that allow energy affordability for women.
4) The continued provision of gender-sensitive services offered by trusted local organizations.

This work provides the scientific community with a contextualized picture of a particular energy access and gender inequality reality. Since gender mainstreaming is context-dependent, more studies are therefore required to build a complete picture of the gender and energy access nexus. Despite the demonstrated utility of mixed methods and the importance of qualitative data in capturing gender biases, more quantitative research is also needed. For this, it is necessary to increase efforts in the collection of sex-disaggregated data allowing statistical analysis and ex-ante and ex-post comparisons. To facilitate their application, the recommendations presented are broad and are not limited to the context's singularities. On the other hand, this study has only addressed the cisgender concern, despite the fact that gender diversity is much greater and includes non-binary or transgender identities. Thus, future research is required to analyse the relationship between energy and gender in its plurality.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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Appendix A. Appendix

I1.1. Average distance travelled during pregnancy for antenatal health care

Healthcare infrastructure and services are very limited in the communities visited. Conditioned by the state of the roads, women prefer to receive prenatal health care at the nearest available health centre. In Remanso, women can only attend the city hospital, since there is no other space available nearby, and travel an average of 453 km during their pregnancy (*"não tem posto"; "Se é um problema maior, tem que ir até Remanso)*. In Pilão Arcado, women's preference is tied to an on-grid health centre with activities 1 day a week (413 km), despite the low service quality (*"muito ruim (…) Não tem medico, uma vez por semana, mas nem sempre"*.) In the municipality of Casa Nova, women prefer to visit a regular PV-powered health centre (300 km) than to go to the nearest city hospital. One of their main endpoints is the presence of good pre-natal health care (*"Em Desterro. Tem um postinho de saúde nota 1000. Faz pré-natal para mulheres gravidas. Consulta, vacina, dentista… La tem placa solar"*.)

I1.2. Users' perception of emergency improvements

56 % of women and 33 % of men perceived an improvement in medical emergency resolution as a result of telephone access ("*Se alguém adoece e tem que ligar de emergência, ajuda* "). 33 % of women and 67 % of the men identified the usefulness of light to avoid dangerous animals ("*Já teve uma cobra no banheiro"; "(a luz) também ajuda para evitar bichos: jararaca, alacraia*"). Concern for safety has also been mentioned by 11 % of the women (*"agora pode sair para fora de noite"*). Additionally, field observations and photographs show that 3/4 of the households use an external light point for outdoor illumination at night.

I.2.1. User's participation in EJA

The women interviewed consider that access to energy at school is not enough to promote a quality education for their children ("*Não tem estrutura, data show, TV, nada, som para o aluno, impressora. Já falta estrutura na escola das cidades…"*). However, the women do perceive some educational improvements related to school meals (*"ajudava um pouco para um suco na merenda"*), home education ("*As crianças podem estudar mais pelas noites, carregam notebook, pesquisam no celular* ") and to the EJA evening courses offered ("*O curso noturno para adultos também ajuda*"). Some of the people interviewed attended EJA courses in person before the pandemic or remotely (physically or online) during COVID-19 ("*Estou estudando o 3° ano no EJA online*"). According to local statistics, on average, the EJA course in off-grid schools has 45 % female and 55 % male participation. However, women represent the majority for ages between 20 and 29 years (59 %).

I3.1. ICTs access

According to regional statistics [52,53], rural women from the Northeast are 8.3 % more likely than men to own a mobile phone and 6.6 % more likely to have used internet in the last 3 months.

I3.2. Users' mentions of ICTs improvement types

100 % of women and men agree that the main ICT improvement has been favoured by access to telephone and 83 % perceived it using TV ("*O celular ajuda pra tudo. Com a TV assiste jornal, tem uma distração*"). In the communities with 4G coverage or rural internet antennae, internet access has been mentioned by a higher proportion of women (35 %) than men (28 %) (*"a placa ajuda pra clarear e pra TV. Assiste o jornal, carrega telefone, liga aparelhinho da internet*").

I4.1. Person in charge of household responsibilities

100 % of the women interviewed mentioned being in charge of household and family care ("*A mulher cuida da casa e dos filhos", "lavar roupa é a filha e a senhora"*) and water gathering ("*Quem tem que pegar água, se tem mulher, é a mulher que faz*"). Some women liken this burden of time-consuming activities to slavery (*"a mulher trabalha muito, é escravizada*"). The rainwater cistern program, received by 100 % of the visited households, has reduced the time invested by women in gathering water and is perceived as a turning point ("*mudou a vida de todo o mundo. Uma tecnologia social muito importante*"). Several households use a small water pump to distribute the water from the tanks to the households. 12 % and 16 % of the men support their partners in household and family care respectively ("*tem os dois, as famílias mais tradicionais, onde a mulher faz tudo, e mais modernas, onde (…) o homen ajuda dentro da casa*"). 53 % of the women interviewed mentioned that they were in charge of collecting firewood on foot (*"ela faz, caminhando 200m"; "Um dia inteiro por mês é ela que vai pegar lenha (caminhando)")*. However, it seems that this activity is increasingly managed by men (82 %), who usually go in a group using some type of transport ("*Agora é mais homen que vai"; "os homens vão junto pegar lenha para fazer carvão. Pegam os jegues*"). 50 % of women and men assume agricultural tasks. In family farming households both play different roles. Women tend to assume low-intensive and time-consuming activities ("*na roça todo o mundo trabalha. Homen abre covão e mulher semeia sementes e cobre a cova")* or care for the productive backyards (*"tem que botar água no canteiro"*). In female-headed households or families where the husband works in other paid activities, women assume agricultural tasks alongside household responsibilities ("*tem que cuidar da roça"*). The payment of the electricity bill is an activity carried out by 70 % of women and 80 % of men. In some cases, men are responsible for the household finances, including paying electricity bills ("*para pagar a conta de luz, sou eu. Ela não sabe a tarifa*"). In other families, regardless of gender, the person who goes to the city pays the bills ("*Os dois. Quem vai para cidade faz*"). However, since women receive the BF social assistance mechanism, they sometimes do both processes together ("*ela vai mais. Vai tirar o Bolsa Família, é uma coisa só*").

I5.1. Current lighting mechanism

100 % of the families use efficient lamps energized with the SHS and 39 % complement them with battery-powered or rechargeable lanterns *("usamos a lanterna de pila, e lanterna de carregar (com a energia das placas)"*). Access to electricity enabled polluting lighting to be reduced ("*antes era uma lata de querosene por mês. Reduziu bastante*") but not completely eliminated. In fact, 32 % of the families use oil or kerosene lamps, 29 % use candles and 26 % use bonfires. (*"tem que usar candieiro, velas, e fogueiras quando a luz (da placa) é fraca"; "antes tinha só o candieiro (5L/mês). Agora usam a placa e o candieiro (2L/mês), porque não tem suficiente!"; "agora usamos as placas. Se dá problemas e ninguém vem, então usamos velas"*).

I5.2. Current cooking mechanism

97 % of the people interviewed use efficient cookstoves based on firewood or charcoal as their primary cooking mechanism. 84 % have LPG at home but tend to economize on it due to its high cost ("*O gás está caro agora"; "(a gente) usa lenha. Ninguém pode comprar gás*"). In general LPG is only used to run the oven or to save time in the morning coffee preparation (*"Só usam para café da manhã. Agora está muito caro"*). Only

one single-parent women-headed household uses it as her primary energy source.

I6.1. Users' mentions of domestic repressed energy demand

Food refrigeration is the main repressed energy need mentioned, with greater concern on the part of women (80 %) than men (67 %) ("*freezer, geladeira"; "liquidificador e geladeira. pra guardar a carne, pra fazer um suco gelado")*. While some families mentioned using food blenders, for others it's a repressed energy demand. Women also mentioned washing machines (45 %) and electric irons (15 %) ("*ferro elétrico, tanque pra lavar roupa"; "tanquinho*"). 8 % of the men interviewed also request these appliances. It should be noted that all of them either live alone or ask for them for their wives or daughters (*"máquina de lavar pra esposa"*). Men are more likely to ask for construction tools (33 %) and greater TV (25 %). ("*makita, furadeira", "geladeira é mais importante. E uma TV maior*").

I6.2. Social assistance mechanisms' main recipient

95 % of men and 100 % of women consider themselves rural workers. 100 % of the older men interviewed received a retirement pension, but only 67 % of the older women ("*lavradora, trabalhou na prefeitura (...) foi merendeira na escola e agora não consegue cobrar aposentadoria rural*"). 68 % of families receive the BF program. The TSE, included in the BF, was mentioned by 13 % of the families, while the LPG subsidy (gas aid) was not mentioned. The SAFRA guarantee is received by 25 % of families to strengthen resilience and recover from losses during extreme weather conditions. DEFESO insurance is received by 7 % of families, dedicated to fishing activities.

I7.1. Participation in community leadership positions

12 % of the women and 37 % of the men interviewed were community leaders (i.e., people designated by the community as natural leaders). The participation of women in association committees was higher (16 %) than that of men (11 %). The associations centralize agricultural tools ("*pega o trator da associação"; "o gerador da associação*") and promote the rights of rural workers (including access to pensions and access to energy *"a associação (...) fez um levantamento para pedir a energia elétrica")*. Women's presence on associations' committees is favouring a more gender-sensitive provision of services and the access of rural workers to agricultural assets *("Na associação recebem muitos projetos do semiárido. Tem Notebook, impressora (xerox), caixa de som, Wi-Fi, forrageira, gerador. Os associados podem usar.")*

I8.1. Users' mentions of current productive activities' improvements

Men have a more technical profile while women assume organizational tasks or functions related to social care (cleaning or food sector). Some individuals perceived productive improvements related to energy access. Among them, 67 % of women and 22 % of men mentioned the extension of their working hours ("*Para buriti ajuda, ajuda pra ilumiar de manhã as 4am ou de noite"; "na extração de mel usamos luz a noite*") and a better quality of working conditions with clean light. But they consider the energy availability limited regarding other productive activities ("*pra ajudar a iluminar, sim, mas pra trabalhar não da"; "luz só para casa. Não ajudou fora.*"). ICT were also cited by 44 % of the men and 11 % of the women, either at household level ("*computador, xerox, ligar a impressora"; "Baixava CD e botava no pendrive para os outros*") or in community associations ("*Na associação (...) tem notebook, impressora (xerox), caixa de som, Wi-Fi*"). Construction tools have also been mentioned by 22 % of the men ("*pra marcenaria e reformas*").

I8.2. Users' mentions of repressed energy needs for economic activities

A part of the population explicitly expressed their repressed energy needs. For 22 % of the women and 11 % of the men, the main repressed productive energy is food refrigeration ("*geladeira para vender coisas geladas"; "freezer pra vender buchada. Agora tem que comprar gelo e pegar em remanso*"). 56 % of men and 11 % of women use agricultural tools (such as blender, macerator, chopper, drilling machine) and water pumps through their own or the association's generators ("*Para o trabalho usam bomba para puxar água, furadeira, makita (com o gerador). Na associação tem maquinaria, máquina para moer ração*").

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