



Linking energy access, gender and poverty: A review of the literature on productive uses of energy

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ABSTRACT

This article reviews the empirical literature about gender and productive uses of energy, focusing on electricity, to answer three research questions: do men and women obtain different benefits from the Productive Use of Electricity (PUE)?; which gendered constraints affect women's chances to benefit from the PUE; and which interventions work to achieve gender equity in the PUE? We find that PUE literature has so far considered gender mainly at the household level, by looking at the labour supply effects of access to electricity. However, the role of enterprises as labour absorbers and income generators, has been devoid of gender considerations. This omission is significant because women tend to operate in smaller and less energy intensive enterprises, and hence can draw less benefits from PUE interventions. The wider literature on gender and labour markets offers valuable insights about the constraints that explain performance differentials between male and female led enterprises. However, this literature is dominated by experimental and quasi-experimental approaches unable to capture the complexity in which gendered PUE interventions would operate. We draw from the insights provided by these different strands of literature, but further recommend a mixed methods approach to advance the research agenda about gender and PUE.

1. Introduction

Access to electricity is increasingly recognised as a key enabler of economic growth and poverty reduction in developing countries. Electricity can drive economic and social development by increasing productivity, enabling new types of job-creating enterprises and reducing household workloads, hence freeing up time for paid work.

The productive use of electricity¹ (PUE) is important for income generation and poverty reduction among consumers. It is also essential for the financial viability of electricity suppliers whether on or off-grid [1]. When electricity is only used for lighting during a few hours in the evening, as often happens in poor rural communities, expensive power generation and distribution infrastructure remain idle for most of the day. This leaves electricity providers with two undesirable alternatives: either recover upfront investments by charging expensive tariffs for the few kWh consumed; or charge affordable tariffs but face bankruptcy. When electricity is used productively during the length of the working day, upfront costs can be shared among more kWh and cheaper tariffs are possible. At the same time, the resulting income improves

consumers' ability to pay, starting a virtuous circle of affordability and financial sustainability.

Harnessing the income generation potential of electricity is not straightforward, though. So far, the literature on electricity access has not provided conclusive evidence of its income generation impact through the creation of enterprises or the improved performance of existing ones (as reviewed in [2,3]; or [4]). Most authors agree that electricity is a necessary but not sufficient condition for income generation and poverty reduction. The most cited complementary factors are: access to finance for electric appliances [5]; access to markets for the additional production [6]; skills for entrepreneurs to identify the new opportunities created by electricity and to prepare sound investment plans [7]; access to other infrastructure or services [8]; and a high quality of the electricity supplied [9,10].

Gender considerations have broadly escaped the debate on how electricity impacts enterprises. The energy and gender literature has instead focused mainly on the household realm, where women suffer heavily the burdens of energy poverty. Household centred literature has provided a strong evidence on the link between energy poverty in the

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¹ Productive uses of electricity are defined as those that result in goods and services with a monetary value, hence enabling income generation.

household and women's health burdens, use of time, education, access to information, and other factors (see for example reviews by Refs. [11] and [12]). However, women can not only obtain benefits from electrification in their care or reproductive roles, but also on their productive role. Women entrepreneurs and employees face different challenges than men to use and derive benefits from electricity. This is mainly because women and men operate in different types of productive activities; at different locations; and have different access to the previously identified key enablers- assets, finance, markets, infrastructure and skills. Furthermore, women's agency, mobility and time-use tend to be restricted due to the interactions between the market and the household economy, resulting in reduced choice of the type, location and nature of paid work that they can undertake [13–17]. By following a gender blind approach to the PUE, policymakers could be depriving half of the potential workforce from its benefits, and electricity suppliers could be missing half of their productive consumers.

The paper reviews the literature about the gendered use of electricity for income generation. The focus is on electricity, instead of energy in general, because most of the literature on productive uses of energy refers to this energy carrier. We group existing evidence around three research questions: 1. what is the evidence that women and men benefit differently from the PUE?; 2. which gendered constraints affect women's chances to benefit from the PUE?; and 3. which interventions work to achieve gender equity in the PUE?

To address this diverse set of issues we engage with a multitude of scholarly disciplines: from neoclassical household economics to feminist economics, as well as anthropology, entrepreneurship or the political and social economy of care. The review also includes normative literature by donors and NGOs about how to implement gender mainstreaming in energy and entrepreneurship interventions.

The combination of insights from different disciplines informs a framework of analysis that challenges the predominant neoclassical view of electricity as a gender neutral technological shock to households and enterprises. Instead, evidence provided by gender sensitive literature shows that power and inequality mean that electricity supply has a different impact on the income generation potential of men and women when they use it productively. We use concepts such as occupational segregation, agency, or the care economy from feminist economics, as well as social norms, from anthropology, to explain why this is so and propose ways forward in research and practice.

The following section presents the review methodology. Section 3 details the existing evidence to address each research question, describing as well the theoretical underpinning and methodological framework of the papers reviewed. The findings are discussed in Section 4, which also presents a framework for the gendered analysis of productive uses of electricity. Section 5 concludes and provides some recommendations.

2. Review methodology

A total of 79 empirical studies and 5 normative studies (handbooks about gender mainstreaming in energy interventions) are reviewed to answer the three research questions. We review mostly peer-reviewed literature, but also include grey literature. In order to identify relevant studies we depart from papers cited in previous literature reviews about the following related themes:

- The impacts of energy for poverty reduction ([2,3]; or [105])
- The impact of energy access on women's economic empowerment [11,18,12]
- The effectiveness of interventions to promote female entrepreneurship ([16,17,19,106]).

The literature included in previous reviews was complemented through additional searches on bibliographic databases to find more recent, or overlooked, publications, including papers citing the ones

identified.

Methodologically, the literature reviewed varies according to the research question posed. The literature to address the first question about gendered impacts of the PUE, is mainly quantitative. Because it is difficult to randomise the provision of electricity for productive uses, due to its high cost, this literature tries to determine causality between electricity and gendered outcomes through quasi-experimental approaches that address the endogeneity of the treatment². These include the use of instrumental variables, difference-in-differences estimations, fixed effects, and propensity score matching.

Second, the literature looking at the gendered constraints that determine women's (dis)enabling elements to benefit from the PUE, combines both quantitative and qualitative approaches. Quantitative studies measure the importance of different determinants of men and women's performance at work. Qualitative studies, using in-depth interviews, case studies or participatory approaches, aim at understanding the context in which women and men make their choices. They are particularly effective in identifying intangible factors, such as social norms, gender roles, ethnicity and religion, that influence these choices. Thus, while quantitative research shows the "what" and "how much"; qualitative research explains the "why" and "how".

Two types of literature address the third question, about what works to enhance the benefits women can obtain from the PUE. The first type looks at PUE interventions in particular, this is very limited in number and eminently qualitative and case study-based. The second refers to all types of interventions to improve women's performance at work, particularly as entrepreneurs. This strand of the literature is dominated by randomised control trials (RCT), where a treatment (such as a training course, a microcredit or a cash grant) is administered randomly to a treatment group, but not to a control group. The observed differences between the two groups, before and after the treatment are subject to quantitative analysis to understand if they were caused by the treatment.

Donors and academics have more or less explicitly identified a hierarchy of methods among all those used in the literature reviewed in this paper, according to their degree of rigour. Evaluation rigour is defined in many academic and donor circles as "lack of bias", and RCT are considered as the most appropriate methodology to eliminate this bias, followed respectively by quasi-experiments, mixed methods and qualitative methods [20]. At the same time, many development professionals consider RCTs and quasi-experiments as reductionist and problematic in conditions of complexity [21–24]. In these conditions, an alternative definition of rigour is required, in terms of methodological consistency and reliability of methods and the rigorous facilitation of participatory processes [25].

Section 4 of the paper discusses the advantages and disadvantages of each approach, and advocates the use of mixed-methods to capture the complex, changing, and diverse reality.

3. Findings

3.1. What is the evidence that women and men benefit differently from the productive use of energy?

The use of electricity has a gendered impact on labour supply and labour demand, leading to different income generation outcomes for men and women. On one hand, electricity use can change the time allocation for productive and non-productive activities for men and

² Meaning that electricity influences outcomes like income levels, but at the same time income levels would influence the likelihood of getting electricity. Consequently, it is difficult to determine causality, as the better-off households, women, or men would be the ones connecting to and using electricity, but their better outcomes as compared to those not connected, could not be attributed to their access to electricity.

women, affecting their supply of labour. On the other hand, electricity can alter the opportunities for income generation that the labour market offers to them.

The literature testing the previous hypotheses focuses predominantly on the labour supply element, using the household as its unit of analysis. Drawing on Becker's Neoclassical Household Economics and his theory of the allocation of time [26], electricity is understood as a technological shock to the household. Its use not only increases the time endowment of the household, through lighting at night, but it also increases the marginal return to time spent doing housework, income generating activities or leisure. The final outcome for the time allocation of women and men would depend on a rational decision at the household level based on opportunity costs and time preferences. For example, if the productivity of paid work increases, women may stop collecting firewood as it is very time consuming [27]. Or if the productivity of housework increases, women may decide to use the time released for leisure or to spend more time with their families, rather than joining the labour market [28].

Sixteen publications reviewed test this theory empirically, presenting gender differentiated results with regards to four outcomes: employment; time use in paid and unpaid work; earnings; and occupational score, understood as involvement in higher value added occupations. Methodologically, these publications mainly use quantitative methods and apply different techniques to estimate the impact of the electrification treatment while addressing endogeneity. These include using the random allocation of connection discount vouchers as an instrumental variable [29]; other instruments such as land gradient or population density [5,27,30–32]; propensity score matching [33–35]; differences in differences or panel regressions with fixed effects [35,36]; or controlling for variables likely to be correlated with the household decision to connect to electricity [34,37–39].

Results with regards to employment tend to agree that women's employment increases with electrification as compared to men's. For example, Dinkelmann [30] observes that women's employment in rural South Africa increases by a significant 9 to 9.5 percent within 5 years after electrification, while male employment raises insignificantly by 3.5 percent. Using a similar identification strategy, Grogan and Sadanand [27] find that women in rural Nicaragua are 23 percent more likely to work outside of the home when there is electricity in the household, while there is no impact on male employment propensities. Dasso and Fernandez [36] reach comparable conclusions, finding that women in rural Peru are more likely to be employed after electrification. Van de Walle et al. [32] also find a significant, but small increase in women's non-farm self-employment in rural India. Finally, Chowdhury [34], shows that the availability of public infrastructure has a significant impact on women's participation in paid work in rural Bangladesh. On the other hand, Costa et al. [38] find that the availability of electricity in a community does not influence women's participation in market activities, but it increases the working hours for those already engaged in paid work. A comparative study of India and South Africa backs these results, finding no significant employment effects of electrification in either country, even if earnings increase for those employed [35].

Time use literature agrees that the time women devote to market work increases after electrification [33,34,38]. However, a study by Salmon and Tanguy [31] finds that when controlling for the interdependence of male and female labour supply decisions within the household, electrification only has a positive impact on the husband's working time. Wives on the other hand tend to increase leisure and housework. Counterintuitively, unpaid work does not decrease for women with electrification. As a result time poverty increases, even if income poverty is reduced. The previous insights match those in the care economy literature, which notes that regardless of the share of household income they earn as paid workers, women do most of the unpaid care-giving, in all contexts [40–42]. However, electricity has been proven to reduce the time allocated to a specific care activity:

firewood collection 3 [5,27,30]. In this case, as the marginal return to market work increases with energy access, women would prefer buying rather than gathering cooking fuels and would use the time saved to increase time for paid work.

Intra-household dynamics and social norms influencing women's time allocation after obtaining electricity are studied in more detail in a publication by Standal & Winther [43], using ethnographic case studies. Their results show that electricity improves women's conditions to perform their expected role as care workers in rural India and Afghanistan. In some cases it also allows them to gain additional income through small scale, home-based activities. But the higher impact on women's empowerment takes place when women's traditional roles are challenged, such as when they were trained and recruited as solar energy engineers. Men in the communities where this happened declared that their perception of women's abilities and role in society had changed after experiencing their new role as engineers. However, many constraints remained for women's economic empowerment, in particular a lack of agency over the newly generated income, which would typically be transferred to the (male) head of household.

If electricity increases women's involvement in paid work, how does this affect to women's economic empowerment? What opportunities open up for women in the labour market with access to electricity? Do these activities generate higher earnings as compared to men? And do they involve higher value added and more satisfying work? The literature mainly addresses these questions from the realm of the household, looking at the earnings and the types of occupations held by women after the arrival of electricity. In this respect, evidence is consistent about women moving out of agriculture and into non-farm related activities, and this shift is more pronounced than for men [27,29,34,37]. The evidence is thin, however, on what these new activities involve. One study in Northern Salvador shows that the new activities that women undertake are typically home based and consistent with gender stereotyping, for example food preparation, clothes washing and ironing [29]. In a similar manner, evidence from India shows that women are more likely to be engaged in manual labour with low daily wages [39]. Research by Van de Walle et al. [32] supports that women have lower quality jobs than men after electrification. While men increase their regular wage work by 17 days per year and decrease casual work by 10 days, only casual work increases for women, by 6 days. In contrast, a study based in Ghana shows that women experience larger increases in their occupational score than men, and are more likely to become wage-earning workers [37].

Evidence on the gendered impact of electrification on earnings is also inconclusive. Some studies based in Peru and El Salvador show that earnings for women increase, while male earnings are unaffected [29,36]. A comparative study of labour impacts of electrification in India and South Africa finds robust increases in earnings for both men and women already involved in paid work [35]. In contrast, Dinkelmann [30] shows that female wages fall in South African districts where electrification is expanding rapidly and van de Walle et al. [32] do not observe any impact on wages for either women or men. The reason why wages decrease as employment increases for women could be that women's supply of labour is increasing (via the home production channel), but there is not an equivalent increase in demand for this labour, which concentrates in small scale home based services.

Literature on the impacts of electricity on labour demand at the level of the enterprise, provides limited insights about gender differences. A study about the impact of solar mini-grids on Kenya's rural enterprises shows that new electricity-using enterprises created after the arrival of mini-grids are typically male owned [1]. These include barbers, video halls or phone charging posts. But, in general, other PUE literature does not differentiate between outcomes for men and female entrepreneurs. It uses a neoclassical framing, where enterprises are rational entities searching profit maximisation and electricity is a technological shock that allows for longer working hours, thanks to improved lighting, and productivity increases, through the use of more

sophisticated machinery. The sign of the final impact on enterprise performance, labour demand and wages depends on several enabling factors such as: the substitutability of labour and capital; access to finance to purchase electrical equipment; access to markets to sell the new or improved products; and the skills of the entrepreneur. While some authors report a positive association between firms performance and the availability and reliability of electricity [8,44,45]; other authors are unable to prove such positive outcomes [1,7–9].

One particular publication digs deeper into the reasons why electricity does not have an impact on the profits of manufacturers in Benin [6]. Results show that firms created after electrification and reliant on electricity for their business have considerably higher profits than the other firms. However, connected firms that existed before electrification perform worse than pre-existing firms that did not connect, and worse than matched enterprises in a control region without electricity. This phenomenon is called “the electrification trap”. Firms decide to invest in electricity connection without having elaborated a business plan. As a result, they might overestimate the profitability of this investment. If the market these enterprises serve is limited, they will not be able to materialise the productivity gains achievable from electricity and will be unable to generate a return on their investment. Indeed, the lack of demand is reiterated in the literature as one of the most important reasons why electricity does not improve the profitability of enterprises [1,9,46].

Gender blindness with regards to the impact of electricity on the enterprise contradicts the findings of non-energy related literature on gender and labour markets. As Elson [40] writes, labour markets are institutions which are “bearers of gender”, in the sense that there are social stereotypes which associate masculinity with having authority and physical strength. These social (or sometimes institutional) norms dictate what kinds of work are deemed suitable for women and men, impacting wages and overall output [47]. The neoclassical ideal of rational profit maximising enterprises therefore disappears under the evidence of gendered inequalities and discrimination in the workplace.

Table 1 summarises the different impacts of electricity in different employment and earning outcomes for women, indicating the literature that provides supporting evidence. The next section reviews the literature on gender and labour markets, to expose the reasons why

women may not benefit as much as men from the PUE.

3.2. Which gendered constraints affect women’s chances to benefit from productive uses of energy?

Little is known about the gendered impact of electricity at the workplace, as revealed in the previous section. While evidence shows that women devote more time to paid work and move away from agriculture after electrification, many studies suggest that they keep on relying heavily on process heat and metabolic energy [48] and that their new activities are informal, consistent with gender stereotyping and less profitable than for men. The energy related literature, so far does not shed much light on the constraints that prevent women from benefitting as much as men from the PUE. However, the benefits women can obtain from using electricity at the workplace are determined by the gender regime in the labour market. There is a rich body of literature about gender, work and entrepreneurship, which we review in this section to answer our second research question.

As long as women’s employment remains lower than men’s and that women in employment obtain lower benefits from it, the opportunities that energy brings to the workplace will remain limited. There is broad evidence suggesting that this is the case. Women’s chances to be in employment are lower than those for men; they are more likely to be employed informally as contributing family workers or as self-employed workers; they are responsible for the largest share of unpaid work; and are overrepresented in a narrow range of sectors and occupations [13,15]. There is certainly a well-defined gender occupational segregation across world regions, with women more likely to be engaged in agriculture, personal services, food preparation, retail trade and textiles. Men, on the contrary have businesses distributed across a wider range of sectors, and in particular in energy intensive sectors like construction, manufacture and repair [14,49].

In like manner, reviews of women’s performance as entrepreneurs show lower entrepreneurship prevalence rates, except in lower income per capita countries where women become entrepreneurs out of economic necessity. Women entrepreneurs concentrate in low productivity, profit, technology and growth sectors; are overrepresented in the smallest and informal enterprises; and are more likely to operate

Table 1
Summary of the evidence: does electricity affect women and men’s income generation potential differently?

Impact	Positive (for women)	Negative (for women)	No influence
Employment	Dasso & Fernandez [36] Dinkelman [48] Van de Walle et al. [101] Chowdhury [34] Grogan & Sadanand [58]		Salmon & Tanguy [93] Costa et al. [38] Rathi & Vermaak [89]
Employment as time use in paid work for those employed	Banerjee et al. [33] Grogan & Sadanand [58] Khandker et al. [66] Dasso & Fernandez [36] Costa et al. [38]	Rathi & Vermaak [89]	Salmon and Tanguy [93]
Time in unpaid work		Dinkelman [48] Grogan & Sadanand [58] Khandker et al. [66]	Costa et al., [38] Chowdhury, [34]
Earnings/wages	Dasso & Fernandez [36] Grogan & Sadanand [58] Barron & Torero [29] Rathi & Vermaak [89]	Dinkelman [48] Parikh et al. [83]	Van de Walle et al. [101]; Standal & Winther [96]
Likelihood of non-farm employment or improvement in occupational score	Akpanjar & Kitchens [37] Barron & Torero [29] Chowdhury [34] Dasso & Fernandez [36]- Grogan & Sadanand [58]	Parikh et al., [83]	

from home, which in some cases damages business performance [16,17,50–53].

These characteristics of women as workers and entrepreneurs influence their role as energy consumers, making them less reliable and smaller customers, unable to invest in electric appliances or connection fees. Under these circumstances, electricity's role as a catalyst of income generation cannot be realised. Understanding why these differences persist is therefore essential to design successful interventions to promote women's PUE.

The literature provides two sets of explanations for the observed gender performance gap in the labour market. Either it is constraint-driven, meaning that it is caused by external barriers; or it is choice-driven, arising from internal motivations such as risk-tolerance and subjective preferences [17,54]. There is evidence to support both explanations, as we will review. It is of course likely that both are inter-linked, as external constraints affect women's choice and agency. Literature suggests that two reinforcing dynamics strengthen the negative relationship between external barriers and personal drivers. The external environment results in women facing discrimination in the labour market; while the drudgery of the care economy can result in women having less time, agency and mobility to choose better options in the paid economy [53,55]

First we review the evidence about the constraint-driven hypothesis. Gender literature highlights the notion of 'bundled constraints' for women – that is, they face constraints along numerous and intersecting dimensions. Common gender-specific constraints include the following:

- **Access to skills and education.** Studies in Brazil, Guinea, India and Pakistan show that women with more schooling are less likely to work in informal or family labour sectors characterised by low or subsistence wages and little security. Furthermore, the quality of education provision is closely related to girls' ability to access decent work subsequently [52].
- **Low access and control over resources** such as land, inputs, energy or income. This affects women's ability, to gather enough capital to create and grow their businesses or to buy domestic labour saving equipment that would increase time availability for paid work ([41,51,53,55,56–58,59]).
- **Unequal distribution of care responsibilities.** The urgency and time intensity of care-giving, particularly for small children, mean women typically 'choose' flexible types of paid work that allow them to accommodate care responsibilities [42,55,56,59–61]. Social norms and unequal institutions are a key determinant of the intra-household time allocation to paid and unpaid work [55,62].
- **Restrictions on women's use of space or mobility.** Women often can only operate in places where they are known to people, or where they perform expected roles at a set time and place, such as looking after dependents or preparing meals at specific times of the day, or cannot access certain locations, relegating them to operate their enterprises in their homes, combining them with household tasks. These mobility restrictions can be due to social norms, caring responsibilities or lack of safe and affordable transportation among others [53,55].
- **Agency.** In some contexts, unpaid work is not seen as contributing to the household economy, which can justify women's low level of control over household income and resources and undermine women's self-esteem. Low decision-making power then affects their ability to, for example, decide to invest in a new enterprise [53].
- **Occupational segregation.** The sector in which women operate is a major determinant of gender differences in business performance [49,63–66]. For example, [14] demonstrate that women entrepreneurs in male-dominated sectors in Uganda perform similarly to male entrepreneurs in those sectors, and better than women in female dominated sectors. In that study, psychosocial factors, particularly the influence of male role models and exposure to the sector from family and friends, were critical in helping women to

crossover to male dominated sectors. However, women in male dominated sectors faced problems such as discrimination from clients and suppliers; threats to close their business; vandalism and sexual harassment.

Two common ways of addressing the cited constraints are: changing the social (or even legal) norms behind them; or providing supporting services and infrastructure to ease women's burdens [52,53]. Energy supply interventions would fall under the second category, but changes in social norms are essential for women's economic empowerment and they require engaging the local power structures to avoid hostility [54].

After reviewing the evidence supporting that women face external constraints to explain work performance differences with men, we now look at the evidence on individual motivations and preferences. Even if these are difficult to measure, some studies have attempted to do so. For example, female entrepreneurs exhibit significantly higher fear of failure and less willingness to take risks than male entrepreneurs in a cross-country study by Minniti (2010). These subjective perceptions explain a significant portion of the gender performance gap in entrepreneurial activity of the sample. Women's short term orientation and lack of financial self-control (understood as the ability to save cash to reinvest) also explained why cash grants and microfinance had a lower impact on female enterprises as compared to male in RCTs by [67,68]. Finally, some evidence supports that motivations influence business performance, with households pushed into entrepreneurship out of necessity being less productive than enterprises taking advantage of an opportunity [69]. However, such conclusions about men and women's preferences influencing their business performance, backed up with data from RCT, are considered as too simplistic for other authors. Women's (socially constructed) lack of self-confidence hinders entrepreneurship [70], and gains in self-confidence, have been shown to reduce risk aversion [71]. In other cases, women and men's different attitudes to growth have to do with women not wishing to risk their home/work balance [72]. A study of Nigerian entrepreneurs found no evidence suggesting challenges related to personal attitudes or motivations and instead pointed to the pressure of family responsibilities, lack of access to finance, and a limited business network as key factors [73]. Further literature finds that gender differences based on individual preferences or motivations are not conclusive and are related to issues of economic necessity [74].

To sum up, unlocking the benefits of the PUE for women requires addressing the constraints they face to access and benefit from paid employment. The literature shows constraints to access education and resources; to undertake male dominated activities; to share and reduce the load of care work; to exhibit self-confidence, agency and risk-taking; and to move and interact freely. Table 2 summarises the different studies supporting or refuting the importance of different constraints. Next section of the paper will review the evidence on what types of interventions can work to address these.

3.3. What interventions work to achieve gender equity in the productive use of energy?

In this section we review two types of literature: first, the literature about gendered interventions to promote the PUE. Because this literature is incipient and does not provide many insights about what works and does not to promote women's performance at work, we complement it with a review of gender and entrepreneurship literature.

3.3.1. Gender mainstreaming in PUE interventions

In the preceding sections we have shown evidence that men and women benefit differently from the PUE; and we have identified the main constraints women face when using energy at work. In this section, we look at literature about what could work to improve the gendered impact of the PUE.

Empirical literature on the impact of gendered interventions to

Table 2
Summary of the evidence: which gendered constraints affect women's chances to benefit from the PUE?

Constraint Type	Constraint Sub-type	Supporting literature	Refute
Worse starting conditions	Skills and education	<ul style="list-style-type: none"> ● Fairlie & Robb [107] ● Dejene [55] ● Hunt & Samman [52]. 	<ul style="list-style-type: none"> ● Campos et al. [14]
	Access to finance and other resources	<ul style="list-style-type: none"> ● Fairlie and Robb [107] ● Nordman & Vaillant [58] ● Dejene [55] ● Eyben [41] ● Chopra [56] ● Chopra & Zambelli [51] ● Maestre & Thorpe [50] 	<ul style="list-style-type: none"> ● Campos et al. [49]
Social norms	Care responsibilities	<ul style="list-style-type: none"> ● Chopra [56] ● Kabeer et al., [70] ● Razavi [57] ● Hunt & Samman [52] ● Maestre & Thorpe [50] ● Chopra & Zambelli [51] ● Hallward-Driemer [56] ● Costa & Rijkers, 2012 ● Nichter & Goldmark [84] ● Nordman & Vaillant [58] ● de Mel et al. [43] ● Bardasi et al. [48] ● Campos et al. [49] 	
	Occupational segregation	<ul style="list-style-type: none"> ● Minniti [108] ● Nagler & Naudé [64] ● Fairlie & Robb [107] ● Duflo, [63] ● Fafchamps et al. [49] 	
Individual preferences/ motivations			

promote PUE is very scarce. We could only find five papers on the topic, all of them using qualitative methods, and with three focusing on the same case study: the Multifunctional Platforms (MFP) in Mali and Burkina Faso [75–77]. The remaining two look at electrification in rural Zanzibar [78] and modern energy services provision to micro-enterprises in rural Ghana [79].

MFP interventions are particularly relevant from a gender perspective because they are designed with the aim of reducing women's physical work burden and empowering them as managers and owners of the technology. MFP consist of a small diesel or biomass engine mounted on a platform with several end-use equipment meeting needs such as rice-hulling, grain grinding, de-husking, pumping water, and electricity generation. The intervention involves both the provision of the technology and business training for groups of women that would go on to own and manage it. Some anecdotal evidence describes how MFP increased girls' school attendance in Mali and improved income generation and leisure time for women [75]. Sovacool et al. [77] describe MFP's success in expanding energy access, reducing women's time poverty, increasing women's income and employment and even empowering them through education and participation in the local economy. However, they also point at some challenges, such as frequent technical faults due to poor maintenance; limited markets; and gender conflicts, with men resisting the enhanced social status of women.

Nygaard [76] provides an insightful analysis of MFP's limitations in Mali and Burkina Faso. In this case, while MPF combined a number of objectives attractive to donors (gender equity, environmental protection, income generation, technological fix), they overlooked village social structures and real technical needs and abilities. Women's associations faced difficulties in operating and managing the platforms and men systematically played a role as supervisors, committee members and employees. Then, when donors left, their imposed structures failed to survive, with the most profitable activities moving away from women's groups and into private ownership. The paper hence concludes that just introducing a new technology with a gender focus in a community is not going to change gender patterns. Therefore, rather than

inventing new complex, all-embracing concepts to mobilise funding, development aid should build on existing structures.

The stickiness of prevailing gender roles became evident in a World Bank's project to create employment in the energy sector for women in rural Ghana [79]. The findings of their contextual analysis, using focus group discussions (FGD) and key informant interviews (KII), showed women's preference towards their traditional economic activities, as opposed to new non-traditional enterprises like assembling lamps. There was a pattern of carrying on with the same trade as their elders which proved difficult to break. They also found that women were reluctant to work in associations, being more interested in individual small-scale and petty trading businesses than in larger scale manufacturing. While these findings only refer to the specific context where the project was taking place, they demonstrate that women might not be interested in the types of productive activities that donors think are better for them. Before promoting what would appear as rational options for women to raise their income, donors should understand why women choose the activities they do, and raise awareness about the benefits of moving out of traditional trades.

Understanding women's existing energy needs, rather than those donors would like to see emerging, should be a key part of electricity planning processes. If women's voices are not incorporated, care services like child-care facilities, or profit-making female dominated productive activities could be overlooked, as demonstrated by an ethnographic study of Zanzibar's electrification [78]

Even if evidence on what works is thin, several handbooks provide general recommendations on how to mainstream gender in energy projects (see for example Refs. [80,81]). The normative literature argues that men and women have different energy needs, different priorities for different energy services and different willingness and ability to pay, all related to their differentiated roles in society. Gender mainstreaming is therefore about taking into account those differences to provide energy technologies and services that both men and women are interested in investing in and using [82] a). Besides, gender considerations should not only refer to men and women as energy users, but in their roles throughout the entire energy system, looking for equal

participation at every stage (design, implementation, generation, distribution, consumption, evaluation) [58,82].

An important element of gender mainstreaming in energy projects is the definition of gender goals. Four broad types of gender goals can be defined in an energy project, in consultation with local stakeholders. The first three would involve improvements for women's welfare, productivity and empowerment, while the last would improve the project's efficiency by increasing the number of consumers [82]. The first three goals are more attractive for development organisations, but with regards to empowerment, the literature recognises that it is not realistic to expect energy on its own to change gender roles [18,48,81]. The last gender goal, about improved project efficiency, might be the most effective way of engaging energy suppliers [81,82]. These gender goals need to be measurable with appropriate key performance indicators, and frequently monitored through a monitoring and evaluation system.

As discussed, energy is only one of many productive inputs, and access to one specific resource will never empower women on its own. There is a need to expand the scope of energy interventions to include a bundle of other services necessarily to shake women's role in society. Some examples are: mentoring and education, access to credit, and institutional spaces for women to participate meaningfully in energy interventions. Energy literature, however, does not provide a lot of insights on whether or not these complementary interventions work, and how they should be implemented to succeed. Like in the previous section about constraints, we turn again to the wider literature on gender, labour markets and entrepreneurship to address these questions.

3.3.2. Gender mainstreaming in entrepreneurship interventions

The literature on gender and entrepreneurship has burgeoned in the last decade, as female entrepreneurship programmes have become increasingly popular among donors. These programmes can involve different interventions, such as general business or specialised training; tailor-made technical assistance or consultancy; improvement of soft skills such as networking or self-confidence; access to markets; access to financial or physical capital; or a combination of several of those interventions. The most common interventions involve financial services and standard business training [17,83].

Many female entrepreneurship programs have undergone rigorous impact evaluations, allowing for a considerable amount of experimental literature. Extensive reviews of these literature (see for example [16,17,106] or [84]) suggest that impacts are highly context and client specific. Overall, training and finance programmes improve intermediate outcomes such as business knowledge and practices, but long-term performance improvements are elusive. Besides, subsistence-level businesses need a more intensive package of services than larger enterprises to improve their performance, and the youth benefits more from interventions than older men and women do.

In our review, we classify the literature according to four types of interventions: access to capital; provision of business training; the combination of access to capital and training; and specialised technical or soft-skills training, including consultancy services.

First, interventions to remove the constraint of access to capital typically consist of loans or grants, whether cash-based or in kind. Impact evaluations of finance-oriented support programs typically use experimental approaches and are mostly focused on microenterprises. Results, as summarised in Table 3, suggest that access to finance alone has a limited impact for women entrepreneurs on key outcomes such as business revenues, profits, and employment. When there is an impact for female entrepreneurs, this is typically lower than for men, and only takes place for the largest or more profitable enterprises. For women running subsistence enterprises, access to capital does not make a big difference.

The poor performance of access to finance interventions for women can be explained by competing demands from the household restricting

women's investing decisions [63]. Under these circumstances, large assets and physical, rather than monetary assets would be easier to protect from capture by others. This hypothesis is validated by Fafchamps et al. [68], who find that in-kind grants are more effective than cash-grants to improve women's businesses. But they attribute this to women's lack of self-control, as opposed to external pressures to share their income with others in the household or extended family. Duflo (2013) supports that women's short term orientation and lack of self-control are important reasons for the low impact of microcredits on business performance. The size of the grants also influences how these are used in women's businesses. While small grants are seldom re-invested, women invest large grants in their businesses as much or more than men [86].

One particular study offers a different perspective about the impact of cash grants for women's economic empowerment. In this case, [85] find that cash transfers were very effective in improving employment prospects and earnings for young women in Uganda, as compared to male beneficiaries and to women in control groups. They present this as evidence that in their particular context, credit constraints were more binding for young women than for men and cash transfers were sufficient to create sustained growth in women's earnings.

On the basis of these results, some authors recommend targeting just growth-oriented female entrepreneurs to increase the effectiveness of interventions. But identifying high growth potential enterprises is not an easy matter. Rather than their performance to date, it appears that personality traits and cognitive skills are the best predictor of firm growth [68].

Interventions removing human capital constraints through the provision of business training also show diverse results (Table 4). Some studies find no impact whatsoever on the performance of women-owned firms, even if business knowledge increases [19,87]. Besides, high social restrictions can stifle the transformational potential of education, as shown in a field experiment testing the impact of business training for poor women working in India's informal sector [88]. On the other hand, [89] present an example of successful business training in Mexico that improved the medium-term results of female entrepreneurs as compared to women in a control group. The study showed that business with lower than average profits were more likely to close down after the training, hence backing up previous claims that the most profitable businesses benefit more. Other evidence also points at business training programmes being effective in getting new businesses started more quickly than in a situation without training [19]. As with the results of interventions on access to finance, some authors attribute the lack of impact to the fact that recipients are subsistence entrepreneurs with low motivation to grow their businesses.

Third, literature on the combined impact of interventions to remove financial and skills constraints, corroborates the results of the literature looking at these separately. Access to business training and finance typically increases the performance of male owned enterprises, but not that of female entrepreneurs [90–92]. Authors attribute the lack of impact for women to household and mindset constraints. On one hand, women are taxed by their families, leaving them with less time and capital to invest in their businesses. As a result of these and other gender norms, they show lower willingness to compete. A couple of studies, however, show positive impact for women of combined interventions. For example, Bandiera et al. [93] demonstrate how women in Bangladesh changed occupational choices from casual day labour to self-employment, and significantly increased their earnings as a result of the combination of capital transfers, asset-specific training, and regular technical follow-up visits. Like in other studies, however, the effect was largest for women who had highest relative earnings at the start. In the same way, De Mel et al. [19] identify a positive effect on profits for women of the combination of training and finance, but this dissipates after two years.

The modest results of the interventions reviewed suggest that they might not be targeting the most binding constraint for women. We now

Table 3
Summary of experimental evidence on the impact of access to capital interventions.

Type of access to capital intervention	Impact	
	Positive (for women)	No influence (for women)
In-kind grants	<ul style="list-style-type: none"> Fafchamps et al. [54] - Positive impact on profits for both men and women, but among women they are only significant for the larger enterprises. 	
Cash grants	<ul style="list-style-type: none"> Klinger & Shundeln [109] positive impact for both men and women starting or expanding a business, but smaller impact for women. Blattman et al. [85]. Very effective in increasing employment in non-agricultural work and earnings as compared to treated men, and to women in control group 	<ul style="list-style-type: none"> Fafchamps et al. [54] cash grants only have positive impact on profits for men. Lack of self-control appears as main reason for lack of impact for women, and not external pressures. De Mel et al. [44]. No short or long term impact on survival rates and profits for women, but impact for men. Coleman [86] Positive returns to capital only for male businesses. Different use of small and large grants by women. They invest very little of smaller grants, but as much or more than men of the larger grants. Attanasio et al. [87] profits and income do not increase for women enterprises. Particularly, loans do not benefit the poorest.
Microcredits	<ul style="list-style-type: none"> Attanasio et al. [87] positive impacts for women on creation and survival of microenterprises. The impact is different per education strata. More educated women increase business in services, non-educated ones, in agriculture. Duflo et al. [50] profits increase at the high-end of income, and more for men than for women, as men show more self-control and future orientation than women. Banerjee, Duflo et al. [111] significant profit increases for the upper tail of profitability for men and women 	<ul style="list-style-type: none"> Banerjee, Duflo et al. [111]. No effect on women's empowerment, human development or monthly consumption.

look at targeted training programmes, including not only business topics, but also gender specific skills, on-the-job training and support to overcome the particular constraints that women face. In this case, outcomes are more encouraging than those of standardised interventions. Programmes involving vocational training and internships, sometimes in male dominated trades, result in women empowerment, higher employment and earnings [94–96] and a decrease in occupational segregation [97]. Still, women show higher dropout rates than men, due to external pressures, which reduces the effectiveness of these programmes [98,99].

Programmes to improve soft skills, such as life skills, leadership, networking, confidence or team work also show positive results for women (Table 5). Examples of such programmes targeting young vulnerable women in Liberia [100] and Uganda [95] showed positive economic and social empowerment outcomes. Moreover, individualised consultancy services demonstrate large and persisting increases in sales for women, and this effect is larger for larger businesses [101].

Some clear messages emerge from the review of different interventions. To begin, interventions must target the most important constraints for women to succeed in their businesses. Otherwise, standardised programmes providing general business skills or access to finance tend to deliver disappointing results. Targeted interventions with the potential to change perceptions and motivations, such as soft-skills

training; mentorships; on-the-job training and customised technical assistance are examples of specialised approaches that work. Furthermore, interventions are more effective for larger women enterprises, suggesting that a minimum size threshold is required to improve performance. To conclude, interventions that minimise the opportunities for other members in the household to capture women's resources, also achieve better results. Some examples are large cash grants, as opposed to small amounts; and in-kind, as opposed to cash-based grants or loans.

4. Discussion and proposed framework for analysis

This interdisciplinary review of the evidence has demonstrated that gender matters for the impacts of energy use on income generation. Gendered literature on the topic has predominantly focused on the time allocation dynamics that emerge in the household with the arrival of electricity. Women's labour supply increases in most cases, and more so than men's. However, the gendered power relationships that influence both time allocation decisions, and the opportunities available to women in the labour market, are not well understood. PUE literature is predominantly gender neutral, looking at electricity as a technological shock that can improve performance of all enterprises, provided that some enabling conditions are in place. Without gender insights it is

Table 4
Summary of experimental evidence on the impact of access to training, alone or in combination with access to finance.

Type of intervention	Impact	
	Positive (for women)	No influence (for women)
Business training	<ul style="list-style-type: none"> Calderon et al. [90]. Increase in daily profits and revenues, and improvement in business practices. De Mel et al. [45]. Training programs help prospective owners launch new businesses more quickly 	<ul style="list-style-type: none"> De Mel et al. [45] no impact on performance Karlan & Valdivia [64] no impact in business revenue, profits or employment Field et al. [55] social norms may annul education's effect Berge et al. [93] training only improves performance for male entrepreneurs. Finance does not improve business outcomes. Gine & Mansuri [56] improvements only for male entrepreneurs.
Training and access to capital	<ul style="list-style-type: none"> Bandiera et al. [94] Changes in occupational choices and large increase in earnings, higher for those with higher starting earnings. De Mel et al. [45] the combination of training and finance increases profits but only in the short term. Training speeds entry of start-ups. 	<ul style="list-style-type: none"> Fiala [110]. No effect for women of any of the interventions, short-term profit increases for men. Berge et al. [93]. profits increase only for male-owned firms

Table 5
Summary of experimental evidence on the impact of targeted technical assistance and psychosocial interventions.

Type of intervention	Impact Positive (for women)	No influence (for women)
Vocational training and internships	<ul style="list-style-type: none"> ● Attanasio et al. [87]. Increases in employment and earnings ● Ibararán et al. [61]. Increased employment only for women, not men ● Maitra & Mani [73]. Improved long-term employment and earnings for women, but large drop out due to family duties. ● Bandiera et al. [95]. A combination of hard vocational skills and soft life skills increased young women’s employment and empowerment. ● Nopo et al. [80]. Training women for traditionally male occupations (both in classroom and on-the-job), providing childcare stipends, results in a decrease of occupational segregation, and an increase in labour income for women. 	<ul style="list-style-type: none"> ● Cho et al. [81]. Women more likely to drop out than men, due to external constraints, but programmes effective in any case.
Soft skills and mentoring	<ul style="list-style-type: none"> ● Adoho et al. [100]. Livelihood, life skills training and assistance with job placement increased employment, earnings and empowerment measures. ● Campos et al. [54] mentoring and networking support women to crossover to higher productivity sectors 	
Customised consulting services	<ul style="list-style-type: none"> ● Valdivia [100]. Customised technical assistance increases sales for female entrepreneurs in the long term, faster than for men. Larger effects for the largest enterprises. 	

hard to explain why women get into lower quality jobs than men after electrification, or why their wages do not increase, as pointed by some authors.

Fig. 1 illustrates the conceptual framework that derives from our interpretation of the literature reviewed. The inner square represents the current study of the PUE as if gender did not matter. It shows the labour supply and demand impacts of electricity, assuming that men and women have equal access to key enablers like finance, skills and markets; and that decision making at the household and enterprise is not affected by gendered power relationships. The outer, shaded square represents the gender regime in which women’s productive use of energy is embedded, which results in different benefits for men and women. This regime is dynamic, changing with new economic circumstances. For example, men may move into typically female activities if these become more productive by improved energy access, as has been shown in agriculture [102]. PUE interventions therefore need to change accordingly.

The proposed framework could be applied to design PUE interventions that are not only aware of the different roles men and women play in the productive economy, but can transform these. Improved access to energy and access to productive equipment could contribute to reducing the income gap between men and women, making male dominated activities accessible for women, or enabling new activities not yet

defined as male or female by the prevailing gender norms. Gender equity of PUE interventions can also improve with activities to challenge gender stereotypes at work, facilitate women’s access to key enablers and improve their agency in the household and at work.

The evidence on what works towards equity in the PUE is very thin. A reduced number of case study based articles provide some important clues, though. For example, they call on donors to resist the temptation of embracing technical fixes – such as the provision of electricity- to solve gender problems, and instead build on existing social structures. This demands a thorough understanding of the context in which gender inequalities manifest themselves. Experimental literature about the effectiveness of women entrepreneurship programmes stresses again the importance of context. Tailor-made interventions, such as mentorships, technical assistance or on-the-job training have proved more effective than standardised business training or microfinance programmes.

The perspective of the electricity supplier is another important element for the success of PUE interventions that has seldom been addressed in the literature. Only recently, a study has looked at the gender set-up of electricity provision, finding that supply projects adopting a gender neutral approach are likely to produce systems dominated by men. These male dominated electricity supply systems have a particular set of ideas about end users in which men do productive work and women occupy households [103]. There is little knowledge, however,

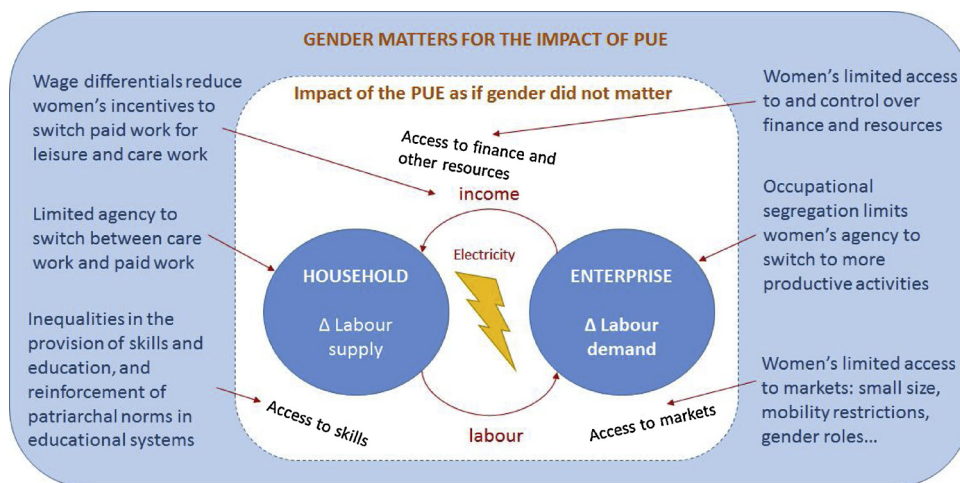


Fig. 1. Conceptual framework for gendered impacts of the PUE.

Table 6
Indicators for the gendered study of PUE interventions

Type of indicator	Indicators	Proposed data collection methodology
Outcome	<ul style="list-style-type: none"> ● Productivity of women: number of enterprises, number of employees, income, enterprise performance, quality of employment ● Empowerment, equality, equity for women: new roles and opportunities for women in the economic sphere outside traditional ones; women and men's increasing equality in income and control over it. ● Project efficiency: capacity utilisation, consumption, IRR, non-payment, etc. 	Quantitative (key performance indicators) Qualitative (subjective perceptions of project success)
Intervention	<ul style="list-style-type: none"> ● Electricity supply intervention ● Gender mainstreaming intervention ● Entrepreneurship and productive uses intervention 	Quantitative (key performance indicators) Qualitative: key informant interviews to understand the implementation process
Constraints and enablers	<ul style="list-style-type: none"> ● HH level: care responsibilities, time use, access to and control over resources ● Market level: skills, mobility, gender roles, market power, access to finance, opportunities to scale up ● Community level: social norms, associations, support institutions ● Motivations and preferences 	Quantitative controls Qualitative: <ul style="list-style-type: none"> ● semi-structured interviews ● life-stories ● participatory focus group discussions ● key informant interviews
Demographic controls	<ul style="list-style-type: none"> ● Owner characteristics (age, education, religion, HH role, ...) ● Business characteristics (location, type of activity, formality, etc.) 	Quantitative controls
Community controls	<ul style="list-style-type: none"> ● Population ● Access to infrastructure ● Economic activity ● Access to external markets ● Access to resources ● Political, community organisation, etc. 	Quantitative controls

about whether or not, and under which circumstances, the promotion of women's PUE could contribute to the financial sustainability of electricity supply. Clancy and Dutta [48] provide some insights about why it is difficult to supply electricity to women's enterprises, including: the informal and unorganized nature of female enterprises; their heavy reliance on process heat and metabolic energy; their lack of access to or control over complementary inputs (energy is only one of them); and their small size. Evidence of the project efficiency benefits deriving from women's PUE could provide an economic rationale for gender mainstreaming and gain wider acceptance in the energy sector.

Methodologically, when assessing the gendered impacts of PUE interventions we recommend a mixed-methods approach. Quantitative methods that build a credible counterfactual have so far not been applied to our subject for two main reasons. First, gender mainstreaming interventions for the PUE are incipient, and there has not been enough time for impacts to take place. Second, the randomisation of energy supply for productive uses is problematic because in order to be cost-effective, interventions need to target communities with a high productive potential, hence incurring in self-selection bias. There are several approaches to deal with self-selection bias or endogeneity in experimental designs and, when these are not possible, quasi-experimental methods, such as difference-in-differences or matching techniques can be used.

Still, endogeneity is not the only limitation of quantitative approaches. While RCT can provide insights about the size and sign of causal impacts, they are not enough to understand the all-important context in which social norms manifest themselves. The form of rigour provided by RCT, for example, is particularly problematic in conditions of complexity, with multiple non-standard treatments; diverse receiving environments; controls liable to contamination; difficult, unreliable or impossible outcome measurements; multiple causality and messy problems [25]. And such are the circumstances that gender mainstreaming interventions are most likely to find: communities using a diversity of energy sources and electricity supply models; where several programmes are being implemented, or have been in the past, by different actors to promote economic activity and gender equality; with very diverse beneficiaries across gender, income, ethnic, and age groups; and gender goals that are hard to measure, like empowerment.

Mixed methods approaches, defined as those combining quantitative, qualitative, participatory and/or action research and learning in a single evaluation, can provide the rigour for knowing and acting in such

a complex environment. Qualitative and participatory approaches allow for a more nuanced and richer understanding of the interrelations between PUE, access to electricity and gender. They can also give voice to outliers, typically neglected in quantitative approaches dominated by averages. For example, they can consider the perspectives of women working in male dominated sectors, and vice versa, to reveal the social norms behind gender segregation at work. At the project design stage, participatory and action research approaches are fundamental to design workable solutions, as they facilitate people to identify problems and solutions by themselves.

The benefits described make mixed-methods the preferred approach to unravel the relationships illustrated in the conceptual framework in Fig. 1. Such methodology would contain a suite of purposively designed tools, tested in the field to reveal differentiated impacts on men and women, and to test interventions that may work. The tools would collect indicators about outcomes, interventions, constraints and enablers, demographic and community controls, as presented in Table 6. Some of these indicators are easier to measure, and hence more amenable to quantitative research, while others are better understood through qualitative methods.

5. Conclusions

To conclude, this paper has uncovered the gaps in the existing literature about gender and PUE. It recommends further emphasis on enterprises as institutions bearers of gender; on the gender constraints preventing women-led enterprises from becoming significant users of electricity; and on the dominant social norms in which interventions operate.

The paper proposes a mixed-methods approach to better understand the complex environments in which PUE take place, and suggests a number of indicators that should be collected with that aim.

Finally, we recommend policymakers and energy suppliers to use this knowledge to design and implement interventions on gender mainstreaming in PUE that are not only aware of women's current productive and caring roles; but can be transformational enabling women to access more productive and profitable activities. Furthermore, the message that women do not benefit as much as men from interventions to promote productive uses of energy, could apply to many other societal innovations. We propose, therefore, that gender considerations like the ones proposed in this paper are considered in the

design of other interventions involving technological transitions in sectors like agriculture, education or the digital economy.

Competing interests statement

The authors declare that they have no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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