

Addressing gender dimensions in energy innovations: a gender analysis framework for informal urban settlements in Africa

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Abstract

Energy innovation to provide energy services for Informal urban settlements is thus far gender blind. The invisibility of gendered energy needs impedes addressing energy insecurity concerns to promote the adoption of energy innovations, especially in the Global South. Energy insecurity is significantly rampant in informal urban settlements inhabited by about 50% of SSA. Women and girls are not only the most vulnerable but also disproportionately affected by this phenomenon. There is a need to understand the gender-energy nexus in informal urban settlements to mainstream gender in the energy innovation process. It is evident that the existing gender analysis frameworks fail to address gendered energy needs, and none are specific to the context of informal urban settlements. The similarity in the formation of informal settlements across the continent informs the scope of this paper. Through an integrative literature review, a critical content analysis addresses two objectives; understanding the gender dimensions within energy innovation processes and conceptualising appropriate gender analysis tools for energy innovation processes in informal urban settlements. Some emergent gender inequality dimensions unique to informal settlements include limited exposure to energy innovations; poor health outcomes and higher mortality rates in women and children; limited financial capacity, poor skills training, low participation and lack of gender-sensitive energy policies. These factors are subsequently reconciled in developing a context-specific gender analysis framework to embed gender in energy innovation processes. The newly devised gender analysis framework could inform energy policy and enhance the adoption of energy innovations in Informal urban settlements in Africa.

Keywords:

Gender Analysis, Energy innovations, Gender and Development, Gender mainstreaming, Informal settlements

1. Introduction

The problem with gender blindness in energy innovation processes is that it slows down the adoption of energy innovations in informal urban settlements of Africa. The energy innovation process entails knowledge production, converting knowledge to products and energy innovation product consumption [1]. Currently, incremental and radical energy technology production is exponential. While this advancement should address the energy needs of poor communities in informal settlements, their level of adoption of energy innovations remains significantly low [2,3]. In addition, energy policy decisions are top-down[4]. This implies that user contexts, including the role gender plays in innovation adoption, barely inform the type of knowledge and the feasibility of the innovation product. While other research sectors apply gender analysis to accelerate innovation uptake, the energy sector lags. Innovations such as biogas have had a lower success rate in African countries due to negative cultural perceptions that would have been addressed prior to implementation [5].

Gender, a socio-cultural component in the energy innovation process, is largely neglected in energy innovation processes. Minimal documentation on the gender-differentiated impacts of energy insecurity in the context of Informal urban settlement households is evident in energy literature [6,7]. Gendering energy innovations could fundamentally increase innovation uptake in informal settlements and improve livelihoods by mitigating energy insecurity and energy poverty [8]. Mediation strategies to reduce poor adoption and accelerate energy innovations mainly focus on technology production rather than the multidimensional social technicalities that influence adoption [9]. A gendered innovation knowledge generation, translation and implementation is lacking.

Biomass, characteristic of high carbon emission levels and inefficient energy, remains the primary energy source in the Global South. Its negative impacts are empirical, more on women and children than on men [10,11]. In addition, institutions for energy planning that would potentially address the gendered energy needs are male-dominated [12,13]. This is a barrier to appropriately contextualising women's needs in energy innovation processes. Gender awareness is not in itself enough to facilitate gendered change. For instance, van der Merwe et al. [13] find that women still suffer the most from energy insecurity despite female-headed households being

more in Sub-Saharan Africa. Therefore, appropriate approaches in gendering still need to be established, especially in low-income communities with high poverty rates.

Africa has the highest rates of energy insecurity, with over 80% of its fuel consumption being biomass, animal waste, municipal waste, industrial wastes and other high carbon-emitting fuels such as paraffin [14]. Energy demand outstrips the supply of clean energy and is aggravated by the rapidly urbanising African cities. UN DESA [15] estimates that by 2050, the number of those living in the African cities will increase by 960 million from 400 million. The expected consequence of urbanisation is a parallel increase in informal settlements with a low-income majority of women and girls [10,16]. Due to financial limitations, the ultimate consequence is unsafe and inefficient energy choices that exacerbate energy insecurity [17].

Mitigation efforts towards achieving energy security often aim at reducing the cost of renewable and clean energy technologies to ease the transition. For example, the price for solar photovoltaic systems decreased significantly compared to other energy technologies [18]. In addition, the diversification of sources for electricity generation through wind hybrid systems and solar resulted in a reduction in electricity supply rates in Kenya [19]. However, other social dynamics, particularly gender- inequality, derail development efforts towards energy security in Africa's cities [6]. Incorporating gender as a development aspect in energy innovation reconciles Sustainable Development Goal (SDG) 7 to increase energy access to affordable and clean energy for all and SDG 5 to empower women and girls [20].

Gender needs are twofold: strategic and practical. Strategic needs inequalities are born from the subordinate social position of women and interrogate gender relations [21]. Practical needs are inequalities emanating from gender roles assignment at the household level [12]. In this bilateral discourse of needs that other scientists have deemed controversial in gender analysis [21], Musango et al. [17] argue that energy insecurity is accelerated when these two categories of women's needs are neglected.

The scope by which gender matters are addressed can also be widened further along with other social dynamics such as race, status and age [22]. Embedding gender across the energy innovation process requires that gender dimensions and their influences are understood. This is a pathway to ease the transition and enhance energy innovations [23].

In Sub-Saharan Africa, centralised policies regulate energy innovations at the micro-level [4]. There is a lack of practical solutions in gendering energy policies, especially in developing countries [17]. Gender analysis frameworks are an opportunity to instrument decentralisation and formulate context-specific policy interventions. March et al. [21] state that effective gendering can only be achieved through gender-informed policy approaches. The existing gender analysis frameworks align with various policy objectives such as welfare improvement, equity, poverty reduction, efficiency and empowering women [24]. However, none has been used in informal settlements, and neither can singularly be adopted to address the unique gendered needs in energy innovation processes.

2. The objective of the study

This paper aims to contextualise gendered energy innovations in informal settlements by mainstreaming gender in energy innovation processes to increase adoption. To achieve this, we address two objectives: understanding the existing gender dimensions within the energy innovation processes and conceptualising appropriate gender analysis tools for Informal urban settlements. An integrative review process was conducted through critical content analysis, as recommended in Torraco, [25]. We apply the emerging concepts in developing a gender analysis framework for mainstreaming gender in innovation processes to enhance adoption in informal urban settlements. Mainstreaming gender is the incorporation of gendered concerns in a development agenda [17].

The paper first describes the Gender and Development theoretical framework, followed by a description of the data and methods. The third section analyses the gender dimensions within the energy innovation processes in Informal urban settlements. The fourth session discusses the different gender analysis frameworks. The fifth section conceptualises appropriate gender analysis tools for informal urban settlements based on the emergent themes in the third session. A gender analysis framework is then developed.

3. Gender and Development

The Gender and Development theory, a post-modern paradigm constructed in the 1980s to 1990s was preceded by the Women In Development theory. Gender And Development, unlike other

development theories including Women in Development 1960-70s, Women and Development 1970-80s and Women, Culture and Development 1990-2000, integrates both the needs of women and men and recognises the cross-gender interdependent relations [26–28]. This supports this study's goal to move away from the stereotypical association of gender advocacies as pro-women to promote equality across gender in energy innovation processes.

Gender and Development theory recognises the need for women's empowerment amidst gradual cultural transitions [29] and acknowledges the broadness of needs as strategic and practical [30]. However, empowerment is perceivably a multidimensional concept that must acknowledge gender interrelations. Johnson [31] conceptualises gender empowerment to include education, equality, confidence and cultural preservation. Indeed, empowerment should not be achieved at the expense of culture loss but instead be integrated within systemic norms and values of the empowered community.

GAD was conceived to transform gender culture holistically without focusing only on women's economic empowerment [31,32]. It addresses gender issues on three sequential levels: assessing user contexts, strategising to enhance development, and proposing actionable remedies to meet gendered needs [30]. A synthesis of this process is an implication of a bottom-up approach towards adopting gendered and relevant solutions. The goal of this paper, which is to develop a gender analysis framework, is attained within the Gender in Development theoretical framework. The first objective: to understand gender dimensions within energy innovation processes in Informal urban settlements analyses user contexts. The second objective is to conceptualise appropriate gender analysis tools for energy innovations and evaluate analysis tools as relevant components as a mainstreaming strategy. Eventually, an analysis framework is proposed as a remedy.

Gender and Development offers an opportunity to understand the systemic structure of socio-cultural norms to achieve appropriate transformation. Diversity, therefore, becomes an opportunity and not an obstacle to development. A diverse mix is anticipated in the energy culture in informal settlements considering the rapid urbanisation in most African cities, as evidenced in Kenya and South Africa [33,34]. However, certain similarities across energy cultures, such as women being at the centre of household energy use [22], are sustained even as roles evolve and tradition is challenged.

Gender and Development, necessitates the understanding of diverse contexts mainly through qualitative research that must be conducted to identify and sufficiently address gender gaps and evaluate the progress of projects [27]. Addressing gender gaps must be done meticulously and aim for gender equity to help eradicate stereotypes that frustrate empowerment initiatives [27,35]. The following section presents the process through which the data used in this study is acquired.

4. Methods

This study was based on an interpretive paradigm to contextualise gender for energy innovations in informal urban settlements. An integrative literature review was undertaken through critical content analysis to address two objectives: understanding the existing gender dimensions within the energy innovation processes and conceptualising appropriate gender analysis tools for Informal urban settlements.

The search for relevant literature was conducted within Scopus, a broad database. The Boolean search method was applied to gather relevant articles in understanding gender dimensions. Firstly, key terms linked to the objective and their generic synonyms were identified. The key terms used were: Gender, energy innovations, Process, Informal urban settlements and Africa. These search terms were used to construct queries based on their generic synonyms. The synonyms were then run as thread queries in all fields for each search term within Scopus. The document results for each search term are represented in table 1.

Table 1: Boolean search thread formulation

Search Terms	Search query	Document results
Gender	(gender OR male OR female OR woman OR man OR sex OR men OR women)	20,290,319
Energy innovations	("Energy innovation" OR "Energy intervention" OR "Energy technology" OR "Energy invention")	212,024

Process	(process OR cycle OR strategy)	25,003,532
Informal settlements	("Informal settlements" OR "slum*" OR "Poor environments" OR "Poor communities" OR "Poor neighbourhoods" OR "urban poor")	154,843
Africa	(Africa)	1,913,160

“(ALL (gender OR male OR female OR woman OR man OR sex OR men OR women)) AND (ALL ("Informal settlements" OR "slum*" OR "Poor environments" OR "Poor communities" OR "Poor neighbourhoods" OR "urban poor")) AND (ALL (Africa)) AND (ALL ("Energy innovation" OR "Energy intervention" OR "Energy technology" OR "Energy invention")) AND (ALL (process OR cycle OR strategy))”

Figure 1: Combine search string

A combination of all the queries, figure1, resulted in 191 documents

The 191 articles were then filtered in terms of relevance and scope. By analysing the titles and abstracts, review articles and articles whose scope was not within Africa were disregarded, bringing the total number of articles to 44. These articles were then reviewed on Atlas- ti software. Articles based on studies in rural areas and those that did not use primary data were deemed irrelevant for the study. This process excluded 18 articles of the 44. 26 qualitative, quantitative and mixed methods were selected. Of the 26, six review studies on two or more African countries were included as they provided a comparative point of view. Emergent themes discussed in section 4 were used to code the data.

Another search was conducted in conceptualising gender analysis tools, this time on the existing gender analysis frameworks. Each framework was run as an individual query, as illustrated in table 2, and all queries combined within one search resulted in 53 documents.

Table 2: Gender analysis frameworks search

Search queries for Gender analysis frameworks	Number of documents
Harvard Analytical framework	6
Moser Framework	3
Social Roles Approach	3
Capacities and vulnerabilities Analysis	5
Gender Analysis Matrix	2
Women empowerment framework/ Longwe	11
Gender analysis framework	24
All Search queries combined	53

Gender dimensions in the existing energy innovation processes in informal settlements that emerged from the literature review process are discussed in the next section.

5. Gender dimensions within the energy innovation processes in Informal urban settlements.

The literature review revealed a limited number of studies in Informal urban settlements in Africa. Figure 2 illustrates the distribution of studies across the different countries on the continent.

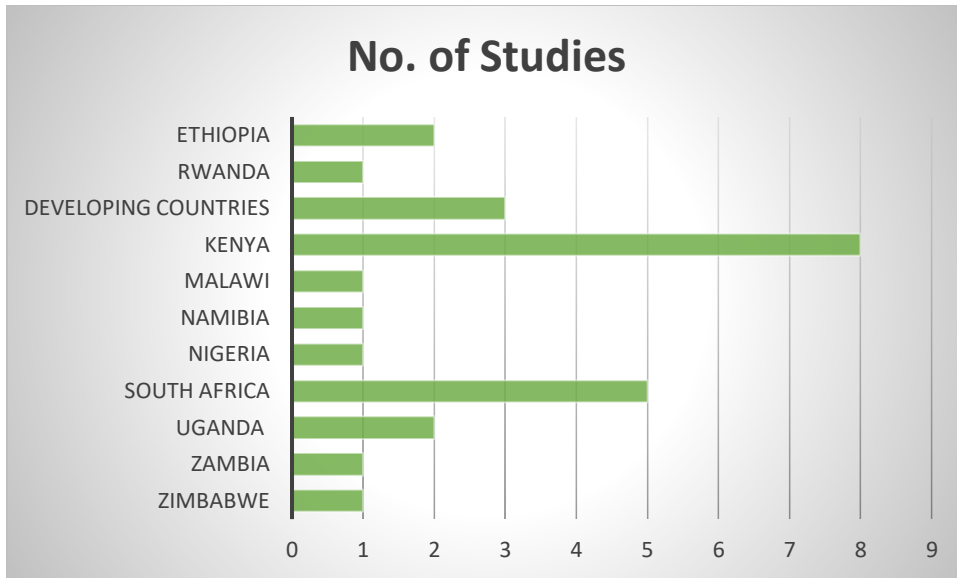


Figure 2: Frequency analysis of the number of studies per country

It is observed that Kenya has the highest number of studies on Informal urban settlements (8 articles), followed by South Africa (4 articles). Fewer studies are evident from the other countries, including three generic articles highlighting gendered situations across the continent. Countries such as Ghana, Senegal and Liberia are mentioned in studies about the Global South. A few articles were conceptual and did not address any specific case studies.

The review indicates that the main dimensions of gender inequality in energy innovations at the household level are energy cost, access and control of energy resources, health and mortality, decision making, skills training, participation, safety, land tenure and policy. These domains are gendered, and if considered in energy innovation knowledge generation, knowledge conversion to products and product consumption can increase innovation adoption.

Cost of energy

Energy innovations often come at a high initial cost that is constraining for low-income communities. A household's willingness to spend is tied to the level of income and the periods of its accumulation. However, informal settlement dwellers survive precariously on day-to-day earnings [36] and end up spending 15% to 20% of their income portion on energy. Moreover, female-headed households have lower income rates and lower economic shock resilience [37,38]. Low income also translates to lower adoption of innovations in female-headed households and is evidenced in South Africa, Kenya and Ethiopia [37,37,39]. It is, therefore, less likely that a purchase decision that does not address these financial dilemmas will be a priority. A study on the impacts of solar water heaters in low-income communities reports a solar water heater project's potential to save up to 1000 dollars within 15years in Zimbabwe [40]. Deductively cost easing strategies are pertinent to consider at various levels of the innovation process. Some of the approaches that have been pursued are extended payment time frames through pay-as-you-go initiatives and low-interest rates [38,41].

Household energy decision making

A study on payment models for liquid petroleum gas for clean cooking in an informal settlement in Kenya established that despite 83% of females being the main cooks in the households that adopted the liquid petroleum gas, only 59% were involved in the household energy decisions [42]. Similarly, another study in Ethiopia establishes that men mainly control household expenditure in informal settlements, even in female-headed households [39]. Cross-gender interrelation and interdependency become apparent. It can be expected that gendering efforts that exclude men in this aspect are, therefore, short-lived. In some instances, including a case on the adoption of solar water heater in canto manor, South Africa, and on improved cookstoves in Rwanda and liquid petroleum gas in Ghana and Cameroon [43], it is observed that female headship, along with higher education levels were attributed to higher innovation adoption. The two desperate scenarios illustrate that holistic empowerment of women is necessary to increase energy innovation adoption.

Health effects of energy insecurity

While women may not always be the decision-makers, they are the primary users of household energy. Biomass, the primary source of household energy in informal urban settlements, results

in indoor air pollution and poor health, including respiratory tract diseases, eye diseases from carbon pollution, backaches from wood fetching, deterioration in mental health associated with inadequate lighting and heating [43]. In South Africa's informal settlements, chromate copper arsenate treated wood fuels are standard. Combustion from these fuels emits copper, chromium and arsenate that, when inhaled, are cancerous and result in respiratory tract diseases [44]. In Malawi, Electric bulbs are reported to attract mosquito vectors, leading to malaria infections discouraging the residence from using these bulbs [43]. Paraffin, a typical energy fuel used for cooking and lighting in these areas, is mainly known to impair the lungs, result in asthmatic conditions and cause accidental fires [45]. A study in Nigeria on burns and scalds indicates that over 60% of the victims are women and children [46]. Additionally, The ingestion of kerosene by children is commonly attributed to poor storage, usually in soft drink bottles.

Mortality

Aside from paraffin, informal settlement dwellers opt for cheaper illegal electricity, also reported as a significant cause of shark fires and poisoning [17,47]. Mills [46] indicates a consistent increase in shark fire over the years, with over 24000 shark fires reported between 1998 and 2006. Overall, by 2012 the rate of mortality by fire reduced by half. However, current statistics indicate that 2.3 million people die prematurely from indoor air pollution, with a five times higher mortality rate in Africa [41,46]. 30% of these deaths are associated with candle use [46]. Majority of the victims are energy-poor low-income earners. A report by WHO in 2017 shows that women and children account for 60% of death from energy poverty [48].

Safety

Street safety is another primary concern in informal settlements. The rampancy of gangs, high crime rates and volatility in these settlements place women and girls at a disadvantage. When sourcing for energy fuels, women and girls have particularly suffered from street violence, including rape, due to lack of street lighting [46,49].

Energy access

Females are at the less profitable ends of the economy with limited infrastructure to support access to improved energy technologies. In an empirical study by Kovacic et al. [34] on three informal urban settlements in Kenya, Uganda, and South Africa, most female populations were reported to work within the settlements. Moreover, the study establishes that daughters tend to

remain in the settlements helping their mothers. The most common female jobs in Kenya's informal settlements include hawking, casual labour and street vending [38,42]. Due to high levels of informality, investors tend to shy away from low-income communities for fear of marginal gains or even destruction of property due to the high volatility [50]. Women mainly based in the settlements are left at a disadvantage and lack access to new energy innovations.

Time factor

Women in informal settlements struggle to balance between homemaking roles and paid work. Energy innovations such as Liquid petroleum gas saves women approximately an hour per day compared to charcoal or paraffin cookers [38]. It also saves 4-6 hours a day spent fetching firewood [41]. In South Africa, the Zanemvula solar water heater project was reported to save women the time they would otherwise spend preparing a bath for their spouses [40]. These projects illustrate that energy innovations can enhance women's productivity by affording them more time.

Participation in energy innovation dissemination

The involvement of women in developing innovations does not only help to determine the appropriate, cost-effective models but is also fundamental in promoting innovation dissemination [17,41,51]. Being at the core of household energy use, women are more informed to determine and sell the benefits of improved household energy technology [2]. The grass-root, paper block innovation success in Namibia is attributed to women's engagement throughout the different phases of the project [47]. Other project studies also recognise that user engagement is vital in identifying specific user needs and progress in innovation [52–54].

Skills training

Lack of skills needed to maintain and repair innovations once they are adopted is eminent in informal settlements. While partnerships and training with local retailers may be a potential solution, organisations that offer these interventions often fail to build local technical and manufacturing capacity [41]. This inadequate human and technical supporting infrastructure only increase energy insecurity.

Gendered Social networks

Social networks are vital in the diffusion and dissemination of energy innovations [52]. Literature on informal settlements shows functional networks for both women and men [37,55]. However, women have more robust social capital as they belong to local social groups that offer financial empowerment. Women's social and self-help groups are essential in accumulating funds for improved cookstoves in a low-income community in Kiambu, Kenya [37]. The financial support from these social groups can be harnessed to counter the high upfront cost of energy innovations. One limitation associated with these networks is their homogenous nature that constrains cross-gender diffusion of information. However, women's networks can facilitate household energy innovation acquisition as they are more concerned with domestic wellbeing than men [52].

Policy in energy innovations

Deliberate action to institutionalise gender matters in energy policy is necessary if gender equality is to be achieved. However, the current policy frameworks are not adequately gendered. For example, the Energy act of 2015 in Kenya does not mention domestic cooking energy at the county level [55]. Several authors, Kimemia et al., Musango et al., Pearl-Martinez, Shupler et al. and Timilsina and Malla [17,38,48,49,56], have recommended different policies in mitigating energy security in informal settlements. These recommendations include promoting awareness of modern energy, safe packaging of risky fuels such as paraffin and ethanol to cushion the vulnerable, lowering energy innovation tariffs, and addressing tenure complexities, which is a barrier in establishing biogas plants.

The following section discusses the various gender analysis frameworks and tools that can address these gender dimensions in the context of informal settlements.

6. Existing Gender analysis frameworks

Gender analysis frameworks are instrumental in planning and implementing intervention programmes and establishing appropriate policy interventions [21,57,58]. Gender analysis has been applied in various academic fields to integrate gender in development projects. Health and social sciences take the lead in the use of these frameworks. A lag is observed in the energy sector, as is evident from figure 4, compounded from the literature search on Scopus for this

study. The frameworks explore gender constructs and identify emergent inequalities for mitigation. Due to the diversity in policy domains for gendering, March et al. [21] recommend that goals and policy approaches be defined appropriately from the onset.

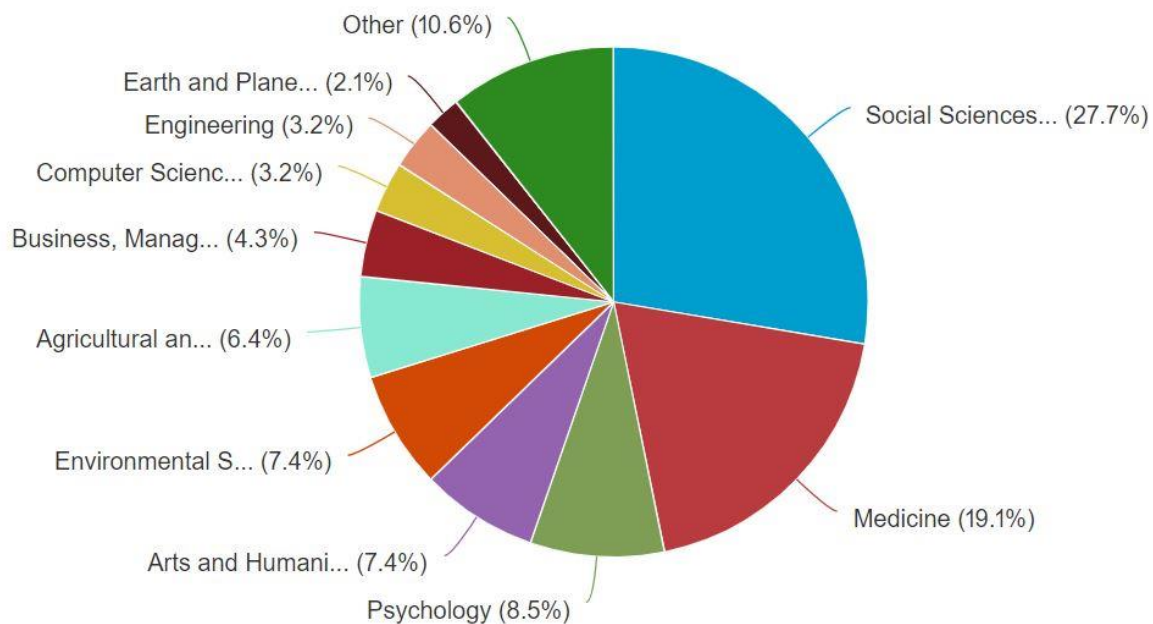


Figure 3: Documents by subject area

These frameworks include the Harvard analytical framework, once used in India to identify gender gaps in forest policy [59–61]. The Moser framework was used to incorporate gender needs in the urban transport sector in South Africa [62,63]. A study on non-communicable diseases assessed gender differences using the gender analysis matrix to propose appropriate gendered policies [64,65]. The equality and empowerment framework is primarily applied in development agendas that aim to empower and improve the welfare of girls and women, as illustrated in Grant et al., Jones and Longwe [66–68]. The social relations approach evaluates gender relationships, their benefits and how they can be implemented in gender policy [69–71].

Table 3 summarises the gender analysis frameworks that are of interest to this study, their tools and concepts. The study excludes the people-oriented and the capacities and vulnerabilities frameworks. These two frameworks are mainly used in humanitarian contexts [21], which does not align with the study context. The women empowerment framework also has a gender bias. Its

focus is mainly on women's needs, purposely excluding men in the development agenda and therefore does not align with the goal of Gender and Development.

Table 3: Gender analysis frameworks [12,21,30,63,72–75]

Gender analysis frameworks and contexts	Tools/ Concepts	Application
Harvard Analysis Framework (HAF) <i>The first framework for Micro-level gender analysis was published in 1985.</i> <i>Aim: efficiency and productivity</i>	Activity profile: Productive and reproductive roles	Assessment of roles directly related to project
	Access and control profile	Outlines resources used to accomplish the activities and the beneficiaries
	Influencing factors	What factors influence the gender division of labour, access and control
	Checklist for project cycle analysis	Assessment of gender needs along the stages of the project cycle
Moser framework <i>Used post-WID pro-GAD</i> <i>Published by Caroline Moser and Caren Levy in 1986</i> <i>Aim: gender integrated planning, equality, equity and empowerment</i>	Gender role identification (triple role): Productive work, Reproductive work, community work	Assessment of involvement in domestic chores, community tasks and paid work
	Gender needs assessment: Practical needs, Strategic needs	Assessment of immediate conditioned needs and needs arising from women's social position
	Disaggregating control of resources and decision-making within the household	Who does what, who decides and how
	Planning for balancing the triple role	How do women meet their competing demands
	Distinguishing between different aims in interventions: the WID/GAD Policy	Determine appropriate policy approach including welfare, equity, anti-poverty,

	Matrix	efficiency, and empowerment approach
	Involving women, and gender-aware organisations and planners, in planning	User involvement in determining appropriate gender strategies
Gender Analysis Matrix <i>By Rani Parker</i> <i>Aim: determine and evaluate the impact of development interventions</i>	Analysis at four 'levels 'of society: men, women, household, Community	
	Analysis of four kinds of impact: labour, time, resources, Socio-cultural factors	Evaluates changes in tasks, time taken to perform a given task, changes in access and control of resources, cultural adjustments
Social Relations Approach <i>By Naila Kabeer- UK in 1994</i> <i>Aim: analyse the existing levels of inequality and empower women as change agents</i>	Development as increasing human wellbeing	Addresses development beyond economic growth and improved productivity
	Social relations	Determine what inequalities emerge in gender relations at the micro-level, their evolution and resources acquired through these relations
	Institutional analysis: State, Market, Community, Family/ kinship	Determine the causes of inequality outside of the household or micro-level setting
	Institutional gender policies include Gender-blind, Gender-aware, Gender-neutral, Gender-specific and Gender-redistributive policies	To determine the appropriate policy initiatives
	Immediate, underlying and structural causes	Assessment of factors that result in gender inequality and the actors involved

Gender analysis tools and concepts vary depending on the goals of a given project. Attempts to incorporate gender in energy innovation processes are recent and mainly focus on rural areas [12]. According to Clancy et al. [12], none of the gender analysis frameworks can be singularly replicated for energy in informal urban settlements

Section 7 conceptualises the gender tools that are important for energy innovations in Informal urban settlements.

7. Conceptualising a gender analysis framework for energy innovation process in informal urban settlements:

In this section, gender dimensions identified in section 4 are applied to formulate appropriate tools for gender analysis in energy innovation processes in informal urban settlements. The discussion is based on the Gender and Development theoretical framework and aligns with the energy innovation process.

Gendered Energy innovation knowledge generation

Sufficient knowledge production requires the presence of users to provide user-centred perspectives. The Moser and Gender analysis Matrix both provide a participatory approach [61,63]. This study recommends the involvement of women, men, gender-aware organisations and planners in gendered knowledge generation for energy innovation projects from the onset. The multi-stakeholder engagement can then be facilitated using the Gender analysis matrix approach, allowing the relevant knowledge to come from the users themselves. This helps to determine what gender concerns are most pertinent to the project. With this approach, the objective and goal of the energy innovation project can be defined clearly and collaboratively.

The efficiency of household innovations must allow for interrogation of household characteristics for appropriate gendered knowledge generation. Gender roles to categorically determine which gender will be primarily involved in using the energy innovation are outlined. Studies indicate that women and children are the immediate users of household energy, and therefore both adult and children's roles must be defined. It is indicated that women in informal settlements are involved in both productive and reproductive work. Therefore, role balancing mechanisms are of the essence at this phase of the process. Tools for role definition and balancing are both provided within the Moser framework.

It is essential in energy innovation projects that the infrastructure that supports the innovation is also defined. Access and control of energy resources are gendered. According to [76], financial control determines household expenditure. Low-income communities are reported to spend about 15% to 22% of their income on energy. This is a factor to be considered in determining subsidies

or proper payment plans. This tool also helps identify the project's primary beneficiaries [73]. The emergent interdependency at the household can be addressed using the social relations tool to determine the strengths and weaknesses of the relationships and how they are essential in innovation knowledge production.

Due to the demanding triple roles balance, energy innovation planners should consider evaluating needs at the three levels of engagement for women and men and time spent performing energy tasks. The Moser triple role balance and binary needs assessment: strategic and practical needs tools combined with the time evaluation tool in the Gender analysis Matrix can produce relevant insights. Issues of negative cultural barriers must also be addressed to promote acceptable energy innovation within various informal urban contexts.

Conversion of knowledge to products

Innovation implementation in informal settlements has also failed due to a lack of technical capacity for maintenance and repair. Informal settlements can benefit from a tool that ensures a gendered capacity-building opportunity to empower women as energy innovation entrepreneurs. Moser's role definition tool can be applied in interrogating existing skills and how they can be gendered.

Innovation consumption

This phase ensures that market needs are met using the innovation product. It involves the efficient dissemination of products. It is crucial to consider the gender dimension that women are better placed to sell household innovation ideas as the immediate users. Involving women as sales representatives should be a consideration in gender analysis. This also falls under productive work, and the Moser tools on role identification and triple role balance can assess the gendered dissemination capacity.

The policy goal and approach can then be determined according to the emergent gender inequalities along the process [32]. Jaquette and March et al. [21,27] reiterate that the policy approaches should align with institutional policy agendas. Follow-ups to evaluate the state of progression are essential. In this regard, we propose **the Gender analysis Matrix impact analysis tool** to assess gender in innovation progress on four levels, men women, household and community. This framework contains flexible tools which allow for any additional analysis dimensions. The information from the application of these tools can again be applied and iterated

in other project cycles. Figure 5 illustrates the gender analysis framework for informal urban settlements.

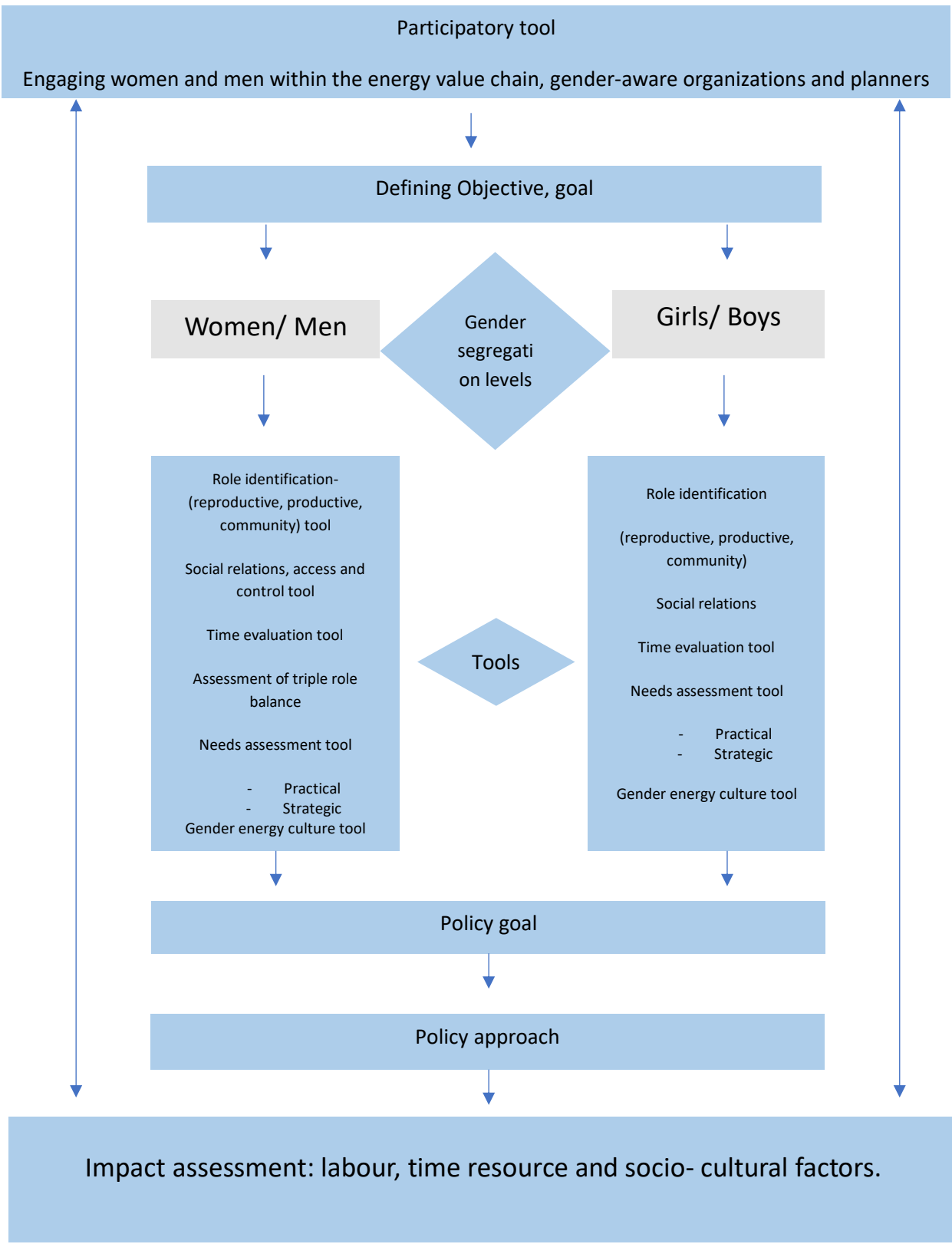


Figure 4: gender Analysis framework for Informal urban settlements

8. Conclusion

Energy insecurity in Informal urban settlements has a unique gender perspective that can enhance the adoption of energy innovations if addressed in context. There are currently no effective instruments for gendering energy innovations in informal urban settlements. The existing gender analysis frameworks can not singularly be adopted as adequate guides in gendering innovation processes in Informal urban settlements.

A combination of tools and concepts from the Moser framework, the Social Role approach and the Gender Analysis Matrix exhaustively provide an efficient basis to interrogate emergent factors vital in gendering energy innovations for Informal urban settlements. The framework is developed within the holistic Gender in Development theory. Unique themes of gender in informal settlements including, time constraining gender roles, limited exposure to innovations for women, restrained participation in energy innovation projects, health and mortality, culture, and gender-blind policies, are addressed within the proposed tools and concepts.

This paper demonstrates the gender inequality across energy innovation processes for informal urban settlements. Urban planning to include informal settlements is recent in most African countries and lacks the infrastructure to facilitate contextualised development. Lack of context-specific instruments for gendering energy innovation increases energy insecurity. However, the paper anticipates that the proposed framework can be adopted in energy innovation policy to promote adoption. The paper appreciates that informal settlements vary in the types and levels of informality and that the proposed framework may need to be suitably adjusted for replication. The proposed framework is a guide formulated from the unique gender aspects in these settlements. It can be adapted differently in line with the immediate gendered energy needs.

9. Highlights

- Current energy policies in Africa do not adequately address gender in energy innovation adoption at the household level.
- There is limited documentation on gender and energy innovations in informal settlements.
- Existing gender analysis frameworks are inappropriate for addressing the energy issues in informal settlements.
- The proposed gender analysis framework conceptualises appropriate tools for Africa's Informal urban settlements.

10. Disclosure statement

Conflict of interest: none

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