FROM ENERGY SECURITY TO SECURITY OF ENERGY SERVICES: THE ROLE OF GENDERED INNOVATIONS IN LIVING LABS

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ABSTRACT

Energy security remains a concern in Sub-Saharan Africa. The conceptualisation of energy security at the urban household level has shifted from the security of energy supply to the security of energy services, which is focused more on the demand side. Women and young girls are affected the most by insecure energy services. However, energy policy discourses often fail to focus on the security of energy services or to recognise gender roles in the provision of energy services at the household level. It is therefore imperative to develop innovative and gender-sensitive energy services solutions with a new paradigm of participatory solution design, such as living labs. We assessed living labs and the energy security landscape in poor urban environments through a systematic literature review, and proposed a framework for demonstrating how living labs could be used as a lever to promote the security of energy services. The security of energy services in poor urban households could be improved by harnessing the different innovative strengths of the respective genders. Living labs provide an ideal space for co-generating, co-designing, and co-learning to produce tailored energy services solutions. There is a need for a collaborative effort in resourcing researchers to undertake practical investigations of interactive multi-stakeholder platforms with those who are intended to benefit from the policy to increase its impact and to bridge the science-policy divide.

OPSOMMING

Energie sekerheid bly 'n bekommernis in Sub-Sahara Afrika. Die konseptualisering van energie sekerheid op stedelike huishoudingsvlak het verskuif van die sekerheid van energievoorsiening na die sekerheid van energiedienste wat meer gefokus is op aanvraag. Vroue en jong meisies word die meeste deur onsekere energiedienste geraak. Maar energiebeleids diskoerse versuim om op die sekuriteit van energiedienste te fokus en om die geslagsrolle in die verskaffing van energiedienste op huishoudelike vlak te erken. Dit is dus noodsaaklik om innoverende en geslag-sensitiewe energiedienste oplossings te ontwikkel met 'n nuwe paradigma om deelnemende oplossings te ontwerp, soos lewende laboratoriums. Lewende laboratoriums en die energie sekerheid landskap in arm stedelike omgewings is beoordeel deur 'n sistematiese literatuuroorsig en 'n raamwerk is voorgestel om te demonstreer hoe lewende laboratoriums as 'n hefboom gebruik kan word om die sekuriteit van energiedienste te bevorder. Die sekuriteit van energiedienste in arm stedelike huishoudings kan verbeter word deur die verskillende innoverende sterkpunte van die onderskeie geslagte te benut. Lewende laboratoriums bied 'n ideale ruimte vir mede-opwekking, mede-ontwerp en mede-leer om pasgemaakte energiedienste-oplossings te skep. Daar is 'n behoefte vir 'n gesamentlike poging om navorsers te verskaf om praktiese ondersoeke van interaktiewe multi-belanghebbende platforms te onderneem met diegene wat bedoel is om van die beleid te baat om die impak daarvan te vergroot en om die wetenskap-beleid skeiding te oorbrug.

1 INTRODUCTION

Energy has been a critical economic driver since the dawn of the industrial and technological revolution. The discovery of conventional sources of energy such as coal, oil, and gas and the development of technologies to exploit these energy resources in commercial quantities became an impetus for rapid economic growth and the improvement of human well-being in many countries. However, in the second half of the twentieth century, concerns about the sustainability and security of these conventional energy sources started to emerge. Some crucial evidence of the fears includes the peak oil hypothesis postulated by Hubbert [1] and the publication entitled *The limits to growth* on the interaction between human activities and the environment [2].

The United Nations also recognised the limitations of conventional energy sources, and enacted various treaties such as the Framework Convention on Climate Change [3] and the Kyoto Protocol [4]. In the twentieth century, the questions about conventional energy were mainly related to long-term sustainability and economic viability. However, some scholars such as Smil [5] opposed the submissions on the limitation of conventional energy resources, and questioned the potential of renewable energy as a sustainable replacement. As a consequence, energy security discourse today still draws on political sentiments and contentions in both emerging and advanced economies, especially because it also relates to economic and human security [6]. The problems of energy security have persisted in the twenty-first century.

Many different definitions and conceptualisations of energy security have been formulated to date, with much of the research having been done since 2000. The Asia Pacific Energy Research Centre (APERC) defines energy security as the availability of energy resources that are environmentally acceptable, economically affordable, and are without barriers to their accessibility [7]. Many scholars have appropriated this definition, often referred to as the ‘four As’, with a few modifications. These dimensions are reiterated by Kruyt, Van Vuuren, De Vries and Groenenberg [8] in their assessment of the indicators for the security of energy supply. Sovacool, Mukherjee, Drupady and D’Agostino [9] point out that energy security consists of interconnected criteria or dimensions that include availability, affordability, efficiency, and environmental stewardship. This definition is consistent with the description by the IEA [10] — namely, that energy security includes sustainability for future needs as well as affordability to the people. The IEA defines energy security as “the uninterrupted availability of energy sources at an affordable price” [10]. This definition captures the essence of energy security across different contexts.

These energy security definitions encapsulate the general understanding of energy poverty in the context of developing countries. Martchamadol and Kumar [11] conceptualised the energy security definition for developing countries. They suggested that energy security is the supply of energy of an adequate quantity and quality to meet all the requirements of all citizens at all times at an affordable and stable price, and to ensure sustainable economic performance, poverty reduction, and an improved quality of life without environmental harm. This definition highlights the need for energy security to have an impact on the quality of life through improved performance. It also captures the core aspects of the descriptions by the IEA [10] and Sovacool and Marilyn [12] — namely, availability, sustainability, affordability, and environmental protection. The seven energy security dimensions — energy availability, infrastructure, energy prices, societal effects, environment, governance, and energy efficiency — that Ang, Choong and Ng [13] presented after reviewing 83 energy security definitions extend the scope of the definition of Martchamadol and Kumar [11].

The broad definitions of energy security offer few contextual specificities at the micro-level. The discourse on energy security at the global, regional, or national level should not cloud or presume an understanding of energy security from the perspective of poor urban households. High-panel debates may reflect on the depletion of major energy reserves at the global level, discuss the security of energy supply networks at the regional level, and muse over energy independence at the national level. These debates, however, are far removed from the daily energy security conversations with household energy consumers. Consequently, understanding, conceptualising, and assessing energy security, especially in poor urban environments, is still lacking [14]. This study thus explored energy security in the context of the security of energy services from the perspective of poor urban households.

The study prioritised the end results of energy use and not of top-level energy supply. The focus on the security of energy services rather than on overall energy security reminds us of the varied energy uses among different classes of households, reveals new vulnerabilities about energy security at the household level, and redirects the scope and purpose of policy interventions on energy [15]. Innovative and gender-sensitive energy services solutions that take cognisance of the limitations of the present energy systems and focus on the energy needs of poor urban households are required in the energy services spheres.

Although females bear the brunt of energy insecurity at the household level, most innovations to address energy insecurity in poor urban environments are not gender-informed. There is thus a range of opportunities for changing that situation and of potential benefits of doing so. The challenges in poor urban environments include limited access to general services, increasing concerns about the security of energy services in particular, and evolving gender roles that, however, still place the responsibility of providing household energy services on females. The solution to these challenges requires a different response: gendered living labs of innovations.

The process of designing solutions to enhance the security of energy services in poor urban environments should not follow the usual top-down socio-technological approach, which has a record of failures. The solution design process requires a bottom-up product-service system approach, a human-centred design solution focused on technology in combination with services and business models and on a stakeholder value chain. This study also aimed to propose a framework for contextualising and designing energy services solutions through gendered living labs. On this basis, the concept of a living lab, and how it can be a conduit to the solution design process for secure energy services in poor urban environments, is explored.

The concept of living labs, as known today, is attributed to William Mitchell, Professor of Architecture and Media Arts and Sciences and Dean of the MIT School of Architecture and Planning at the Massachusetts Institute of Technology. He regarded living labs as a user-centred methodology to create solutions through a refining process. Since then, the general concept of the living lab has remained ambiguous, with different understandings and interpretations of its meaning and representation. According to Eriksson *et al.* [16], living labs are user-based research methodologies used to sense prototypes, to validate, and to refine solutions for real-life problems. The European Network of Living Labs (ENOLL), established by the European Commission in 2006, regards living labs as a methodology that adopts a user co-creation approach in a real-life setting involving multiple stakeholders in an open innovation system [17]. A living lab is a physical or virtual environment in which key stakeholders come together to co-generate ideas, co-learn, and co-design specific solutions that appropriately address some pertinent problems they encounter in their environment. Living labs thus embody crucial elements for understanding and addressing the energy services security problems in poor female-dominated urban environments.

In the context of households in poor urban environments, the discourse would more appropriately be narrowed down from energy security to the security of energy services. Our objective thus was to contextualise energy security in poor urban environments based on the security of their energy services, and to provide insights into how gendered innovations in living labs could help to bridge the gap in demand-side energy security.

Therefore, the key research question of this study is: How can gendered living labs promote the security of energy services in a poor urban environment?

This study focused on establishing that urban household energy services are gendered and on demonstrating how gender-sensitive innovation in living labs could boost the security of energy services. The results particularly focused on the role of living labs in providing gendered energy services at the household level. We proposed a framework for how gender-centred energy living labs could become a conduit for innovations to provide products and services to elevate energy security and to address the energy services security challenges in poor urban environments.

The rest of the paper is structured as follows: Section 2 details the methodological approach applied to conduct this investigation; section 3 expands on the definitions and conceptualisation of energy security with a focus on urban environments; section 4 showcases the gender sensitivity in household energy services; section 5 explores how gender-sensitive innovation in living labs could boost the security of energy services; and section 6 presents the conclusions from the investigations.

2 METHOD

A systematic literature review was done to study the available literature on the key themes — namely, energy security, gendered innovations, living labs, poor urban environments, and gendered innovations in energy. The aim was to unveil practical cases of innovative and secured energy services solutions designed in poor urban environments and to feature gender contributions through sharing knowledge and experiences as well as other means of participation. The systematic literature review process followed the eight-step method outlined by Okoli and Schabram [18]. These steps are: determining the purpose of the literature review, protocol, training, searching for literature, practical screen quality appraisal, data extraction, synthesis of studies, and writing the review. This process served as a guide to remain focused on the research themes and their interlinkages.

The search began on 21 October, 2019, and was mainly conducted through Scopus. This database was chosen because of the quality of the resources available on it and its flexibility in filtering information using a varied combination of matrices. Later, on 9 December, a follow-up search was conducted on Google Scholar and Semantic Scholar to determine whether the results they yielded were widely different from those of Scopus. Although the additional resource databases yielded more results, their top results were consistent with the output from Scopus. The search terms used were *energy security, poor urban household, gender innovation, energy services*, and *living labs*. The search results were refined on the basis of their relevance to the field.

The search first considered three key parts of the documents: the title, keywords, and abstract. Initially, a phrase was searched by combining all three parts, followed by a search focused on a single part. The results of this exercise are shown in Table 1. The search term with the highest yield for all document parts was energy security, while gender innovation in energy yielded the fewest results. Publications that contained the key search phrase in their title and keyword were of the greatest interest. The field of energy was selected to exclude articles that were not related to the energy domain.

Table 1: Results of the literature search

Systematic literature search

	Number of hits in Scopus				
Search term	Energy field	Title only	Keywords	Abstract	All combined
Energy security	1 076	3 133	19 953	35 723	48 211
Poor urban environment	0	26	35	3 154	4 352
Gendered innovation	3	182	496	2 095	2 969
Gendered innovation in energy	0	0	0	35	43
Living labs	35	652	837	2 474	3 236

The search for articles in Scopus with living lab in the title and the keywords yielded 3 236 results. After being filtered, 2 474 had the phrase living lab in their abstract, 837 in their keywords, and 652 in their title. The search results for living lab in Scopus, when limited to title search alone, yielded a total of 652 publications, most of which (286) comprised conference proceedings, 222 journal articles, 75 book series, 64 books, and five trade publications. Only 35 publications were related to energy. The annual publications on living labs from 1990 to 2020 are shown in Figure 1. The data presented is only from the search of Scopus as of 25 January 2020.

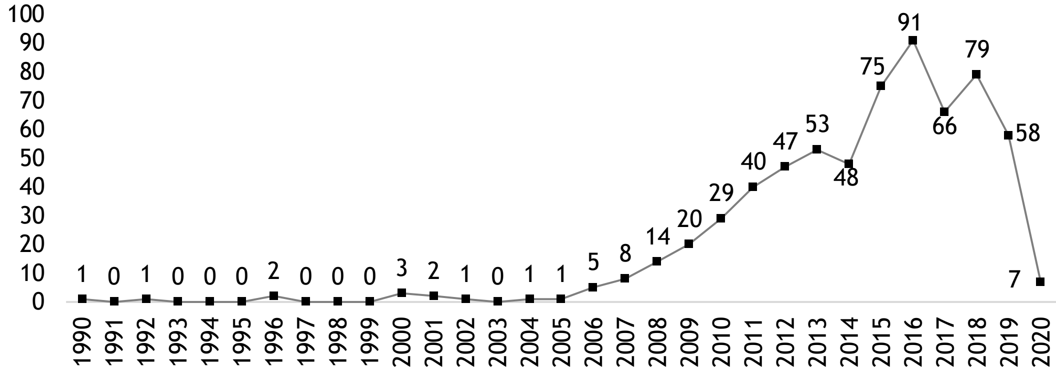

Figure 1: Annual publications on living labs

The living lab articles used in the review transcend the energy field to include technology incubation labs, mainly in the field of information and communications technology (ICT). A total of 35 articles on living labs were eventually selected for the review. The selection criteria included the time of the publication and how closely related the field of publication was to energy. We based the criteria for determining the close relation of the field of publication to energy on the association of the content with energy. The role of energy in ICT dissemination, energy in health, and energy for quality education are examples of relevant themes in the selection of publications. This period was chosen in order to focus on contemporary development and applications and on the fact that the concept of living labs emerged in the twenty-first century. The earliest articles on living labs used in the review were published in 2005, and the most recent in 2019. Overall, 64 publications were selected and previewed for the systematic literature analysis and write-up, and 61 were used in the final review.

3 ENERGY SECURITY AND URBAN ENVIRONMENT

When energy security concerns started emerging on a global scale, much of the attention centred on how to reduce dependence on foreign sources in order to boost supply security for national economies [19]. Predictably, most of the energy security literature explored the geopolitical implications of energy security for industrialised economies, specifically looking at how they could absorb shocks such as disruptions of the supply beyond a given threshold [20]. The extent of insecurity emanates from the scarcity and irregularity of geographical distributions, the unreliability of energy systems and supply flow to the end-users, and the potential conflict of interest between the supply and the demand nations [21]. Energy security concerns remain today, and the basis for those concerns is not very different from those of the twentieth century. However, energy security today is about more than the availability of conventional energy resources, and thus goes beyond merely having national control of the energy supply system [20]. There are environmental issues at play, such as the preservation of the ecosystem, economic issues such as low prices and available supply, as well as social issues such as the recognition of human rights [22]. Until the twenty-first century, very little literature had been published on energy security, and it had primarily concentrated on the security of supply at the global and national levels. It was only recently that definitions of energy security recognised the need to pay attention to demand-side security.

There are different definitions of energy security in the literature, but the different contexts are usually the reason for the variations [13]. There is a level of rigidity in generalising these definitions beyond the original contexts and case studies that influenced them. Moreover, these differences highlight the complexity of energy security in general, which makes it difficult to provide a concise and universally applicable definition of what energy security entails [23]. The differences in energy security definitions generate diverse energy security metrics and dimensions, and some energy security definitions, such as the four As, are primarily based on such metrics, according to APERC [7] and Kruyt et al. [8]. It is therefore essential regularly to revise what energy security entails in order to address new threats or priorities [13] as the energy landscape evolves.

The measures taken to tackle the problem of energy insecurity to date are inadequate [10, 24], and sub-Saharan Africa suffers more than most from energy insecurity. The actions to increase energy access and security in sub-Saharan Africa need to intensify, as this region's population continues to grow faster than in other regions of the world. This need is particularly crucial because of the positive correlation between population growth and energy use [25-27]. Given the enormity of the energy security challenge, it is critical to invite the private sector to partner and play an active role by providing financial resources [28] and technological assistance for secure energy services. There is also a need to revisit energy policies with special attention to energy security [13], as policy constitutes an integral part of the actions to secure energy services.

The world is becoming increasingly urbanised, and more than half of the global population now live in urban areas [29, 30]. Africa and Asia are considered the epicentre of urbanisation. The United Nations has projected Africa's urban population to increase from 40% to 56% between 2014 and 2050 [31]. This rapid urbanisation involves structural transformation, as production shifts from predominantly rural agriculture to urban industry concentrated in cities [32]. The rapid urbanisation that is common across many countries in the sub-Saharan region increases the residential energy demand in urban areas, and widens the general energy insecurity gap.

Cities are home to more than half the global population, and this will increase to about two-thirds of the world's population and account for 85% of global GDP by 2050 [33]. The magnitude of this projected urban growth signals a point in urban transition that requires appropriate actions to achieve sustainable development in those areas [34]. The impact of this growth is already being felt today as more energy resources are exploited, unemployment increases, and urban poverty persists in major cities across the continent [35]. The urbanisation challenges are more prominent in the global south. Also characteristic of modern urban dynamics is the emergence of poor urban communities and the noticeable gender compositions in such environments.

Resolving energy security at the household level is not merely a question of access to energy or transitioning to sustainable energy systems. It also involves the household technologies needed to transform energy into energy services. Figure 2 indicates the energy security debates and focus at the global, national, and household levels. It should be noted that the purpose of Figure 2 is to depict the interpretation of energy security by different categories of energy stakeholders. The figure does not attempt to present all the energy sources, transformation processes, distribution networks, energy types, energy devices, or energy services.

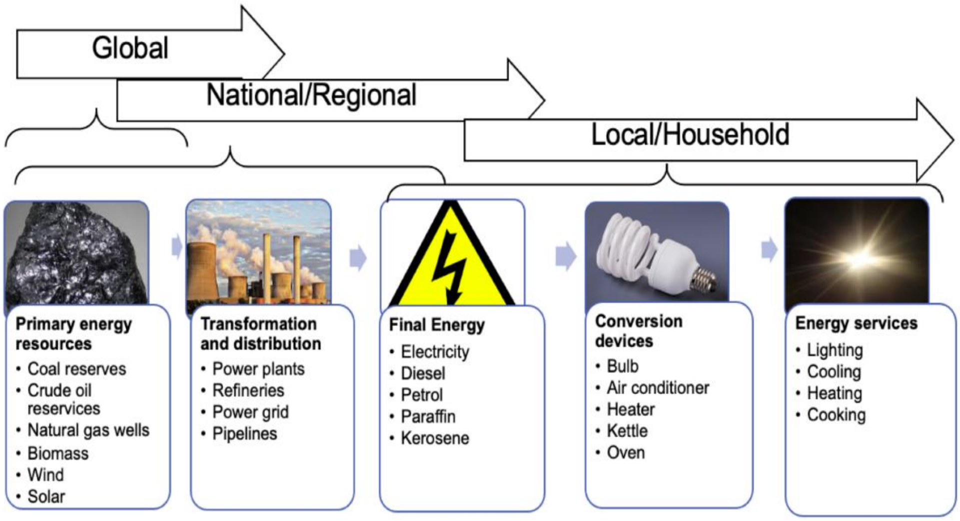

Figure 2: Conceptualisation of energy security at different levels

The concept of co-designing solutions to address energy issues among the urban poor is essential, as co-design is a bottom-up approach that engages the beneficiaries of the product or service from the start. This approach reduces the obstacles of adoption relating to unfamiliarity and disconnection between the innovator and user. The co-design process takes the comfort level of the user into consideration, as well as the user's ability to afford and maintain the product or service.

This user-centric design approach has some features of a product-service system (PSS). PSS is defined as "a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs" [36]. PSS shifts from the product ownership outlook to user satisfaction objectives [37]. It provides improved value at minimal cost, and is therefore appropriate for delivering secure energy services to poor urban households [38]. Living labs could play an essential role in this context

4 GENDER AND ENERGY SERVICES IN URBAN HOUSEHOLDS

The world's leaders met at the Fourth World Conference on Women in Beijing in 1995, and resolved to eliminate gender inequalities in all aspects of development. However, there are still issues on gender and energy today [39]. Gender roles, which are determined by society and have existed for a long time, ascribe needs, responsibilities, rights, and opportunities to women and girls that differ from those assigned to men and boys [40]. These roles remain conspicuous today, despite the many overt efforts to blur them, especially at the household level. Culture and religion form the foundation of most of these defined roles.

During International Women's Year in 1975, the international community made some of the earliest overt pronouncements that recognised gender disparities in development [41] and the gender-related expectations that exist in society. In essence, this study aimed to determine how to promote energy services security among urban poor households along gender lines. A disproportionate gender composition in urban households, and the variations in the impact of energy services security issues on the different genders, further advance the objective of this discourse.

Most of the researchers currently involved in the energy sector and in technology development are males [42]. Some authors contend that blurring gender disparities in energy services would boost gender balances in other spheres [43]. If women had access to electricity, for example, it could create new business opportunities and produce new female entrepreneurs [43]. It is challenging to achieve a development goal of secured energy services without including women in the process [44]. The disparity in gender participation, coupled with the failures of top-down energy technologies in poor urban environments, necessitate a review of the approach to providing energy services to individuals in these communities. It is critically important that the two genders play an equal role in the energy services innovation process.

In Africa, traditional households are mostly headed by males [45]. In the wake of rural-to-urban migration, however, there seems to be a reconfiguration of household headship: new family settings and dynamics are emerging, especially in the new urban environment. The number of female-headed households has increased over time [45]. Urbanisation affects conventional gender roles and relations in different forms and intensities in different places, and so creates many factors that lead to female-headed households [46]. Gender roles and relations in poor urban environments are different from the conventional structures, in which males dominate most aspects of household decision-making processes. In poor urban communities, female-headed households are common [47]. Accordingly, females are usually the ones who bear the brunt of energy insecurity and the concomitant socio-economic risks.

5 GENDERED LIVING LABS FOR THE SECURITY OF HOUSEHOLD ENERGY SERVICES

Living labs can be regarded as public-private partnerships (PPPs) in which businesses and public agencies or individuals work collaboratively to create, prototype, validate, and test new services, businesses, markets, and technologies in real-life contexts [48]. Living labs are research and development methods in which innovations are co-created and validated with multiple stakeholders [49]. This co-creation is expected to address the design flaws that account for a significant percentage of the failures associated with new products.

A review of the literature on living labs shows that the concept is widely applied in various academic and social domains, but mainly in information and communications technology (ICT). These ICT-related studies [50, 51, 16, 52] span more than a decade. Schuurman, Mahr, De Marez and Ballon [53] reviewed the characteristics of 64 ICT living labs, and found four typologies of living labs: i) living labs for collaboration and knowledge support activities; ii) original American living labs; iii) living labs as an extension to testbeds; and iv) living labs that support context research and co-creation with users. Leminen and Westerlund [54] also investigated 40 living labs, and presented a new conceptual framework for analysing innovation processes and the use of tools in living labs. The framework depicts four kinds of living labs: linearised, iterators, mass customisers, and tailors.

In the field of energy, living labs provide some added value in innovation, such as the more substantial commitment of renewable energy users and immediate interaction with the major industry actors [55]. Voytenko, McCormick, Evans and Schliwa [56] investigated how urban living labs as a concept are operationalised for sustainability and low-carbon cities. They identified a few key features of urban living labs: geographical embeddedness, experimentation and learning, participation and user involvement, leadership and ownership, and evaluation and refinement. On the subject of gender, Ahmadi *et al.* [50] investigated the challenges in applying living labs in gender and IT, and noted the lessons learnt in the process. Living labs are also considered a multi-disciplinary concept [48] that is applied in different academic domains.

Barakabitze *et al.* [51] define a living lab as "an open innovation environment in real-life settings, in which user-driven innovation is fully integrated within the co-creation process of new services, products, and societal infrastructures". Bergvall-Kåreborn, Eriksson, Ståhlbröst and Svensson [57] identified five components of living labs: ICT and infrastructure; management; partners and users; research; and approach. They also found five key principles for living labs from empirical experience: openness; influence; realism; value; and sustainability. Most recently, Chronéer, Ståhlbröst and Habibipour [58] set out to investigate and unpack the complexity in the meaning of living labs, particularly urban living labs. They arrived at seven main components of urban living labs: governance and management structure; financing models; urban context; nature-based solutions; partners and users; approach; and ICT and infrastructure. This list of components is an expansion of those that Bergvall-Kåreborn *et al.* [57] identified earlier.

A number of studies on living labs in Africa have been done [59-62], most of which were about cases in Southern Africa. After examining five case studies of living labs in South Africa, Coetzee *et al.* [60] found that the Southern African network of living labs was focused on co-creating with rural communities, as opposed to the user-centred and urban-situated living labs found in Europe. Barakabitze *et al.* [51], who authored one of the most recent studies on living labs in Africa, looked at ICT and its role in science, technology, engineering, and mathematics (STEM) education in Africa.

Living labs can be situated in both rural and urban centres, although the recent literature tends to focus on those in urban areas. Consequently, urban living labs — that is, living labs at the city or regional level [63] — are gaining prominence. Since this study investigates the urban context, it is essential to gain a more specific understanding of the urban living lab. The agency responsible for funding projects on living labs in European cities (Joint Programming Initiative Urban Europe) defines an urban living lab as "a forum for innovation, applied to the development of new products, systems, services, and processes, employing working methods to integrate people into the entire development process as users and co-creators, to explore, examine, experiment, test and evaluate new ideas, scenarios, processes, systems, concepts and creative solutions in complex and real contexts" [64]. It is experimental governance in which urban stakeholders design, develop, and test products and services as well as ways of living to produce innovative solutions to urban challenges [56].

Living labs already exist in many urban cities, and academic research on living labs and urban cities [65, 63, 66, 56] is gaining popularity. Our study identified with the definitions of urban living labs; it looked at urban stakeholders (poor urban households), considered a product (energy mix), and identified a challenge (security of energy services).

We conceptualised our understanding of living labs and contextualised that understanding for poor urban environments in Africa, based on our preliminary work as part of the Africa-UK Trilateral Research Chair: **Mainstreaming Gender for Energy Security in Poor Urban Environments (in short, Gender for Energy Security (GENS),** hosted by the University of Stellenbosch. Our conceptualisation of living labs is the result of the initial research activities conducted:

A research and innovation concept for experimental and experiential learning in a real-life environment, involving users and multiple private and public stakeholders, and aimed at 1] co-designing, prototyping, testing, and observing new solutions and novel organisational structures iteratively; and 2] stimulating changes in the socio-technical regime to create the most favourable conditions for the scaling-up of innovations.

Based on this definition, the key elements of a living lab are that:

- Activities take place in a *real-world setting*, with real users in real-life situations.
- Activities involve *multiple stakeholders*, including users, researchers, industries, NGOs, policymakers, and experts.

Activities are based on user-centred, co-designed, and participatory approaches, through which users and stakeholders are enabled and empowered to take part in the innovation processes. Stakeholders, therefore, are immersed in a creative social space for co-designing and experiencing their future.

Activities aim at designing, prototyping, and testing solutions that can then be further developed and commercialised outside the protected environment of the living lab.

A framework for energy security in a poor urban environment is illustrated in Figure 3. The framework is based on our understanding of moving along the continuum from unfulfilled to fulfilled energy services. It also shows the role of gender-sensitive energy living labs in upscaling energy security in poor urban settings. The framework combines the bottom-up approach with the conventional top-down approach, which involves policymakers. Our conceptualisation of living labs will also drive innovation at the policymaking level.

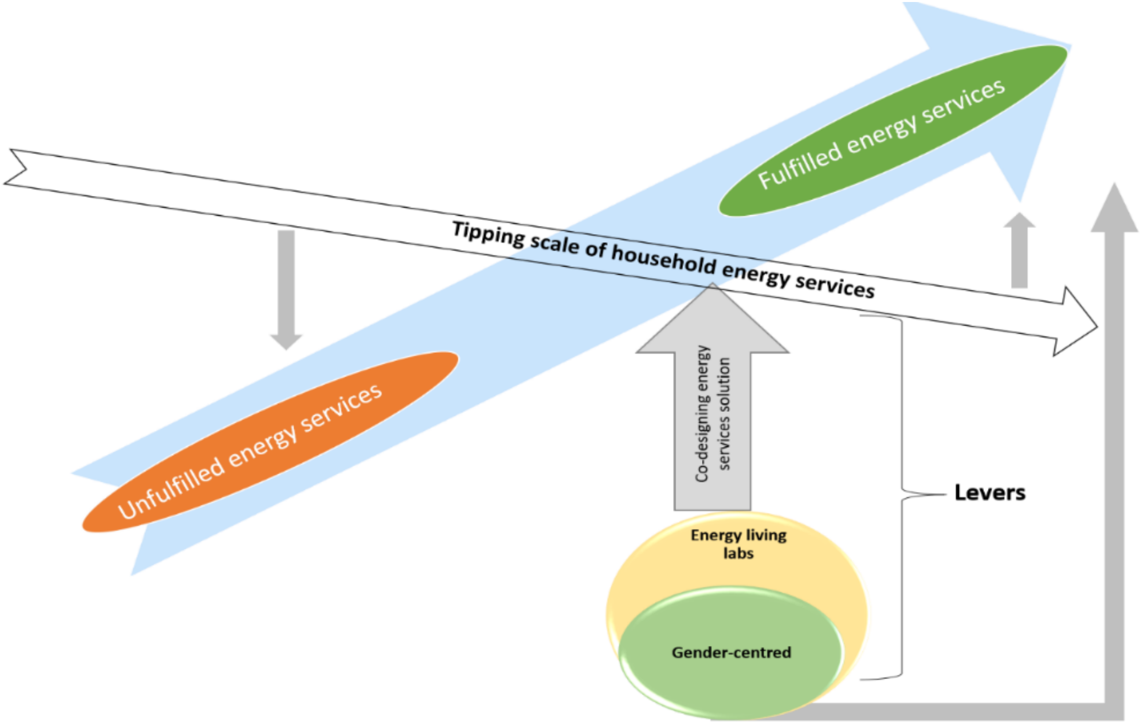

Figure 3: A framework of gendered energy living labs for the security of energy services in a poor urban environment

The framework shows how living labs that are centred on gender and focused on co-designing energy technologies with potential users to deliver a range of energy services would affect the scale of energy security and insecurity. A living lab, in this setting, is a lever of energy solutions and interventions that tips the balance of the energy scale in such a way that energy insecurity declines while energy security improves, and consequently boosts the security of energy services.

How could urban living labs help us to address the concern about the security of energy services, which disproportionately affects women and girls in poor urban environments in Africa? First, females are most affected by energy services insecurity, but they are least represented in the energy policymaking and technology design process. Urban living labs could be an interface between design and user. Women and girls could participate in the decision about which energy technology design would be suitable, based on the energy services they expect.

Second, poor urban households have specific ways to maximise the services they consume from a mix of energy carriers. In many instances, the overall energy service that is fulfilled from the total energy consumed is far below the total services that could be obtained from that energy. This disparity implies that poor urban households pay a hefty amount for energy that is not used. A living lab provides the platform for them to co-generate new ideas and to adopt better ways to increase their actual energy return (useful energy output) from the energy mix available to them. This optimisation process would lead to an overall decrease in their energy consumption and energy budget and an increase in the quality of energy services.

Third, households in a poor urban environment are actively involved in various economic and technical activities such as providing energy services by using different energy technologies. The presence of living labs that focus on improving energy and females' participation would help them to design innovative ways through technology modifications and improvements to suit their specific context and to meet their energy service needs. This user-centred approach mitigates the embedded limitations associated with the top-down products that are often oblivious to consumer-specific needs.

6 CONCLUSION

This study investigated the security of energy services in poor urban environments, and explored the role of gendered living labs in delivering household energy services. It focused on demand-side security, and specifically on the security of energy services through gendered innovations. We established that the security of energy services is a global concern, but most prominently in sub-Saharan Africa. Rapid urbanisation is sweeping through major cities across the subregion, putting enormous pressure on urban infrastructure and creating poor urban settlements. The subject of gender thus features centrally, as women and young girls make up the majority of poor urban households' population, are mainly responsible for providing energy services, and therefore are most encumbered by insecure energy services at the household level. This imbalance makes the exploration of gendered innovations in living labs an essential and topical issue in the efforts to achieve sustainable development goals.

The study found cases where gender-centred living labs were used to increase females' participation in science education. It did not, however, find instances where gender-informed reconfigurations of energy technologies in a living lab setting delivered specific energy services. It concluded that, if the security of energy services in poor urban households is to be achieved, the different innovative strengths of gender — particularly of women and girls — need to be harnessed. To harness these strengths, organised settings such as living labs are needed, where women and girls can be engaged in co-generating ideas and co-designing energy technologies, products, and services that appropriately answer their specific energy service needs. It is recommended that keen attention be paid to bridging the science-policy interface by resourcing researchers to conduct practical investigations through interactive multi-stakeholder platforms. This interface would facilitate connections with intended policy beneficiaries and ensure the direct and immediate impact of the research outcome.

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