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An *Imbokodo*-driven cooperative model for wheeling rural-generated solar-PV electricity to facilitate clean induction-stove cooking among low-income urban households in South Africa

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Declaration

I, Dimpho Teffo, Student No. 797367, declare that this research report is my own work, conducted independently. It is being submitted as part of the requirements for the Master of Urban Studies in Sustainable and Energy Efficient Cities at the University of the Witwatersrand in Johannesburg. I declare that this work has not been previously submitted for any other degree or examination at any other university**.**

Signed: ……D.Teffo…………………… Date: 15/10/2024

Abstract

Global efforts to address climate change are shifting the debate towards Just Energy Transitions (JET) paradigm which entails more environmentally friendly and inclusive economies, especially in terms of access to clean energy sources. Despite South Africa's past attempts to improve energy access for low-income households through policies such as Free Basic Electricity (FBE) and Free Basic Alternative Energy (FBAE), energy poverty continues to intensify especially for poor urban households. On the other hand, increasing adoption of renewable energy (RE) technologies such as solar-PV due to factors such as rising grid electricity costs and falling prices of RE technologies provoked an investigation into equitable and innovative modalities based on a women-oriented JET focusing on rural and urban low-income households.

Inspired by the *imbokodo* paradigm during anti-apartheid struggle ('*solidness of rock*' as metaphor of *women resilience*), the study applied a qualitative approach towards a model for addressing gendered energy poverty especially among low-income urban households. The model is based on a transformed role of rural and urban women as clean energy *prosumers* (generators and consumers), thus envisaging leadership roles for women in the sphere of zero-carbon energy and climate change mitigation initiatives within the overarching JET paradigm. The study focused on Alexandra township in Johannesburg as the urban energy consumer community (especially for clean cooking with induction stoves) coupled to Chebeng Village in Limpopo as the rural energy-generating community. Primary data were gathered through ethnographic observations in Alexandra with specific focus on cooking using conventional appliances versus induction stove. Data tools such as photographs, audio and video recordings, individual interviews, and direct observations were employed. Key challenges identified include limited kitchen space and a lack of incentive to replace existing faulty/inefficient stoves. A transect walk helped to identify constraints limiting rooftop solar-PV installations thus warranting alternative mechanisms such as wheeling green electricity. In spite of optimal solar resource of Chebeng Village, ethnographic observations identified critical challenges such as stifling control by tribal authority over women's access to land for large-scale RE projects such as solar-PV farms.

Nexus of gender and energy poverty, particularly in cooking as well as socio-political challenges specific to the urban and rural contexts suggest that a wheeling coupling of women-led solar-PV generation cooperatives in rural areas with consumer cooperatives in urban settings would facilitate clean electricity for zero-carbon cooking with induction stoves for urban households. Leveraging wheeled solar-PV electricity from rural to urban women-led cooperatives would also catalyze value-chain benefits such as green skills, jobs and entrepreneurship which are also JET goals for equitable low-carbon economies.

Key Words: *gendered energy poverty*, *clean induction-stove cooking, cooperative business model*, *electricity wheeling, Just Energy Transition (JET), solar-PV*

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To both Prof Daniel Irurah and my parents, I am profoundly thankful for your invaluable contributions to my academic and personal growth. Your encouragement and support have been instrumental in the successful completion of this research project. I am indebted to you for the guidance, wisdom, and love that have shaped this academic achievement.

Dedication

To my daughter Khumo Alba – we did it!

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List of abbreviations and acronyms.

ACSA – Airports Company South Africa

CIS – Co-operative Incentive Scheme

CO2 - Carbon Dioxide

CPI - Consumer Price Index

CSP: Concentrated Solar Power

CSR - Corporate Social Responsibility

DLA - Department of Land Affairs

DNI - Direct Normal Irradiance

DoE: Department of Energy

DTIC – Department of Trade Industry & Competition

EGA - Ener-G-Africa

ESG - Environmental, Social, and Governance

FBAE - Free Basic Alternative Energy

FBE - Free Basic Electricity

GHG - Greenhouse Gases

GHI - Global Horizontal Irradiance

GNU - Government of National Unity

IEA PVPS: International Energy Agency Photovoltaic Power Systems

IPP - Inndependentt Power ProducersProducer

IRP: Inttegrated Resource Plan

JET -l Just Energy Transitions

kWp - Kilkowatt Peak

LCOS - Levelized Cost of Storage

LEDET - Limpopo Economic Development, Environment, and Tourism

MW – Megawatt

NERSA - National Energy Regulator of South Africa

PACE - Property Assessed Clean Energy

PPAs - Power Purchase Agreements

PTO - Permit-to-Occupy

PV - Photovoltaic

R&D - Research and Development

RE - Renewable Energy

REIPPPP: Renewable Energy Independent Power Producer Procurement Program

SA - South Africa

SABC - South African Broadcasting Corporation

SALGA – South African Local Government Association

SANS - South African National Standards

SARS - South African Revenue Service

SDG - Sustainable Development Goals

SEA - Sustainable Energy Africa

SOE – State-Owned Enterprise

SSEG - Small Scale Embedded Generation

SWFlux - Solar Shortwave Flux

TOU - Time Of Use

Chapter one
Introduction and background of the study

1.1. Background, context, and motivation

The discourse of global climate change mitigation and adaptation has engendered intense debates around aspirations on transitioning towards inclusive low-carbon economies. In particular, the complexity of environmental and social justice concerns has given rise to the paradigm of Just Energy Transitions (JET), which seeks to ensure that the shift to low-carbon energy sources is undertaken in a socially just and equitable manner, especially in developing countries currently faced with endemic energy poverty.

In previous attempts at addressing energy poverty in South Africa, the government introduced the Free Basic Electricity (FBE) policy in 2003 followed by the Free Basic Alternative Energy (FBAE) policy in 2007 which targeted households which are not connected to the grid (Ayamolowo, Manditereza & Kusakana, 2022). The key policy objective of both policies was to increase access to electricity and alternative energy sources for low-income households (Ayamolowo, Manditereza & Kusakana, 2022). However, due to inconsistencies in policy implementation coupled with an escalation in income poverty due to increasing levels of unemployment and loss of livelihoods, energy poverty has continued to intensify especially in urban areas.

The concept of a just and equitable renewable energy future, often termed as energy democracy, seeks to integrate environmental sustainability, community resilience, social justice, and economic equity. A prominent framework within this discourse conceptualizes energy democracy through three primary objectives (Allen, Lyons & Stephens, 2019, 2):

- resisting the hegemony of the fossil fuel agenda,
- reclaiming public and social control over the energy sector and,
- restructuring the energy industry to foster democratic governance, social justice, inclusivity, and environmental sustainability.

These goals are further translated into actionable strategies (Allen, Lyons & Stephens, 2019, 2) that resonate strongly with the South African context:

- disrupting the existing fossil fuel-dominated energy systems,
- transitioning from centralized energy production models to distributed generation systems,
- establishing democratic, community-based governance over energy systems, encompassing both supply and demand and,
- promoting equitable ownership and access to energy resources, with particular attention to race, gender, and socioeconomic disparities.

Energy poverty crisis in South Africa is deeply intertwined with issues of gender, thus making the women-energy nexus a critical area of focus. The intersection of gender and energy poverty is particularly pronounced in low-income urban settings, where women often bear the primary responsibility for managing household energy (Allen, Lyons & Stephens, 2019, 2). As a result, they disproportionately experience the socio-economic and health burdens associated with energy poverty. Drawing inspiration from the resonance with the anti-apartheid expression *"Wathint' umafazi, wathint' imbokodo"* (you strike a woman, you strike a rock) this study explores how the *imbokodo* paradigm could be leveraged towards opportunities for mitigating energy poverty in low-income urban households such as in Alexandra township in Johannesburg while also contributing to national and global initiatives towards mitigation of climate change.

The study investigates the clean-cooking value chain within Alexandra township, Johannesburg, with a focus on evaluating how empowering women can both mitigate energy poverty and support broader climate change mitigation objectives at national and global levels. The research critically examines the role of women in clean energy generation and consumption for zero-carbon cooking with the objective of developing gender-sensitive interventions that address specific challenges encountered by women in these settings.

1.2. Problem statement and rationale

The growing affordability and widespread adoption of solar photovoltaic (PV) technologies across multiple sectors present a significant opportunity. At appropriate scale and design, solar-PV systems can support solar-powered induction stoves, thus offering significant potential to substantially reduce carbon-intensive cooking practices and also mitigate related health risks. However, successful implementation of these technologies in marginalized areas requires a thorough examination of critical structural barriers (Shapurjee & Charlton, 2013, 8) which impede widespread adoption. These include limited roof space, inadequate infrastructure, and the potential for theft.

This backdrop primarily arises from the legacy of the spatial and development planning policies of the apartheid era Such that, to date, South African cities are marked by high levels of segregation (mainly by income levels) and low-density development, especially in middle- and high-income suburbs. This situation results in significant financial and infrastructural difficulties in distributing electricity (Baker & Phillips, 2019, 182). The Department of Energy (DME, 2012, 22) points to reality that energy poverty persists as a critical issue in South Africa, disproportionately affecting marginalized households despite their access to the grid. Inadequate grid infrastructure, limited access to modern energy services, and reduced economic opportunities are prevalent challenges in both rural and low-income urban contexts within contemporary

South Africa. Communities such as those living in Alexandra township in Johannesburg and Chebeng village in Limpopo were systematically deprived of resources and opportunities during apartheid, and continue to experience the impacts of the resultant historical injustices. The shared historical marginalization of places such as Alexandra township in urban areas and Chebeng village in rural areas make the envisaged mutual benefits under urban-rural energy cooperatives under JET particularly relevant.

As affordability of green technologies for renewable energy (RE) continues to improve primarily due to falling procurement costs, a new tax incentive for RE investment has been announced by the government in March 2023 (National Treasury, 2023). The tax incentive, commonly referred to as the rooftop solar tax incentive, provides an opportunity to examine the effectiveness of such measures towards benefiting low-income communities and households. Under this incentive, individuals/households investing in rooftop solar panels will be eligible for a rebate of 25 percent of the panel cost, with a maximum rebate of R15 000 (National Treasury, 2023). The complementarity between rural and urban contexts as appraised in this study presents an untapped opportunity for innovative, market-driven models aimed at ensuring that rural and urban low-income households, and particularly women, equitably participate in the benefits of responsive energy policy reforms. Despite this promising potential, several critical barriers still require to be systematically addressed.

1.3. Objectives

Within the broader pursuit of an inclusive transition to low-carbon economies under the Just Energy Transition (JET) framework, the study explored the complementarity between rural and urban low-income communities and households in relation to generation and consumption of renewable energy based electricity with women empowerment as a critical goal of the initiative. It therefore examines how women can be empowered as energy prosumers—entrepreneurs who generate and supply clean energy for their own use, particularly for cooking, and for the wider economy. By leveraging the strengths of rural solar generation and urban energy demand (with clean cooking as the key energy use), the study assesses the potential for empowerment through a mutual-benefit structure such as a cooperative model. Such an approach would not only support sustainable and equitable energy transitions but would also position women as leaders in zero-carbon cooking initiatives and climate change mitigation efforts in both contexts.

This study adopts a case study approach to assess the complementarity between Alexandra township in Johannesburg (see Figure 1c) and Chebeng in Limpopo (see Figure 1b), as urban and rural case studies respectively. The urban context of Alexandra provides a platform for an energy consumer cooperative, while the rural setting of Chebeng offers a foundation for an energy generation cooperative. By assessing the potential for integration of solar-powered induction stoves and energy cooperatives, the study explores how these distinct settings could leverage mutual benefits by enhancing each other's strengths. The interplay between the two contexts offers a holistic perspective towards tackling energy poverty whilst leveraging a consumer-generator synergy for zero-carbon cooking.

The study therefore entails the following key components:

- An urban-based ethnographic investigation into the potential for a zero-carbon energy consumer cooperative supporting clean induction stove cooking among low-income households in Alexandra (see figure 1c)
- A rural-based ethnographic examination of the potential for a solar-PV electricity generation cooperative in Limpopo Province, focusing primarily on rural women with potential access to land for leasing (see figure 1b).
- A cross sectional evaluation of the feasibility for a mutually beneficial wheeling framework for electricity generated by the Limpopo cooperative to the Alexandra consumer cooperative in Johannesburg (see figure 1a).

1.4. Research question and sub-questions

In view of the background and motivation for the study, the overall research question was conceptualized as follows: How could an *imbokodo*-driven energy cooperative model empower women in rural and urban areas as energy entrepreneurs through leveraging solar electricity wheeling for clean cooking in low-income households and thus create mutual benefits while also advancing the just energy transition (JET) paradigm?

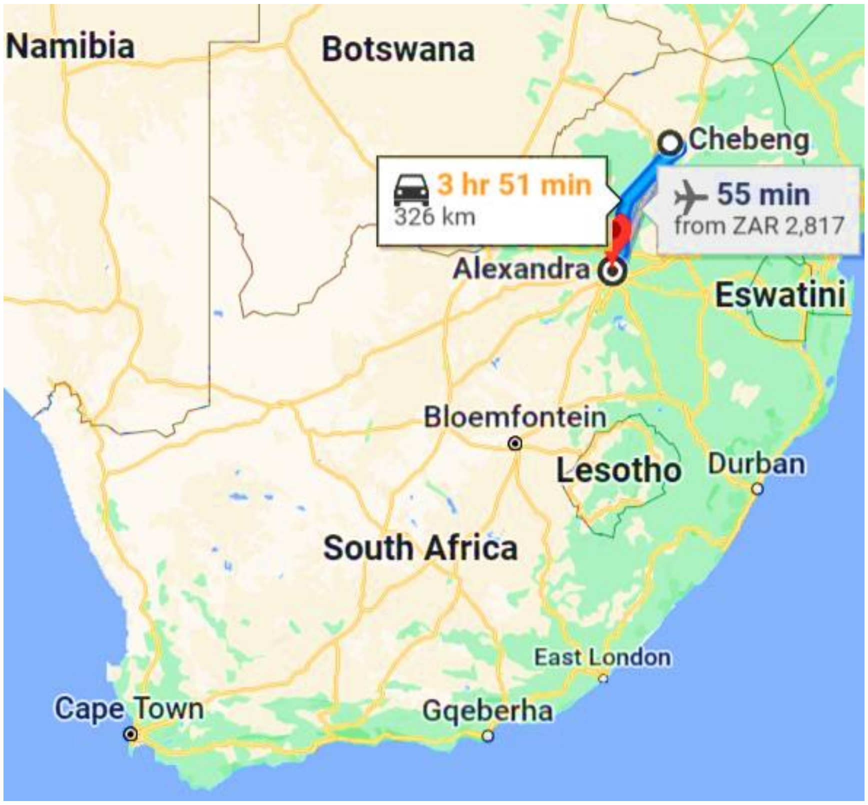

Figure 1a. South Africa - Distance between Alexandra and Chebeng. Source: Google Maps (nd)

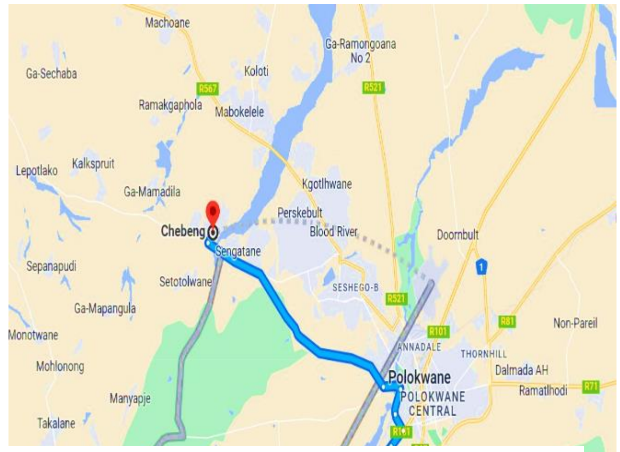

Figure 1b – Chebeng in Limpopo. Source: Google Maps (nd)

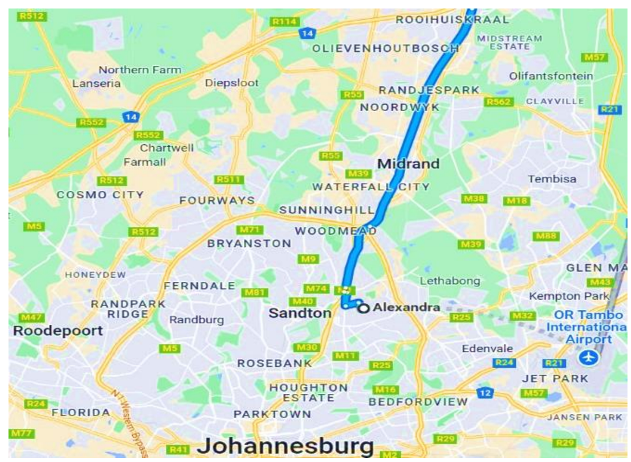

Figure 1c – Alexandra township in Johannesburg. Source: Google Maps (nd)

1.4.1. Sub-questions

In order to guide the formulation of a working hypothesis, conceptual framework and research method of the study, the research question was structured into three sub-questions as follows:

- **Sub-Question 1:** What is the potential of adopting induction stoves as a substitute for combustible fuels among low-income households in Alexandra township when considering cultural preferences for traditional cooking methods and limited access to alternative technologies?

- **Sub-Question 2:** To what extent can rural-urban women-led cooperatives leverage wheeling as a business model to address operational cost barrier associated with the adoption of solar-PV induction stoves among low-income households, given prevailing low levels of commercialization?
- **Sub-Question 3:** How could a women-led operational model be leveraged towards assembly, repair, and maintenance of solar-PV induction stoves, thus contributing to Just Energy Transition (JET) outcomes (green skills development, job creation, and entrepreneurship among others) in both rural and urban contexts?

1.5. Expected findings (Working hypothesis)

The constraints of limited roof space and the risk of theft or vandalism in low-income urban areas highlight the need to address the intersection of gender and energy poverty, particularly for cooking. This study hypothesizes that coupling women-led solar-PV electricity generation cooperatives in rural areas with consumer cooperatives in low-income urban households can facilitate wheeling of clean electricity for zero-carbon cooking with low-carbon technologies such as induction stoves. Such a model could be expected to not only alleviate energy poverty but also create green jobs, skills, and entrepreneurship opportunities for women in both urban and rural settings. The study anticipates that wheeling solar-PV electricity from a women-led generation cooperative in Limpopo to a women-led consumer cooperative in Alexandra can facilitate a firmly grounded translation of the Just Energy Transition (JET) framework. Overall, the approach could serve as a viable model for empowering women across the renewable energy value chain in South Africa.

1.6. Definition of key terms

Clean cooking: Describes the adoption of sustainable and environmentally friendly energy sources, such as solar power, as alternatives to combustible fuels for cooking purposes, especially among low-income households.

Cooperative: Describes a membership-based socio-economic organization that operates with a primary focus on optimizing value for its members as opposed to solely focusing on monetary profit as commonly pursued in private sector entities. This makes cooperatives essential contributors toward addressing the social and environmental aspirations of its members and communities in general. In the context of this study, their fundamental purpose would be in facilitating the transition towards a more sustainable energy paradigm by prioritizing societal welfare and collective benefits based on shared ownership, and democratic decision-making on energy generation and consumption.

Energy poverty: A situation where individuals, households or communities experience affordability constraints in accessing or benefiting from adequate and clean energy sources for their various household energy needs such as cooking or conducting informal/micro-enterprises for their livelihoods.

Host- household: Refers to the family or group of individuals with whom the researcher lives or interacts closely with during fieldwork. The host household serves as a primary site for gathering qualitative data, offering the researcher insights into the lived experiences and perspectives of the people within that cultural setting.

***Imbokod*o:** Originating from the isiZulu phrase "*Wathint' umfazi, wanthint' imbokodo*," this expression extends beyond a simple description of a woman and encompasses a profound representation of strength and resilience. In the context of this study, *imbokodo* is metaphorically leveraged to highlight the resilience and strength of women as agents of change, just as *imbokodo* is symbolized by a strong and unyielding stone in African, and more specifically isiZulu, traditional knowledge system.

Just Energy Transition (JET): Emerges from the pursuit of transitioning from carbon-intensive to low-carbon economies and lifestyles, but with the imperative of equity and inclusivity as key principles of such a transition.

Solar cooking: Two main solar cooking typologies have been systematically studied and reported – solar stoves and solar-PV induction stoves. Solar stoves are characterized by their reliance solely on direct solar radiation and are defined as cooking technology that exhibit simplicity and affordability. However, it suffers a key disadvantage in that it is only functional when the sun shines. It also entails extended cooking durations. In contrast, solar-PV induction stoves are powered by electricity generated by solar-PV panels resulting for expedited and more precise cooking processes. However, the technology suffers a key disadvantage of high upfront cost and also requires battery storage for cooking when direct solar radiation is not available for electricity generation from the PV-system.

Solar-PV induction stove: In contrast to direct heating with electrical energy, induction stove technology utilizes electromagnetic induction to achieve efficient and precise heat transfer. The integration of renewable energy such as solar-PV as a power source for induction stoves exemplifies innovative and sustainable solutions to meet energy demand through low-carbon resources and technologies.

Stokvel: A collective savings and investment scheme where members come together to pool financial resources regularly, typically every month. These pooled funds are then managed collectively and distributed among members according to predetermined rules and agreements. Stokvels serve various purposes, including social support, financial security, and investment opportunities. They are primarily based on high levels of trust and mutual understanding among members.

Wheeling: This entails the generation of electricity at a remote site relative to a targeted consumer which thus necessitates the transmission of the electricity through a third-party grid. It normally entails grid-use fees in compliance with related national policies and regulations aimed at governance of operations of the national grid.

Zero-carbon cooking: Refers to preparing food using energy sources that emit minimal or no carbon dioxide (CO_2) or other greenhouse gases. It typically involves the use of renewable energy, such as solar, to power cooking appliances like induction stoves. The goal is to eliminate reliance on fossil fuels which contribute to carbon emissions and environmental degradation, thus promoting sustainable, clean energy solutions for daily cooking needs.

1.7. Structure and organization of the research report

The report is structured into seven chapters. Chapter 1 provides an introduction, encompassing an overview, background, statement of the research problem, study objectives, research question and sub-questions, working hypothesis and this outline of chapters. In Chapter 2, a review of pertinent literature is presented to establish the theoretical base of the study. Selection and review of literature were guided by key factors including the potential of PV-based induction stoves for providing affordable clean cooking energy in low-income households, solar-PV trends, consumer and generation cooperative business models, solar potential in South Africa's climatic zones (with a focus on Limpopo), and the influence of rural tribunals on land use and administration for renewable energy (RE) projects.

Chapter 3 outlines the research method thus covering data requirements, criteria for data collection and analysis, derivation of findings, and ethical considerations. Data presentation and analysis corresponding to the sub-questions are presented in Chapters 4 and 5. Chapter 4 explores ethnographic findings concerning current cooking practices by households in Alexandra and their willingness to adopt induction stoves once prototyped for cooking. In Chapter 5, an analysis is conducted on the geographical feasibility and socio-political consequences of current tribal governance over land, alongside the possibilities for solar generation within the cooperative network. In Chapter 6, the focus shifts to the South African wheeling landscape, spotlighting three key entities leading this effort: PowerX, Mahlako Financial Services, and Ener-Gi-Africa. Notably, the latter two prioritize the inclusion of women in their workforce. Finally, Chapter 7 presents the consolidation of subfindings in order to derive overall findings and conclusions as well as recommendations for future research.

The report also has the following Appendices:

- **Appendix 1:** Research instruments and tools used.
- **Appendix 2:** Ethics clearance letter

Chapter 2

Literature review

2.1. Introduction

This chapter applies a thematic analysis approach to identify and systematically review the relevant literature. According to Riger and Sigurvinsdottir (2016, 33), thematic analysis is a qualitative method that involves a thorough examination of complexities and interactions within a subject matter of a study to guide the grouping into themes. The study leverages thematic analysis approach as it offers a holistic understanding of how clean inductive-stove cooking and solar-PV energy can contribute to JET within a specific, localized socio-economic and geographical setting. Guided by the approach the analysis centers on women's empowerment, gendered energy poverty, and complementarity between urban and rural communities and their contexts.

In this multidisciplinary context, thematic analysis serves the purpose of bridging across the various disciplines involved in a study. Literature selected for the review was identified through a comprehensive search of academic databases, using keywords such as "*gendered energy poverty"*, "*clean induction-stove cooking", "cooperative business model"*, "*electricity wheeling", Just Energy Transition (JET)", "solar-PV*". The search accessed peer-reviewed articles, reports, and policy documents published in the last decade to ensure an up-to-date perspective of the subject matter. Studies conducted in similar socio-economic contexts were prioritized, as these offer insights directly applicable to the research focus.

Readings were then categorized according to the study themes. The chapter concludes by synthesizing the findings in order to lay the groundwork for the subsequent analysis in Chapters 4, 5, 6 and 7.

To guide the literature review, the main themes under were articulated as follows:

- status quo on energy consumption in low-income households and communities
- nexus between energy poverty and gender among low-income households in urban areas
- solar-PV induction stove value chain
- energy cooperatives, wheeling challenges and opportunities in non-conventional markets
- exemplary case studies highlighting the success and impact of cooperative models

2.2. Energy consumption patterns of low-income households in South Africa

Department of Energy (DoE) (2012, 22) notes that the issue of energy poverty experienced by disadvantaged households in South Africa persists, even where such households are connected to the electrical grid. Based on living standards and income levels in South Africa, Table 1 reveals a pronounced socioeconomic gradient in the choice of primary energy sources for cooking.

Table 1. Variations in energy consumption and poverty in South Africa. Source: (Department of Energy, 2012, 22)

	Electricity	Firewood	Paraffin	Gas	Solar System	Coal	Generator	Other	Total	Base N
South Africa	76	11	7	3	2	1	0	0	100	2970
Geographic location										
Urban formal	91	1	2	3	2	0	0	0	100	1873
Urban informal	68	1	27	0	2	1	1	0	100	239
Rural, trad. auth. areas	53	36	8	3	0	0	0	0	100	619
Farms	62	18	11	3	1	4	0	0	100	239
Province										
Western Cape	94	0	1	3	1	0	0	0	100	393
Eastern Cape	65	18	10	4	2	0	0	0	100	330
Northern Cape	81	10	1	7	0	0	0	1	100	155
Free State	87	2	5	2	4	0	0	0	100	223
KwaZulu-Natal	72	14	9	4	1	0	0	0	100	575
North-West	75	11	10	2	1	1	0	0	100	217
Gauteng	84	0	10	2	2	1	1	0	100	583
Mpumalanga	62	23	4	1	2	7	1	0	100	224
Limpopo	55	40	3	1	0	0	0	0	100	270

Households in the poorest income quintiles show a higher prevalence of using firewood and paraffin, even among those with access to electricity. This suggests the presence of critical barriers or entrenched practices hindering a complete transition from combustible fuels to electricity for cooking among socio-economically disadvantaged households.

To facilitate the identification of households experiencing energy poverty, Department of Energy (2012, 8) established a set of criteria where households that satisfy any of the following conditions may be classified as experiencing energy poverty:

- spending 10% or more of their monthly household earnings on energy costs
- experiencing challenges related to affordability and accessibility of energy services,
- inhabiting homes with low thermal efficiency

In an examination of household energy consumption patterns over the previous ten years, Sustainable Energy Africa (SEA, 2018, 26) notes an upward trend in the adoption of electricity to meet fundamental household energy needs, specifically for cooking. Notably, the use of electricity for cooking has experienced the highest increase (23%) compared to other end-uses. SEA (2018, 27) breakdown of household energy patterns shows 76% of households (a significant majority), rely on electricity for cooking.

This percentage rises even higher to 91% in formal urban areas, thus underscoring the prevalent use of electricity in urban settings. However, in urban informal settlements, approximately two-thirds of households (68%) use electricity for cooking, while nearly one-third (27%) still rely on paraffin as an alternative energy source (SEA, 2018, 27).

Among households with access to electricity, a small but notable 8% continue to depend on firewood for cooking. In contrast, non-electrified households primarily rely on paraffin (50%) and firewood (40%) as their predominant energy sources for cooking, thus highlighting the disparities in energy access and utilization among different segments of the population (SEA, 2018,27).

Qeqe, Kapingura and Mgxekwa (2022) examined the prevailing Eskom tariff structure and its impact on affordability which highlights the discrepancy between the desired vision set out in the Energy White Paper of 1998 versus prevailing tariff levels. The study further highlights ongoing increases in electricity tariffs and their adverse effect on households which now have to continue allocating increasing financial resources towards electricity costs. Consequently, this increased expenditure on electricity limits available resources for other essential needs. The study therefore concludes that a country's electricity tariff structure should respond to the critical importance of ensuring affordability as a fundamental objective in its design and implementation.

2.3. Evaluating energy access and disparities

In contemporary societies, power and authority are predominantly concentrated in the hands of men across political, economic, and familial spheres (Ateba, Prinsloo & Fourie, 2018, 54). This entrenched power dynamic reinforces rigidly defined gender roles. In particular, the allocation of cooking and other household responsibilities to women is deeply rooted in historical and cultural norms. Historically, many societies have established the notion that domestic duties are inherently suited to women. This division of labor has been perpetuated through institutionalized cultural practices and societal expectations, thereby reinforcing a reality where women's roles are predominantly confined to the domestic sphere (Ateba, Prinsloo & Fourie, 2018, 54).

Cultural beliefs and traditions further entrench these gender roles, with many societies viewing household tasks, including cooking, as inherently feminine responsibilities. Such norms are transmitted across generations, becoming ingrained in societal expectations and creating significant barriers for women seeking to transcend these roles (Ateba, Prinsloo & Fourie, 2018, 54). The interplay of historical precedents, cultural norms, economic structures, and power dynamics collectively constructs a framework in which cooking and other household duties are predominantly assigned to women. This framework thus reinforces traditional gender roles and restricts women's opportunities for involvement in wider economic and decision-making domains (Ateba, Prinsloo & Fourie, 2018, 54).

There is a critical role of energy availability in fostering social development and enhancing industrial competitiveness (Ateba, Prinsloo & Fourie, 2018, 52). Access to reliable and sufficient energy is foundational for progress and economic growth. Despite the growing recognition of the need for improved access to sustainable energy, energy inequality persists and even intensifies in contemporary societies (Ateba, Prinsloo & Fourie, 2018, 52). This ongoing disparity indicates that while some regions and populations benefit from advancements in energy technology and access, others continue to face significant barriers, resulting in a widening gap in energy availability and quality. It is within this context that traditional gender roles and socio-economic factors frequently limit women’s access to modern energy solutions but also exacerbates their vulnerability to energy poverty.

2.4. Gender and energy poverty nexus in low-income urban areas

Given that energy poverty is intricately intertwined with the social and spatial contexts of low-income households, it can be conceived as a contemporary fuel deficit. Within this framework, understanding the gendered roles and dynamics within traditional households illuminates the need for radical Pan-African feminist perspectives in green transition agendas. This transformative approach aligns with the notion of gendered dimensions of energy poverty and energy justice as substantiated in Moniruzzaman & Day (2020).

In addition, Odeku (2019) posited that access to electricity ensures an energy resource that is able to meet a wide range of socioeconomic needs among households and communities. Women in particular are dependent on electricity for carrying out their daily activities such as cooking, cleaning, and other household commitments (Alstone, Niethammer, Mendonça, Brendon & Eftimie, 2011). According to SEA (2017,18), a consistent and nuanced pattern emerges within low-income households, revealing the limited agency of women in controlling household resources and participation in decision-making processes, leading to minimal influence over energy purchases and fuel choices. This multifaceted dynamic perpetuates a disproportionate burden on women and children, as they experience heightened exposure to unsafe fuels and bear the detrimental health consequences associated with such energy sources. The nuanced implications of this gender disparity underscore the complex nature of energy poverty, thus illuminating the unequal vulnerability of women to its adverse effects compared to men.

Critically examining prevailing power dynamics that marginalize women's perspectives, particularly in the pursuit of ambitious targets like achieving net-zero carbon emissions by 2050, reveals gender blindness within South Africa's energy transition and thus calls for disruption of prevailing male-dominated approaches (Moniruzzaman & Day, 2020). Historically, efforts to reduce South Africa's dependence on fossil fuels and promote RE transitioning have been characterized by hierarchical and homogeneous approaches that fail to adequately address the issue of gendered energy poverty (Allen, Lyons & Stephens, 2019). However, drawing inspiration from radical Pan-African feminism, an *imbokodo*-inspired approach emerges as a potential catalyst for change (Ramantswana, 2019, 2). In a similar vein to Eurocentric feminist endeavors, in the context of the proposed study, *imbokodo* perspective seeks to diversify ownership, management, and beneficiaries within the energy sector, with the broad aim of challenging existing power structures and nurturing inclusivity and diversity as conceptualized by Allen, Lyons & Stephens (2019).

2.5. Solar-PV trends

According to GreenCape (2021), the adoption of solar photovoltaic (PV) systems has recently witnessed substantial growth across various sectors such as residential, commercial, governmental, and industrial buildings. This surge can be attributed to several factors such as the escalating cost of grid-supplied electricity, and the declining costs associated with procurement of PV technology which has significantly enhanced affordability for the technology. Notably, cost analysis presented in Table 2 demonstrates a divergence in pricing between small-scale systems (below 100 kWp – kilowatt-peak) and large-scale systems (above 500 kWp), with smaller installations averaging approximately R15k per kWp and larger installations falling below R10k per kWp (GreenCape, 2021, 2).

Table 2. Overall solar-PV system costs. Source: (GreenCape, 2021, 2)

System size	Capital cost of system (per kWp)	Power Purchase Agreement tariff (per kWh)
> 50 kWp and 100 kWp	R12 000 – R15 000	R0.90 – R1.20
>100 kWp and <500 kWp	R9 000 – R13 000	R0.80 – R1.00
>500 kWp	R8 000 – R12 000	R0.60 – R0.90

According to Greencape (2022, 6), the procurement of new generation capacity in South Africa is predominantly driven by the Integrated Resource Plan (IRP) of 2019, and showcases substantial growth potential. Notably, the well-established framework of the Renewable Energy Independent Power Producer Procurement Program (REIPPPP) has contributed to relatively low entry barriers, enabling a wider range of stakeholders to actively engage and contribute to the market's expansion and maturation. As shown in Table 3, there are emerging and evolving opportunities within the large-scale RE market in South Africa due to the evolving enabling environment.

Table 3. Opportunities in large-scale renewable energy market. Source: (GreenCape, 2022, 7)

Opportunity	Stakeholders	Key drivers	Barriers	Term	Macro context
Public procurement	• Developers/IPPs, EPCs, OEMs, O&Ms. • Industrialists. • Local manufacturers. • Financiers & legal. • Municipalities. • Energy-intensive users.	• 11.8 GW by 2030. • Expected 35 GW decommissioned coal by 2050. • Electricity Regulations on New Generation Capacity. • Municipal Energy Resilience fund in the Western Cape.	• Requirement for grid infrastructure investment to upgrade the grid. • Local governments lack capacity (financial, technical, procurement planning).	Short term (**Present**).	• Energy crisis. • Unemployment rates. • Economic Recovery. • Just Energy Transition. • Infrastructural development plans. • Heavy industries and mining sector net-zero targets. • The global[8] effort to drive a hydrogen economy and elimination of CO_2 emissions by replacement of existing grey/black hydrogen processes. • COP 26.
Private procurement		• 100 MW licensing exemption. • Declining RE prices. • Wheeling framework.	• Policy and clarity of procurement rules. • Capital requirements.	Medium to long term (**3 – 5 years**).	
Local manufacturing of renewable energy components and systems	• Local manufacturers, OEMs, EPCs. • dtic, DMRE, IPPO.	• Increased local content requirements in all public procurement, including in upcoming REIPPPP rounds.	• Policy uncertainty. • Procurement rules change (90:10 in REIPPPP). • Commercial viability. • Market certainty.	Medium to long term (**3 – 10 years**).	

Since mid-2015, solar PV has emerged as a cost-competitive alternative to Eskom's new coal-fired power plants. According to Baker (2017, 104), this shift mirrors a global trend where solar PV is rapidly approaching parity with traditional energy sources. The REIPPPP has played a pivotal role in this transformation mainly by driving a remarkable decrease in tariffs for successful projects. As shown in Table 4, on average, solar PV tariffs have dropped by 75%, wind tariffs by 50%, and CSP tariffs by 43% since Round 1 in 2011. In addition, REIPPPP has attracted substantial investments, thus positioning it as one of the country's most significant contributor to capital inflows in recent years.

Table 4. Average tariffs. Source: [(CSIR, 2017, 5) cited in (Baker 2017, 105)]

Tariffs	Round 1 (Nov. 2011)	Round 2 (March 2012)	Round 3 (Aug. 2013)	Round 4 (Nov. 2015)	Average percentage drop, Round 1–4
Wind	R 1.52	R 1.19	R 0.87	R 0.62	50%
Solar PV	R 3.65	R 2.18	R 1.17	R 0.62	75%
CSP	R 3.55	R 3.32	R 3.11	R 2.02	

2.6. Business model canvas

Business model canvas, introduced by Osterwalder, Pigneur, and Clark (2010, 44), has gained increasing recognition as a valuable framework for the systematic development and analysis of business structure and operation. Its inherent capability to elucidate the core vision of a business and the underlying thought processes has proven notably attractive. As emphasized by the IEA PVPS (2014), when appropriately employed as a conceptual tool rather than a substitute for essential planning, business model canvas has the potential to enrich and complement these processes, thus offering a more nuanced understanding of the opportunities and challenges inherent in any business venture.

Within the context of the prevailing energy crisis in South Africa and the accompanying tax incentives for solar panels, a promising market potential and value proposition emerges for the deployment of solar induction stoves. This, in turn, holds the potential to propel the adoption of renewable energy (RE) technologies within marginalized communities, particularly among women. To investigate and elucidate on the dissemination of these technologies with a focus on engaging with the solar energy supply chain as a green electricity source, this study closely referenced the nine blocks illustrated in Figure 2. Considering the constraints imposed by our current 'carbon-constrained' societies, governments worldwide are actively pursuing clean energy technologies and grid independence to address the impacts of climate change and energy poverty in rural, peri-urban, and urban areas. (Ockwell et al., 2019, p. 2).

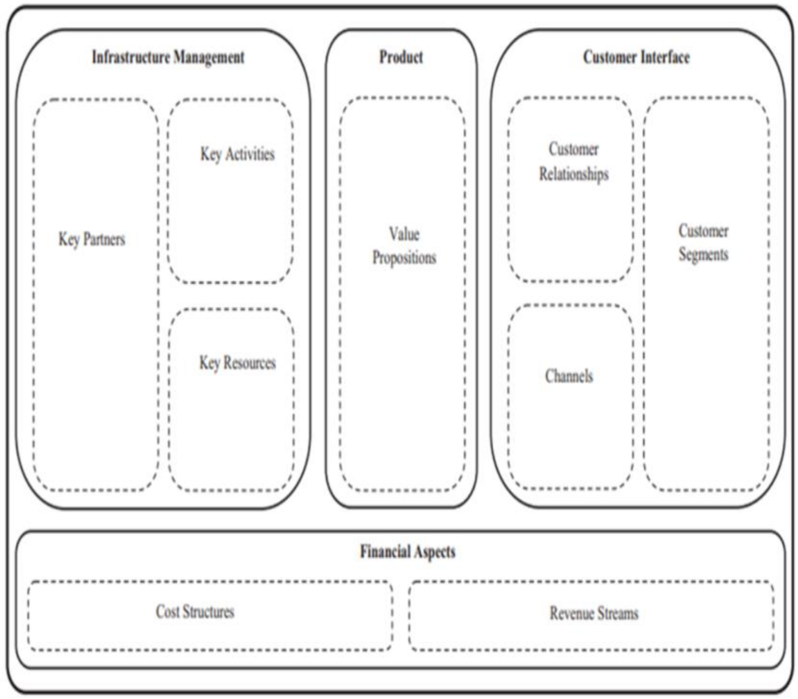

Figure 2. Business Model Canvas. Source: (Osterwalder et al, 2010, 44 cited in IEA PVPS, 2014, 8)

2.7. A consumer and generation cooperative

Cooperatives rely on the active participation and financial contributions of their members to fund their activities for direct mutual benefits for the members. Members invest in the cooperative and collectively share the ownership of its capital (Sánchez-Robles, Saura & Ribeiro-Soriano, 2023, 4). This cooperative capital is distinct from traditional shareholder-owned businesses where profits are distributed to external shareholders. Cooperatives have the advantage of mobilizing financial resources from their members, who have a vested interest in the success of the cooperative. In addition to member contributions, cooperatives may also seek financial assistance from external sources such as banks or credit institutions. This growth-oriented approach allows cooperatives to pursue sustainable development, expand their impact, and contribute to the well-being of their members and the communities they serve.

Pueyo and Maestre (2020) advocate for the utilization of cooperatives as a means to foster energy entrepreneurship based on an ecosystem where they can access essential resources such as knowledge, social support, and symbolic capital. By establishing social networks based on cooperatives, women entrepreneurs can benefit from solidarity, achieve financial autonomy, and enhance their contribution to sustainable communities. Consumer cooperatives emerge as a viable response to unmet demands and high risks, especially in face of obstacles encountered in accessing private financing. As demonstrated in the operational framework in Figure 3, Sadowski (2017) argues that consumer cooperatives emerge as a means to mitigate uncertainties and risks that inhibit private sector investments in unconventional markets such as low-income households living in areas with inadequate infrastructure and resources. The decision of individuals to join such cooperatives hinges upon the potential of such alternative market structures to safeguard their interests, mitigate risks, and yield the expected benefits.

On the other hand, energy or generation cooperatives consist of an ecosystem of members who pool their resources and expertise to develop renewable energy projects as shown in Figure 3. Members can benefit from economies of scale, share the costs and risks of project development, and access financing options that may be otherwise unavailable to individual members. Lakomiak (2022, 10) also emphasizes the role and significance of energy cooperatives in electricity generation from renewable resources and maintaining a supply-demand equilibrium. The study highlights the contribution of cooperatives as follows:

- Energy cooperatives fulfill their own energy needs and meet the requirements of interconnected members connected to a power distribution network
- By becoming prosumers, members actively participate in electricity generation and consumption
- The combined installed capacity of renewable sources should cover at least 70% of energy requirements for the cooperative and its members throughout the year
- Total installed capacity should not exceed 10 MW to maintain balance
- Energy cooperatives offer cost-effective benefits for new prosumers
- Collaboration involves the energy cooperative, electricity seller, and distribution system operator

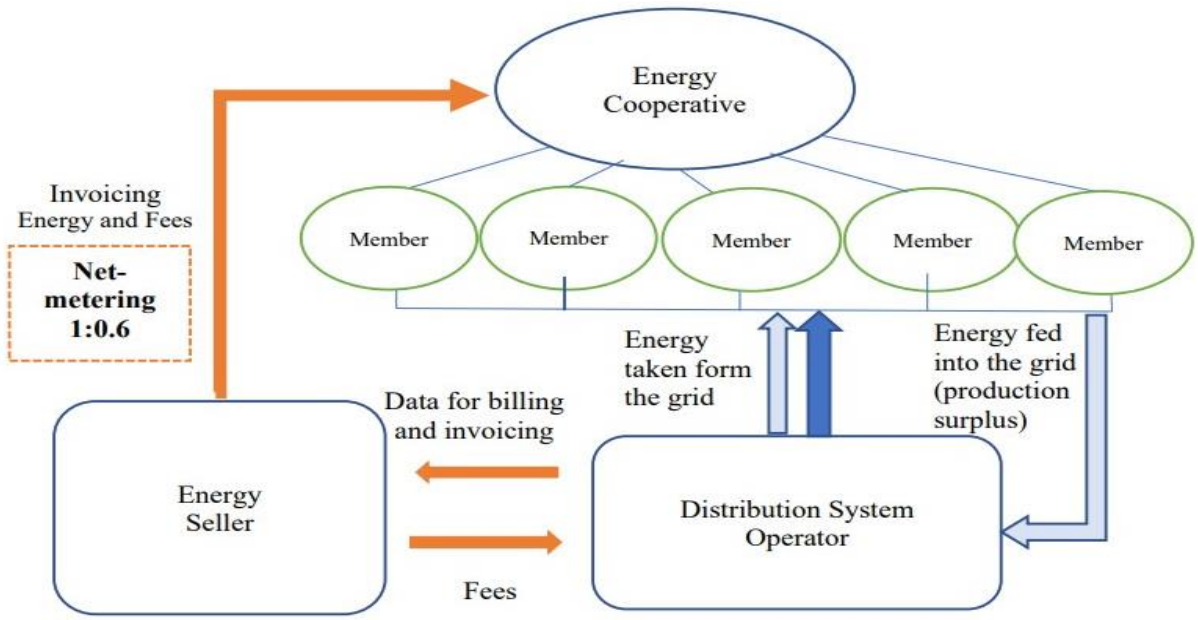

Figure 3. Operational framework in electricity generation from RE sources within an energy cooperative. Source: (Łakomiak, 2022, 10)

2.8. The South African Cooperative Landscape

In South Africa, the legislative framework governing cooperatives is primarily defined by the Cooperatives Act 14 of 2005, which is based on internationally recognized cooperative principles (Department of Trade and Industry [DTI], 2010, 3). This Act underwent significant amendments in 2013, accompanied by the introduction of a Code of Good Practice (DTI, 2010, 3). Complementing this framework are key policy documents, such as the DTI's Co-operative Development Policy of 2004 and the Co-operative Regulations of 2007 (DTI, 2010, 3). Despite these regulatory efforts, the DTI's "Integrated Strategy on the Development and Promotion of Co-operatives 2012-2022" highlights the persistent challenge of inadequate support mechanisms as a critical factor contributing to the high failure rate of cooperatives in the country (DTI, 2010, 36).

In response to the oppressive apartheid policies that restricted black South Africans to townships and 'homelands,' these communities developed alternative economic structures, such as consumer cooperatives organized through *stokvels* — community-based savings groups and burial societies (DTI, 2010, 25). The *stokvels* enabled members to purchase goods in bulk at discounted prices and provided financial support for funeral (DTI, 2gig010, 25). While these informal cooperatives have evolved into a significant economic force with approximately 800,000 active groups involving around 10 million members, their mixed success highlights the limitations of informal cooperative structures, especially when faced with systemic challenges. The internal conflicts and governance issues that have plagued many of the *stokvels* and cooperatives (DTI, 2010, 25) suggest that a transition to more formalized, well-supported cooperative models may be necessary for operation in the energy sector with the ultimate objective of achieving JET outcomes.

A critical challenge facing cooperatives today is the lack of a dedicated support agency that could provide focused and coordinated assistance (DTI, 2010, 36). The absence of such an agency leads to fragmented and ineffective support, characterized by inadequate mentorship, limited investment, and a pervasive sense of neglect across various government departments and enterprise development agencies (DTI, 2010, 36). This is particularly concerning in the context of JET, where effective cooperative models could be instrumental in addressing energy poverty, especially for women in low-income communities. The formation of cooperatives primarily to access financial grants such as the Co-operative Incentive Scheme (CIS), rather than to genuinely build a resilient cooperative movement, further complicates the sustainability and efficacy of these initiatives (DTI, 2010, 36). This raises important questions about the need for more responsive governance frameworks and stronger community engagement to ensure that cooperatives are not only formed with genuine intent but are also capable of managing and utilizing their resources effectively.

The high failure rates of cooperatives, particularly in rural provinces such as the Northern Cape, Eastern Cape, and Free State—where failure rates are 97.5%, 93%, and 92%, respectively (DTI, 2010, 36)—pose significant challenges for leveraging cooperatives for JET-driven initiatives. Even in more developed provinces like Gauteng, KwaZulu-Natal, and the Western Cape, high failure rates (with the Western Cape recording a 93% failure rate) indicate systemic issues that must be addressed if cooperatives are to play a meaningful role in energy transition strategies (DTI, 2010, 36). These statistics underscore the urgent need for more effective policy interventions aimed at enhancing the resilience and sustainability of cooperatives, particularly in their potential role in bridging the urban-rural divide in energy access. Moreover, the involvement of state-owned enterprises (SOEs) such as Eskom, Transnet, Telkom, and Airports Company South Africa (ACSA) is critical in providing the logistical and infrastructural support necessary for cooperatives to thrive (DTI, 2010, 48). These SOEs must also create procurement opportunities for cooperatives, in alignment with existing legislative frameworks (DTI, 2010, 48). However, in the context of JET, the role of SOEs needs to be re-envisioned to ensure that their support is not only logistical but also strategically aligned with the broader goals of social equity and sustainability. This might involve prioritizing energy cooperatives that focus on clean energy solutions, such as solar-PV systems, particularly in marginalized communities.

The Rural and Community Development Fund which falls under the National Empowerment Fund, was designed to promote sustainable change in social and economic relations and supporting the goals of growth and development in the rural economy, through financing of sustainable enterprises (National Empowerment Fund, nd). This would be achieved through the mobilization of rural communities in legal entities such as cooperatives, in order to facilitate participation in the broader economic activities and realize the economic transformation goals for rural South Africa. The fund has three products: Acquisition Finance, Expansion Capital and Project Finance (New Venture/Start-up/Greenfields) with the funding threshold ranging from a minimum of R1 million to R50 million (National Empowerment Fund, nd).

SunKissed Technologies has implemented an innovative financing solution called "Solar Society" which leverages a *stokvel* platform based on a cooperative model. The model, commonly found in South African communities, involves members contributing a set amount of money over time, with lump sum payouts distributed to individuals on a rotating basis (News24, 2023). By adopting this approach, Solar Society enables households and small businesses—typically unable to afford the significant upfront costs of solar PV installations—to access renewable energy technologies. These installations include not only solar panels but also crucial components such as battery storage and inverters.

What sets Solar Society apart is its community-driven approach to financing. Unlike traditional financing options, Solar Society requires no upfront payments. Instead, SunKissed Technologies installs the solar PV systems immediately, and members of the *stokvel* collaborate to support each other in repaying the installation costs over a 12-month period. This cooperative financing model fosters a sense of collective responsibility and ensures that even those with limited financial resources can participate in the clean energy transition. By removing these financial barriers, Solar Society aims to accelerate the adoption of solar energy and empower communities to become more energy-independent while contributing to sustainability goals (News24, 2023).

The *stokvel* model implemented by SunKissed Technologies operates as a financial intervention that mitigates the prohibitive upfront costs of solar PV systems by distributing payments across a collective group. Each *stokvel* is composed of 12 members, and the group's contributions are pooled monthly. Instead of each household or small business bearing the full financial burden of purchasing a solar PV system outright, the *stokvel* members contribute incrementally, with one solar system being paid off per month. Over the course of a year, each member benefits from a fully paid-off installation. This rotation-based system reduces financial strain, enabling members to collectively fund solar PV installations in an affordable and sustainable way.

To further enhance the financial stability of this model, SunKissed Technologies has established partnerships with a local bank and an insurance provider. The bank plays a critical role in ensuring liquidity and financial oversight, offering secure channels for collecting and managing the pooled funds. This partnership also facilitates access to credit services for members who may need additional support. The insurance provider, on the other hand, mitigates risk by offering protection against potential defaults or system failures. This financial safety net adds an extra layer of assurance, making the investment less risky for members.

In terms of financial strategy, SunKissed Technologies operates with a focus on cash flow optimization. By installing solar PV systems upfront without requiring an initial payment from the customer, the company accelerates system deployment, thus ensuring immediate energy benefits for members. This front-loaded investment is balanced by the guaranteed cash flow from the stokvel's monthly contributions which reduces the need for large working capital reserves (News24, 2023). The company further mitigates financial risk exposure by sourcing equipment locally from SkyNet Solar, which reduces supply chain costs and allows for more flexible pricing and warranties.

A chief financial officer oversees budget allocation and ensures cash flow consistency through financial planning. The chief technology officer ensures that the solar systems are cost-effective and technologically sound, while the head of sales and marketing focuses on growing the *stokvel*'s membership base to maintain scalability (News24, 2023). The electrical engineer guarantees that all installations meet certification standards, preventing potential reinstallation costs or technical failures. This ecosystem approach (combining community-based finance, strategic partnerships, and internal expertise) forms the foundation of innovative solar PV financing model by the company (News24, 2023).

2.9. Solar-PV value chain

Garlet, Ribeiro, de Souza Savian, and Siluk (2020, 398 – 399) note that the value chain for distributed solar-PV energy generation consists of upstream, midstream, and downstream segments, as demonstrated in Figure 4. The upstream segment involves activities such as PV cell production and the processing of raw materials for required inputs. Operations in this sector require advanced technology and substantial investments. To address technical challenges and ensure a reliable supply chain, upstream companies often form international alliances. They also play a role in advocating for policies that support market expansion and trade liberalization. The upstream value chain creates significant value through specialized knowledge and expertise.

The midstream segment encompasses a range of essential activities such as the production of PV cells, the manufacturing of accessory components such as cables, frames, and back sheets along with the overall assembly of the PV modules. The downstream segment encompasses a set of activities directly associated with the final consumer. These activities include integration of the PV system through activities such as project development, system installation, and ongoing operation and maintenance. In addition, the downstream segment addresses important aspects such as system deactivation/decommissioning, de-installation/disassembly, waste disposal, and material recycling.

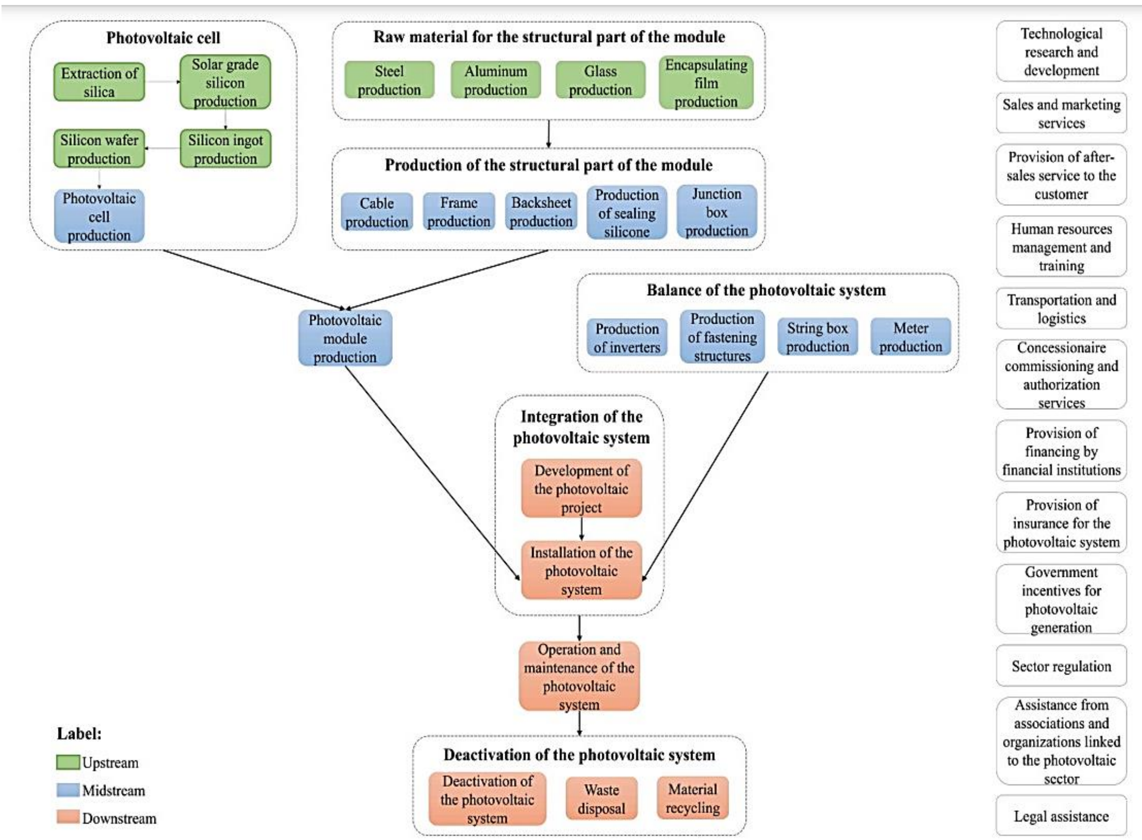

Figure 4. Value chain of distributed generation with solar-PV technology. Source: (Garlet et al., 2020, 399)

In the realm of South Africa's RE landscape, World Wide Fund (WWF) highlights scarcity of local enterprises venturing into solar PV manufacturing (WWF, nd, 1). The apprehension among small businesses to dive into the government's REIPPPP stems from the challenging nature of navigating constantly evolving prerequisites. To unlock the true potential of the solar technology segments as demonstrated in Figure 5, establishing a steadfast demand and providing a stable policy environment are some of the critical challenges which need to be addressed.

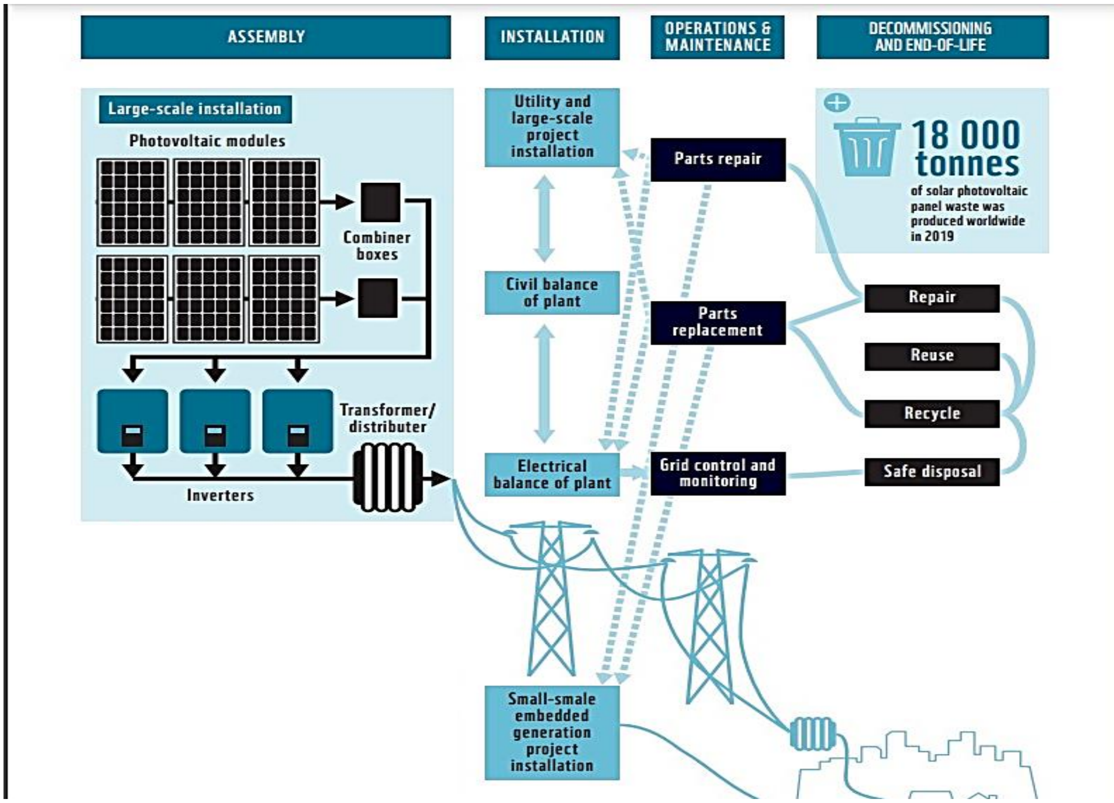

Figure 5. South Africa's solar-PV value chain. Source: (WWF South Africa, nd, 3)

2.10. Wheeling green electricity

Wheeling presents itself as an adaptable energy solution with profound relevance in the context of addressing the acute electricity supply gap relative to demand that confronts developing economies such as South Africa. This entails the judicious transmission of energy originating from a designated private-sector generator through the existing distribution and transmission grid infrastructure to a predetermined end-user in public or private sector. According to Schedule 2 of the primary law governing electricity regulation in South Africa (Electricity Regulation Act - ERA), certain activities are exempt from the requirement of obtaining a license. However, such exempt activities still need to be registered with the National Energy Regulator of South Africa (NERSA), which is responsible for overseeing licensing and tariffs in the electricity sector (van der Poel, Kota & Felekis, 2020, 1).

2.10.1. Wheeling green electricity in India

As a third-world country, India faces challenges similar to those facing South Africa, making its experiences particularly relevant for understanding the complexities of energy access for marginalized communities. The operational framework of electricity wheeling conveys long-term transmission services closely aligned with the operational precepts governing electricity procurement, as outlined within power purchase agreements (PPAs). This encapsulates a contractual interplay between power generators and procurers (Heeter, Mathur, Madrigal, Chatterjee & Shah, 2016, 8). Within this paradigm, India's power sector has observed substantial progress in terms of power generation in the past decades and especially the rapidly increasing role for renewable energy in the last 10 years. The installed generation capacity has diversified India's energy mix as reflected in Figure 6.

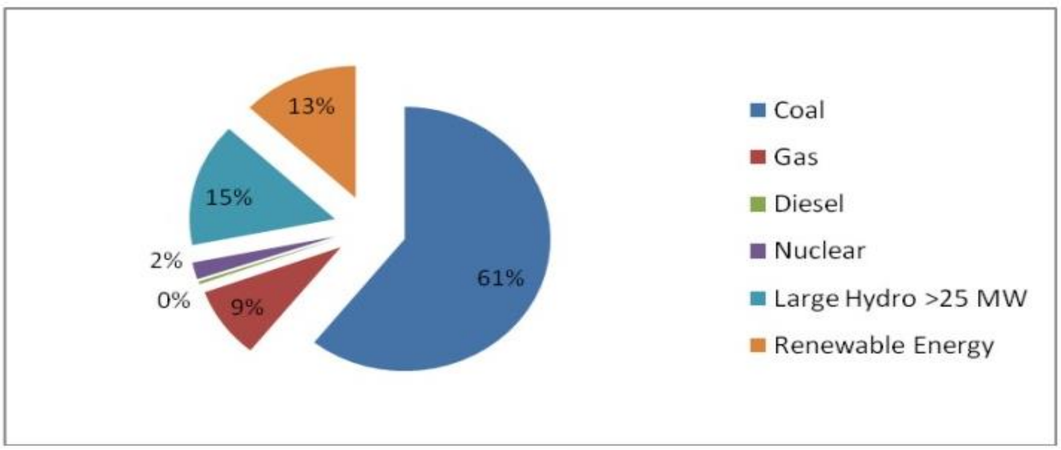

Figure 6. India's energy mix. Source: (Central Electricity Authority 2015, cited in Heeter et al, 2016, 20).

According to Heeter et al (2016, 24), the Indian government introduced rules to streamline the sale of solar power between different Indian states. This move was driven by a desire to foster solar energy utilization, particularly from expansive solar projects situated in sunny regions like Rajasthan and Gujarat. The regulations require that solar power projects be exempted from certain charges (known as transmission charges) when transmitting power across state boundaries. Subsequently, the government extended this exemption to wind power projects to facilitate a favorable environment for the wind energy sector as well. This exemption effectively reduced the cost of selling solar energy across states, thereby incentivizing more substantial investments in development and operation of solar energy projects. To put it into perspective, the cost of this exemption for a solar project producing 15 GW equates to approximately 0.04 cents per unit of electricity. Table 5 provides an overview of how open-access banking regulations manifest in states enriched with abundant renewable energy resources in India (Heeter et al, 2016,27).

Table 5. Summary of open access utilization of solar energy in India. Source: (Heeter et al, 2016,27).

State	Wheeling Charge for using Transmission System	Wheeling Loss in Transmission System	Wheeling Charge for Using Distribution System	Wheeling Loss in Distribution System	Cross Subsidy Surcharge (CSS)	Electricity Duty/ Tax on Sale of Electricity
Andhra Pradesh	Exempt	Applicable	Exempt	Applicable	Exempt	Exempt
Rajasthan	50% of rates as applicable to conventional power	Applicable	Applicable	Applicable	Exempt	Exempt
Maharashtra	Concessional rates applicable to conventional Short-term open access transactions	Applicable	Applicable	Exempt	25% of normal CSS applicable to conventional power	Applicable
Tamil Nadu	30% of normal charges to solar power. However, for the plants with remaining RECs, 100% of relevant charges will be applicable.	Applicable	40% of normal charges	Applicable	50% of the CSS for third-party open access consumer	Exempt
Punjab	Exempt	Exempt	Exempt	2%	Applicable	Exempt
Karnataka	Exempted for non–REC projects					
Gujarat	Wheeling with injection at 66 kV or above (applicable to solar plants of capacity greater than 4 MW): no exemption and normal open access charges. Below 66 KV: payment of transmission charges as applicable to normal open access customers.	Wheeling with injection at 66 kV or above No exemption in losses	11 kV or above and below 66 kV (within the area of same distribution licensee) at 3% of the energy fed in to the grid; Otherwise, normal open access charges apply and transmission and distribution loss at 10%.	Transmission and wheeling loss at 7% Wheeling at two or more Locations at INR (Indian rupee) of 0.05 per unit	Exempt	Applicable

2.10.2. Wheeling green-electricity in South Africa

Similar to India's wheeling context, wheeling transactions in South Africa are based on a distinct agreement that underscores the imperatives of compliance with meticulously outlined technical standards, as advocated in the Grid Connection Code for Renewable Power Plants (SEA, 2017). According to Farmers Weekly (2020, 8) independent power producers (IPPs) have multiple options for transacting with off-takers in the sale of electricity. One of the notable options is the concept of wheeling which allows IPPs to transmit electricity directly to end-users within a municipality using the municipality's own infrastructure. This approach bypasses the need for the electricity to be sold to the municipality first, thus providing a more direct and efficient route for delivering electricity to the intended consumers (Farmers Weekly, 2020, 8). Wheeling offers increased flexibility and control for both the IPPs and the municipalities, thus facilitating a streamlined process for supplying electricity to the end users. As demonstrated in Figure 7, the implementation of wheeling would thus facilitate the transmission of electricity generated from RE resources from an area with optimal solar radiation to residential customers located in areas that are less favorable for renewable energy production.

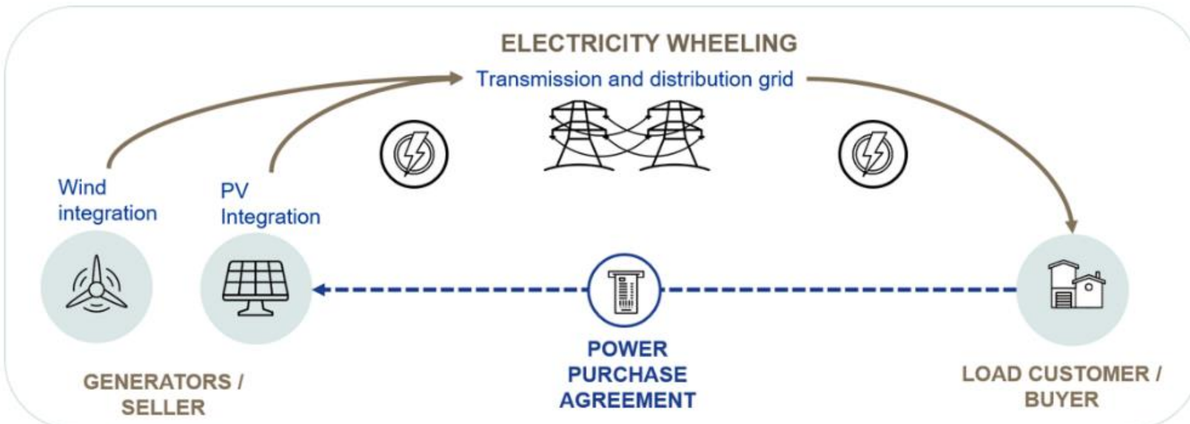

Figure 7: Schematic illustration of wheeling in South Africa. Source: (Eskom, 2022, 1).

While the practice of wheeling has shown success in open markets worldwide, its application in regulated markets like South Africa has been limited to a small number of projects. Related to this phenomenon is the wheeling charges that signify the payment made by Independent Power Producers (IPPs) and other network users to the custodians of the transmission network for granting access to its infrastructure (Murray, 2018, 25). The fundamental driver of these transmission costs is the need for recovery of expenditures incurred in facilitating transmission activities (Heeter et al., 2016). According to Murray (2018, 25), wheeling charges can be segmented into the following categories:

- Capital Outlay: This pertains to recouping the investments made in the network's physical assets and equipment. The valuation of the existing network assets serves as the bedrock for determining this cost recovery.
- Operation and Maintenance (O&M) Expenditures: Within the range of 2.5% to 5% of the capital outlay annually, these expenses encompass the ongoing operational and maintenance facets of the network.
- Network Loss Expenditures: This involves regaining the costs stemming from the energy losses incurred during the transmission process.
- Congestion-Related Costs: These costs stem from instances of transmission congestion, which can lead to bottlenecks or limitations within the network.

2.11. Geographic factors that shape the feasibility and performance of solar energy projects

In the pursuit of sustainable and energy efficient solutions, the assessment of solar potential emerges as a key focus in contemporary literature. Determining suitable locations for renewable energy projects involves considering multiple criteria such as environmental safety, social acceptance, financial viability, and policy compliance. Decision-making in this process typically involves two main perspectives: multi-attribute decision-making (MADM) and multi-objective decision-making (MODM) (Adedeji, 2020, 2). MADM helps in selecting the best option from a set of alternatives based on specific criteria, while MODM uses mathematical programming to find the optimal solution within given constraints. These decision-making methods are beneficial for addressing energy system issues due to their flexibility and ability to incorporate input from various decision-makers (Adedeji, 2020, 2).

As advancements in artificial intelligence continue to progress, the field of land suitability analysis is gradually becoming more 'intelligent'. In this context, various factors are crucial in shaping the feasibility and effectiveness of solar energy projects. These factors include geographical location, solar insolation and other climatic conditions, with geographical coordinates playing a pivotal role in determining solar radiation levels. Duvenhage, Brent, Stafford, and Van Den Heeve (2020,1) highlight the concept of Direct Normal Irradiance (DNI) (solar radiation reaching the Earth's surface), as a critical metric for assessing solar energy potential. Figure 7 shows how DNI is influenced by Earth's position relative to the sun, surface coordinates, and atmospheric conditions. As seen in Figure 8, in South Africa, the minimum, average, and maximum DNI values are 1290 kWh/m2/y, 2397 kWh/m2/y, and 3141 kWh/m2/y, respectively. The general consensus within the literature is that optimal DNI falls within the range of 1800 to 2000 kWh/m2/y (Duvenhage et al., 2020, 5). However higher DNI is directly associated with reduced electricity generation costs for solar-PV and CSP (concentrated solar plant).

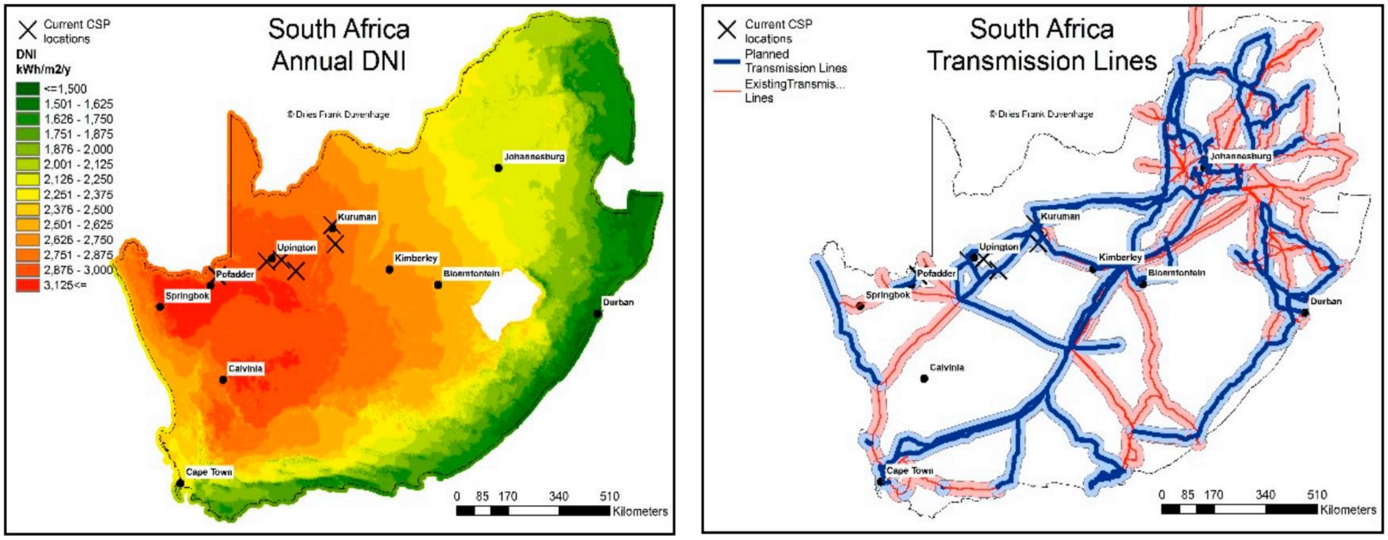

Figure 8: Maps of South Africa showing Direct Normal Irradiance (DNI) and South Africa's transmission grid network. Source: (Duvenhage et al., 2020, 5)

2.12. Tribal authority on land access in rural areas

According to estimates from 2013, the majority of rural South Africans, ranging from 16 million to 19 million people, reside on tribal land (Urban Landmark, 2013,23). Land tenure in South Africa is influenced by various factors such as political, racial, locational, and traditional considerations (Hull et al., 2016, 70; Muthambi, Cloete & Cook, nd, 360). In rural regions, particularly in former homelands, land is typically categorized as tribal or communal land and is managed by traditional councils. Although plots are registered under the state's name, communal tenure is practiced (Muthambi, Cloete & Cook, nd, 358). However, despite the constitutional recognition of traditional land rights and tenure, there is currently no established legal framework for registering tribal land (Muthambi, Cloete & Cook, nd, 360).

Land allocation, as defined by Hull et al. (2016,71), involves the distribution of state-controlled land on behalf of citizens. This land may be overseen by various bodies, including the Department of Public Works, Department of Rural Development and Land Reform, tribal authorities, or quitrent land (a tenure in which a person holds land by paying an annual fixed rent to the government or a landowner instead of fulfilling traditional feudal obligations although the ultimate control or ownership often remained with the government or colonial authorities. It is considered a semi-freehold form of tenure). Traditional leadership plays a significant role in South Africa, with tribal authorities being responsible for administering tribal and communal affairs, offering guidance and assistance in land development and improvement (Black Authorities Act No.68 of 1951 section 4.1). These land rights are granted temporarily under the Interim

Protection of Informal Land Rights Act of 1996, which aims to safeguard certain land rights not adequately protected by existing laws.

Acquiring land under tribal authority jurisdiction involves adhering to specific processes outlined by the authority as they provide for in the Act. While the legal ownership of land remains with the state, tribal authorities hold customary land rights such that any proposed development on such land would require permission from the individual holding the land rights, with compensation payable directly to them rather than to the state for land acquisition (Muthambi, Cloete & Cook, nd, 359).

2.13. Conclusion

The literature review highlights the persistence of energy poverty in low-income communities across South Africa which contributes to heavy reliance on hazardous, polluting fuels like paraffin and coal-based value chains. These traditional energy sources exacerbate health risks, environmental degradation, and entrenched economic disparities. While clean energy technologies such as induction stoves, present a transformative opportunity, widespread adoption faces substantial barriers. Cultural preferences for conventional cooking methods, prohibitive costs, and inadequate infrastructure — particularly in disadvantaged areas — are significant obstacles to adoption at scale.

While many low-income households are connected to the national electricity grid, access does not equate to energy security. Frequent power outages which are exacerbated by load shedding, and the high cost of electricity make it inaccessible for many, forcing continued reliance on unsafe, inefficient energy sources. This further highlights the urgent need for innovative, affordable energy solutions that bridge the gap between grid connectivity and actual energy access, particularly as South Africa navigates it's Just Energy Transition.

The review further informs the hypothesis, revealing that gender plays a critical role in household experiences of energy poverty. This provokes deeper questions about the transformative potential of women-led cooperatives, suggesting that such entities could disrupt entrenched patriarchal systems within the energy sector. Given that cooperatives could also serve as vehicles for fostering women's leadership in renewable energy, particularly through models like wheeling, they offer more benefits beyond addressing the immediate challenge of energy poverty. While strategic partnerships could alleviate energy poverty and unlock women's potential within the energy value chain, the review also highlights significant constraints towards realization of this potential.

Despite ongoing grid connections, the energy landscape remains mired in the legacies of apartheid, which perpetuates inequities that limit the envisaged impacts of connections and policies aimed at addressing energy poverty. The review also highlights South Africa's wheeling landscape (a critical mechanism for enabling the transmission of privately generated electricity through the national grid) as one key area of policy reform that can be leveraged towards addressing energy poverty under JET. Wheeling holds the potential to decentralize energy access, particularly for renewable energy projects. However, South Africa's regulatory framework remains complex, making wheeling difficult to implement, especially for smaller cooperatives. Prevailing legal and logistical barriers exacerbate existing inequalities, thus raising important questions on how wheeling could be leveraged to facilitate equitable energy access.

The potential for women-led cooperatives to engage in the wheeling of solar-generated electricity offers radical opportunities for economic empowerment. Women in rural areas could generate and sell electricity to urban communities such as Alexandra, thus addressing energy poverty while creating new revenue streams. However, this circles back to the regulatory bottlenecks that hinder wheeling across regions must be addressed. Literature suggests that the prevailing wheeling market favors larger entities and excludes unconventional entities such as cooperatives from participating in the renewable energy market. The cost of wheeling is also often opaque and unaffordable, especially for smaller renewable energy producers. In many cases, related fees are not only complex but also prohibitively high.

Further insights from the review raised questions about the sustainability of women-led cooperatives within South Africa's resource-constrained environments. While these cooperatives are promising models for advancing the Just Energy Transition (JET), their financial stability and governance structures remain vulnerable. The high failure rates of rural cooperatives in provinces like Limpopo highlight deeper structural challenges — such as limited capital and market access. Similarly, the complexity of the wheeling landscape further limits the participation of cooperatives thus calling for the development of innovative financing models to unlock the potential of women-led cooperatives.

In reviewing the scalability of cooperative models across South Africa's diverse regions, the literature reveals another constraint where successful approaches in one area cannot be uniformly applied to others. This variability prompts a critical examination of South Africa's wheeling landscape and whether it can adapt to meet the needs of both urban and rural cooperatives. Pilot programs and localized adaptations may be necessary to bridge this gap. In addition, literature leaves open the question of whether South Africa's energy system can accommodate such diversification in contrast to its prevailing centralized and monopolistic regime under Eskom as a state-owned utility. A particularly thought-provoking aspect of the literature is the suggestion that generation cooperatives could leverage stored electricity as an economic asset. The idea of energy entrepreneurs managing and selling electricity during peak demand periods presents a radical opportunity for economic empowerment. Realizing this vision requires overcoming regulatory and logistical barriers related to energy storage

The review also emphasizes the scarcity of empirical evidence on the potential for the adoption of solar-PV induction stoves. Without comprehensive field studies that provide data on cost-efficiency, performance, and it's socio-economic impact, the full potential of this value chain remains speculative.

In conclusion, the review points to the need for South Africa's Just Energy Transition to evolve from theoretical constructs to practical frameworks that ensure equitable access to sustainable energy for all. While South Africa's wheeling market offers promise, without significant regulatory reform, marginalized communities will continue to be excluded from participating in renewable energy markets. Subsequent chapters of this study will explore case studies, offering critical empirical evidence on how an *imbokodo* model within a cooperative structure could play a towards addressing this market constraint in wheeling.

2.14. Conceptual Framework

Guided by the working hypothesis and insights from literature review, the study conceptualized its conceptual framework as presented in Figure 8. The framework emphasizes the importance of integrating sustainable and low-carbon revenue-generating activities within social entrepreneurship. As defined by Kamaludin, Xavier, and Amin (2021), social entrepreneurship, involves dynamic and innovative approaches that use diverse resources to address unmet social needs. Within this perspective, an *imbokodo-inspired women-led* cooperative model can enhance its social impact while ensuring financial sustainability along the solar-PV induction stove value chain, tailored to the urban-rural dynamics of Alexandra and Limpopo.

The commercial viability of the cooperative model would be reinforced by key enablers such as the National Empowerment Fund (NEF), which would play a crucial role in the initial financing of the establishment and operation of such cooperatives. Alongside member contributions, government grants, and access to microfinancing, the NEF's involvement would provide the necessary financial backing to mitigate the financial barrier and related risk. In Limpopo, the consistently high levels of Direct Normal Irradiance (DNI) make the region particularly conducive to solar energy generation. Availability of land, coupled with the potential formalization of the existing *stokvel* network into a cooperative, further enhances the scoped opportunity. In Alexandra, similar enablers include the transformation of the *stokvel* network into a cooperative and the potential of social acceptance of induction stoves, particularly when coupled with the concept of an alternative electricity supply system. As shown in figure 9 below, the core components of the framework are as follows:

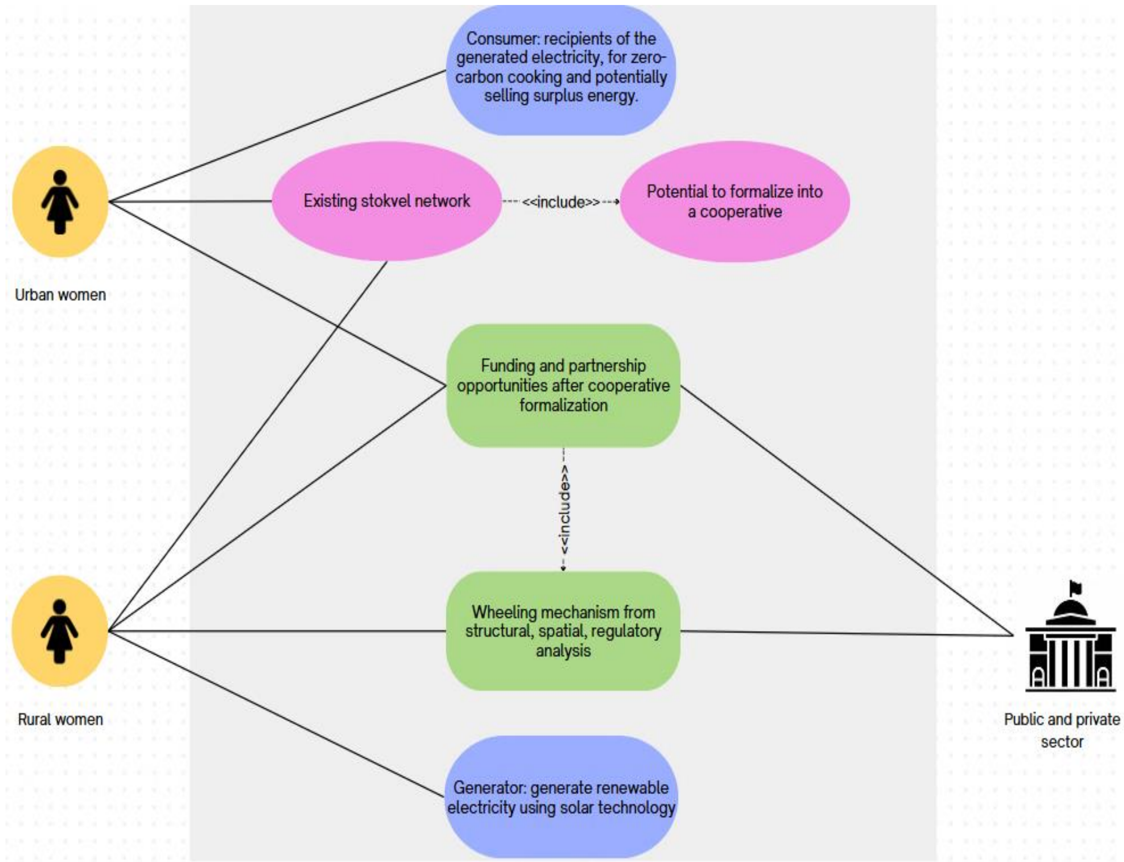

Figure 9. Conceptual framework. Source

- **Mutual benefits between women-led cooperatives:**

    - **Rural generation cooperatives**: Women-led solar-PV cooperatives in rural areas generate renewable electricity using solar technology.
    - **Urban consumer cooperatives**: Women-led cooperatives in low-income urban areas act as the recipients of the generated electricity, primarily utilizing it for zero-carbon cooking and potentially selling surplus energy.

- **Wheeling mechanism**:

    - **Transmission of electricity**: Wheeling allows the generated solar-PV electricity to be transmitted from rural areas (Limpopo) to urban centers (Alexandra). This decentralized energy model leverages existing grid infrastructure but requires engagement with regulators (NERSA) as well as key stakeholders such as Eskom and municipalities.

  - **Regulatory environment**: Key variables include policy reforms, financial mechanisms, and compliance with South Africa’s national energy grid laws. The complex regulatory landscape can either enable or hinder the success of wheeling.

- **Energy poverty and gender inequality**:

  - **Energy poverty**: Refers to the lack of access to modern, clean, affordable energy. Women in low-income urban and rural settings bear the brunt of energy poverty especially where households and communities resort to unsafe fuels for cooking (e.g., paraffin).
  - **Gender roles**: In both rural and urban areas, women are often excluded from decision-making roles in energy governance, technology adoption, and economic opportunities. Energy poverty exacerbates socio-economic and gender inequality.
  - **Intersection with clean cooking**: Solar-PV induction stoves represent a shift towards clean energy use, thus also mitigating health and environmental risks associated with traditional cooking methods.

- **Socio-economic empowerment**:

  - **Job creation**: Women in rural cooperatives gain employment through solar-PV installation, maintenance, and energy management. Urban women take on roles in stove maintenance, energy distribution, and cooperative management.
  - **Entrepreneurship**: Women entrepreneurs in rural areas sell surplus electricity to urban centers. Urban cooperatives, in turn, generate income by offering clean cooking solutions to the broader community.
  - **Skills development**: Cooperative members, particularly women, acquire new green skills related to renewable energy technologies and cooperative management, thus helping to create a sustainable energy transition.

- **Sustainability and Just Energy Transition (JET)**:

  - **Sustainability**: The study anticipates that this model can contribute to South Africa's broader goals of sustainability, reducing carbon emissions and dependence on non-renewable energy sources.

- **Just Energy Transition (JET)**: Ensuring that marginalized communities, especially women, are not left behind in the energy transition. Wheeling provides a pathway for equitable energy distribution, while cooperatives ensure community ownership and local empowerment.

Chapter 3

Research method

3.1. Introduction

This chapter presents the study method in terms of research paradigm, research design, population and sampling, data collection, data analysis and ethical considerations. The method is rooted in an ethnographic framework which constitutes the underpinning of both its design and process components. The study aligns itself with a qualitative approach, and thus resists the imposition of a singular, all-encompassing research paradigm (Denzim and Lincoln's (2011, 19). Instead, qualitative research projects adopt diverse and blended approaches which in turn incorporate various qualitative research tools and methods that allow researchers to gain a comprehensive understanding of the complexities of the subject/phenomenon of study based on a coherently framed interpretive lens.

3.2 Research paradigm

A research paradigm is a framework for examining and explaining social phenomena. Saunders, Lewis, and Thornhill (2003, 138) visually represent a research philosophy or paradigm within the research onion model, as shown in Figure 10.

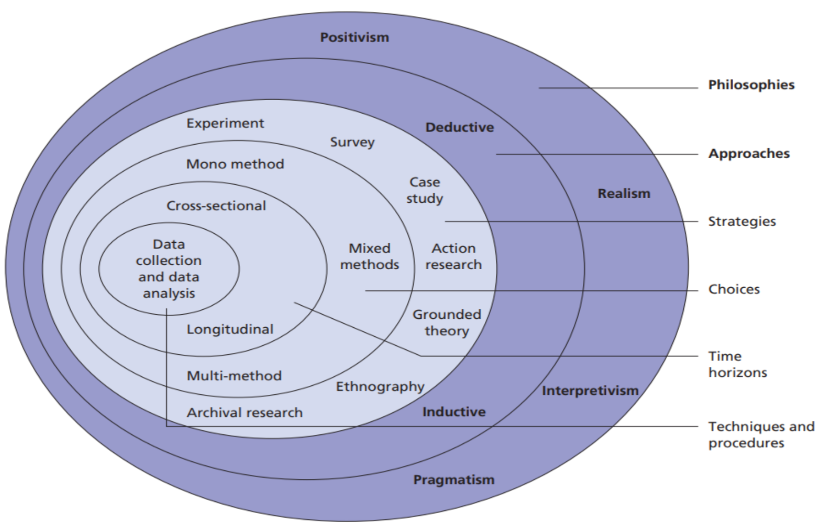

Figure 10. Research onion. Source: (Saunders et al., 2003, 139)

Two primary research approaches are commonly utilized in socially oriented studies: positivism and interpretivism. Positivism aligns with the philosophical stance of natural scientists, which focuses on studying real things in society to draw generalizable conclusions across similar contexts and phenomena, without incorporating personal opinions. Conversely, interpretivism emphasize on the study of differences between individuals in society. It argues that social sciences research should distinguish itself from natural sciences research by considering factors such as different cultures, situations, and times (Saunders et al., 2003, 139). As shown in Table 6, these research paradigms significantly influence how social phenomena are comprehended. In view of this understanding in relation to the socio-economic phenomena covered in the study, an interpretive approach was deemed to be the relevant and appropriate one.

Table 6. Overview of research paradigms. Source: (Saunders et al., 2003, 150)

	Positivism	**Realism**	**Interpretivism**	**Pragmatism**
Ontology: *the researcher's view of the nature of reality or being*	External, objective and independent of social actors	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)	Socially constructed, subjective, may change, multiple	External, multiple, view chosen to best enable answering of research question
Epistemology: *the researcher's view regarding what constitutes acceptable knowledge*	Only observable phenomena can provide credible data, facts. Focus on causality and law like generalisations, reducing phenomena to simplest elements	Observable phenomena provide credible data, facts. Insufficient data means inaccuracies in sensations (direct realism). Alternatively, phenomena create sensations which are open to misinterpretation (critical realism). Focus on explaining within a context or contexts	Subjective meanings and social phenomena. Focus upon the details of situation, a reality behind these details, subjective meanings motivating actions	Either or both observable phenomena and subjective meanings can provide acceptable knowledge dependent upon the research question. Focus on practical applied research, integrating different perspectives to help interpret the data
Axiology: *the researcher's view of the role of values in research*	Research is undertaken in a value-free way, the researcher is independent of the data and maintains an objective stance	Research is value laden; the researcher is biased by world views, cultural experiences and upbringing. These will impact on the research	Research is value bound, the researcher is part of what is being researched, cannot be separated and so will be subjective	Values play a large role in interpreting results, the researcher adopting both objective and subjective points of view
Data collection techniques most often used	Highly structured, large samples, measurement, quantitative, but can use qualitative	Methods chosen must fit the subject matter, quantitative or qualitative	Small samples, in-depth investigations, qualitative	Mixed or multiple method designs, quantitative and qualitative

3.3. Research design

Essentially, research design refers to the overarching strategy employed by a researcher to systematically organize various aspects of a study in a coherent and logical manner. The selection of an appropriate research design is shaped by factors such as sampling techniques, the nature of the population, question format and content, response rate, associated expenses, and the duration of the data collection process

(Creswell, 2016, 100). As highlighted in Section 3.2, the concept of the research onion serves as a tool to illustrate the underlying considerations influencing the choice of data collection method or methods. Specifically, the outermost layers of the research onion (research philosophies/paradigms and research approaches/designs) were revealed.

3.4. Data collection

Ethnographic and interview data collection tools for Alexandra were used to gather comprehensive data on prevailing versus induction-stove cooking practices, women's participation in urban stokvels, and other community-based initiatives. Factors such as size and quality of physical structures with extent of roof area as the key issue for SHS systems were also considered and captured with the use of the data collection tools. Interview questions were carefully designed to elicit in-depth qualitative information on the specific participant categories of the study.

Alongside interviews and observations, the study also collected photographic data as a key component of direct observation under the ethnographic approach. Short-term ethnographic studies have been employed effectively in a range of disciplines to generate deep insights into community practices and socio-cultural dynamics (Jelsma & Clow, 2005). In line with these precedents, this research adopted an ethnographic approach, enabling the capture of detailed observations that highlight critical aspects of energy dynamics within the host household.

3.4.1. Participant and spatial observations in Alexandra township, Johannesburg

Table 6 outlines the data collection strategies employed in Alexandra township, Johannesburg. This section of the research used ethnographic observations to capture the nuances of cooking practices and spatial dynamics. Data were collected through a range of tools including direct observations, semi-structured interviews, ethnographic notes, a transect walk, and photographs, all aimed at providing a comprehensive understanding of the energy dynamics of the host-household. The primary focus was on comparison of traditional cooking methods currently in use and if these traditional versus induction stoves. Spatial observations were conducted to support the hypothesis which is that low-income areas such as Alexandra are plagued by various socio-economic challenges. It is important to note that the observations made in this study are not representative of all households or community structures within Alexandra township.

Considering the thematic focus of this study, Table 7 provides a summary of the data needed, collected, and analyzed for both primary and secondary data in response to the sub-questions identified in Chapter 1, Section 3.4.

Table 7. Overview of the approach and rationale behind obtaining data in Alexandra township

	Approach	Rationale
Methodology	Ethnographic observations, semi- structured interviews, and transect walks	A qualitative research approach aimed at deep understanding of community and cultural dynamics
Sampling technique	Purposive sampling was used to identify host household and community structures, such as *stokvels,* that operate on a mutual-benefit basis. *Stokvels* and households were selected based on their alignment with the research criteria. One particular *stokvel* was prioritized due to its formal structure, including a bank account, which reflected a higher level of organization and potential for conversion into a cooperative. Similarly, a specific household was chosen based on socio-economic factors and familiarity with the author which ensured safety during the study.	Method for selecting specific participants and settings relevant to the study's focus. This approach was not only used to strengthen the ethical foundation of the research but also to ensure that participants were selected in a manner that respects their context and experiences. Overall, purposive sampling provides a targeted lens through which to examine targeted dynamics within social/community structures and systems.
Key data issues	- Cooking Practices: Comparison between prevailing versus use of induction stove - Meal Types: Documentation of breakfast, lunch, dinner, light meals, and boiling water - Cookware: The cookware normally used and the required cookware for induction stoves - Rooftop: The state of the roof and its potential for installation of solar-PV panels (structurally integrity, area, level of security) - Existing community-based organization (CBO): CBOs such as *stokvels* that can be leveraged as formal cooperative models	Aspects of daily life and gendered and community practices explored through targeted observations
Data collection duration	Three days of ethnographic observation in the host-household	Time frame dedicated to gaining an understanding of daily cooking practices and technological adoption for 3 meals. The purpose of participant and spatial observations in Alexandra was exploratory, aiming to identify key factors influencing the adoption of renewable energy technologies in this specific context. Despite the brevity of the time frame, the observations were designed to capture essential insights into daily routines and practices related to cooking.
Data collection tools	- Direct Observations: Recording of daily activities and interactions. - Semi-Structured Interviews: Obtaining detailed insights into experiences and perceptions. - Ethnographic Notes: Comprehensive contextual notes.	These instruments were used to gather qualitative data and contextual insights of the household under investigation and the surrounding community.

	- Photographs: Visual documentation of cooking practices and equipment	
Main objective	- Adoption Potential: Assess the viability and acceptance of induction stove technology within the household. - Impact Analysis: Evaluate the implications of different cooking methods on the participant's life and practices. -Business Model Formalization: The possibility to formalize existing *stokvels* into cooperative business model - Assessing Complementarity: Evaluate the potential synergy between rural and urban contexts in advancing renewable energy solutions.	Goals focused on understanding technology adoption, limitations and documenting social acceptance of induction stove versus prevailing cooking practices. The ethnographic observations aimed to identify opportunities for collaborative models that can facilitate a more inclusive urban-rural green economy
Ethical considerations	Ensuring informed consent from all participants with a clear explanation of the research objectives, methods, and the researcher's role	Maintaining ethical standards in research by securing consent and ensuring transparency

3.4.2 Participant and Spatial observations in Chebeng village, Limpopo.

As in the urban setting, data collection in Chebeng was not intended to provide a representative view of the entire community but to offer exploratory insights into the potential for energy cooperatives and rural energy entrepreneurship in such settings. Tools such as direct observations, interviews, detailed ethnographic notes, and photographic evidence were employed to document the interplay between local traditions, land use, and energy practices, thus providing a foundation for future longitudinal studies in this field.

In the context of Chebeng village, Limpopo, Table 8 outlines the data collection strategies aimed at assessing the complementarity of the Limpopo region to the Alexandra township and ultimately close the value chain loop. Similar to Alexandra township, an ethnographic approach was used, integrating participant observation with semi-structured interviews to gain insights into land-use activities, spatial potential for RE projects and existing community structures. In Chebeng, the study also focused heavily on spatial observations related to land availability and the role of tribal authority in facilitating women's participation in renewable energy initiatives. Data were collected through a range of tools including direct observations, field notes, semi-structured interviews, ethnographic notes, a transect walk, and photographs

Table 8. Overview of the approach and rationale behind obtaining data in Chebeng village

	Approach	Rationale
Method	Ethnographic observations, semi- structured interviews, and a transect walk	A qualitative research approach aimed at assessing the complementarity of the 2 case studies
Sampling technique	Purposive sampling to identify key household and community structures, such as *stokvels,* that function on a mutual-benefit basis. The selected household and *stokvels* observed were chosen with attention to their established networking with the tribal authority while also factoring researcher safety into the criteria. The identified contact contributed to a sense of security, which, in turn, facilitated engagement with the community and helped enhance the quality of the data collected.	Method for selecting specific participants and settings relevant to the study focus. The approach ensured data collection towards specific understanding of how existing networks function to support economic collaboration and resilience, particularly in rural settings where resources can be scarce.
Key data issues	- Land: Availability of land for large scale RER projects and the most common land-use activities - Community-based organizations (CBOs): Investigate	This timeframe was focused on understanding rural cooking practices, land access for women, and the potential for adopting solar PV technology. While exploratory in nature, the findings

	local *stokvel* operations and potential transformation into energy cooperatives. - Tribal Authority: Understand role of tribal authority in enabling women's access to land for renewable energy projects	provide insights into key factors influencing renewable energy adoption in rural contexts.
Data collection duration	Three days of ethnographic observations were conducted on the an existing *stokvel,* which holds potential for conversion into a cooperative, as well as on the land's terrain and role of local tribal authority In women's access to land for RE projects	Time frame dedicated to assessing the potential for adapting existing mutual-benefit women initiatives such as *stokvels* into energy generation cooperatives, and the forms of complementary support and resources from local/traditional governments. Data on availability of government or traditionally owned land for leasing were prioritized.
Data collection tools	- Direct Observations: Recorded land usage, household energy practices, and interactions with tribal authorities. - Semi-Structured Interviews: Captured perceptions on land access, *stokvel* operations, and energy entrepreneurship. - Ethnographic Notes: Detailed documentation of socio-cultural dynamics and renewable energy potential. - Photographs: Visual documentation of land, household infrastructure, and community interactions.	The rationale for this approach was to build a comprehensive understanding of the community's energy landscape and cultural context. These data collection tools enabled the identification of key factors that support or hinder the adoption of renewable energy.
Main objective	- Land and Energy Integration: Assess the potential for utilizing available land for renewable energy initiatives, particularly solar PV. - Assessing Complementarity: Evaluate the potential synergy between rural and urban contexts in facilitating renewable energy adoption. - Women's Empowerment and Land Access: Analyze the implications of tribal authority on women's land rights and participation in energy initiatives	Aimed to analyze/assess how rural context can complete the value chain loop and play a complementary role to address constrains in Alexadra in relation to clean cooking
Ethical considerations	Ensuring informed consent from all participants with a clear explanation of the research objectives, methods, and the researcher's role	Maintaining ethical standards in research by securing consent and ensuring transparency

3.5. Data presentation and analysis

The qualitative nature of the study necessitated the collection of primary data based on interviews and direct observations (ethnographic data) and secondary data from diverse sources such as government policies and reports as well as published industry/market reports on relevant case studies, especially focusing on similar themes within a developing country context. The qualitative nature of the study may introduce an element of subjectivity due to the inherent worldviews and mindset of the researcher. In mitigation of this risk, every effort was made to minimize the risk through triangulation—cross-verifying data from multiple sources and applying systematic coding techniques to ensure the findings are robust and reliable. As summarized in Table 8 the following key steps provide an overview on data capture, presentation, and analysis:

3.5.1. Primary data analysis:

Based on qualitative methods, analysis of primary and secondary data was conducted systematically to ensure rigor and relevance. Key approaches applied in data presentation and analysis were as follows:

- Data preparation/cleaning
    - This step involved reviewing the collected data that was stored in password-protected files in a laptop accessed by the author only. The aim was to check for any inaccuracies or incomplete information. Careful attention was given to ensuring that all relevant data are usable for analysis.
    - Example: If some interviews contain unanswered questions regarding the adoption of induction stoves, those responses were carefully excluded from the analysis to maintain the integrity of the dataset.
- Data structuring:
    - Organizing the collected data to facilitate thorough analysis is important. This involved categorizing data based on themes or subjects relevant to the research.
    - Example: Qualitative data from participant interviews were organized into categories such as "barriers to adoption" and "factors influencing acceptance." This structure enabled a focused exploration of the themes that emerge from the participants' experiences.
- Thematic analysis:
    - This involves identifying, analyzing, and reporting patterns (themes) within qualitative data. The approach helps in understanding the various factors affecting energy practices.
    - Example: During the analysis of interview transcripts, initial codes like "economic constraints" and "cultural acceptance" were identified. These were grouped into broader themes such as "Barriers to Adoption," highlighting key insights into how socio-economic factors affect technology uptake among women in low-income households.
- Narrative analysis:

- An ethnographic approach was chosen for this research and therefore nuances and story-telling may be captured in these settings. This approach focuses on the cultural preferences and experiences shared by participants, providing context and depth to the data.
- Example: A participant's account of transitioning from traditional cooking methods to using induction stoves was examined to understand the social dynamics influencing technology adoption.

- Integration of findings
  - Mixed-methods integration: Even though the quantitative analysis is not part of this study, integrating qualitative findings provided a richer understanding for addressing the sub-questions and overall research question.
  - Example: Qualitative themes, such as "Community Support Networks," was cross-referenced with insights gained from participant observations, highlighting how social dynamics impact the adoption of renewable energy technologies.
- Cross-referencing:
  - Explanation: This step involved connecting different pieces of qualitative data to enhance the depth of analysis.
  - Example: If a common theme emerges regarding the importance of trust in adopting new technologies, the findings from various participants were compared to paint a comprehensive picture of this factor's role in energy choices.
- Reporting results and presentation of findings:
  - The findings were compiled and presented in a clear and accessible manner, often accompanied by visual aids to enhance understanding.
- Interpretation:
  - Interpretation of results involved situating findings within the existing literature and broader context of energy access.
  - Example: An analysis will be discussed on how socio-economic and cultural factors intersect to shape energy choices, emphasizing insights derived from participants' narratives and observations.
- Reflexivity and limitations

- Maintaining reflexivity was important to acknowledge subjectivity or preconceptions that may influence the analysis. Acknowledging limitations was equally important as it helped to contextualize findings and suggests areas for future research.
- Example: Researcher kept a reflective journal documenting thoughts and feelings about the research process, ensuring a balanced representation of both positive and negative experiences shared by participants as the research unfolded. The analysis recognized that focusing on a specific sample of households may limit the generalizability of findings. This prompts need for future studies to ensure a broader range of participants across multiple communities to enhance robustness.

3.5.2. Primary and secondary data analysis and biases:

- Data analysis: The data were analyzed using qualitative research approach based on identifying recurring issues, patterns, and themes from the data. Codes were assigned to various data segments to facilitate identification of commonalities, differences, and significant findings.
- Data interpretation bias: The subjective interpretation of qualitative data could lead to selective reporting or overemphasis on particular themes. To mitigate this, data triangulation was employed, whereby data from multiple sources such as interviews, field observations, and secondary sources were verified to ensure consistency and accuracy. Furthermore, systematic coding techniques were used to ensure that data interpretation was grounded in the evidence, and not influenced by subjective biases.
- Interpretation and synthesis: Data were initially analyzed in relation to each sub-question and sub-findings were then synthesized to develop a coherent narrative that captures the key insights and themes emerging from primary data in relation to the overall research question.

3.6. Overview of case studies

This section presents an overview of five case studies and their relevance to the study. The five case studies were selected based on their relevance to key themes such as rural-urban energy dynamics, gender empowerment, cooperative business models, and the commercialization of renewable energy solutions. The analytical framework is qualitative with an emphasis on cross-case analysis to identify common key themes, challenges, and opportunities. The analysis focuses on the effectiveness of cooperative models, the potential for scaling clean energy solutions, and the social and economic impacts of energy transitions in low-income communities. Each case study strategically contributes to this research in the following ways:

- Alexandra Township: Alexandra provides the foundation for assessing how energy cooperatives can function in an urban setting, making it a key case for analyzing cooperative viability and the empowerment of women entrepreneurs in urban environments
- Chebeng Village: Chebeng highlights the importance of rural-urban synergies in developing a holistic energy cooperative model, showing how rural land and resources can be leveraged to enhance cooperative sustainability.
- Mahlako Energy Fund: This case reinforces the importance of financial mechanisms in empowering women-led cooperatives towards achieving sustainable growth within the Just Energy Transition framework.
- Ener-G-Africa (EGA): This case illustrates how reliable supply chains and local manufacturing could support the scalability and economic viability of energy cooperatives across the full energy value chain, thus empowering women as leaders in both rural and urban energy markets.
- PowerX: PowerX demonstrates wheeling company operations which can be leveraged towards realization of the mutual benefits among rural generators and urban consumers with women-led cooperatives as the key actors. However, a key shortfall in this case is that the company itself is a black male-led business and therefore does not fully align with the women-led motivation/rationale underpinning this study.

3.6.1. Case study 1: Alexandra township

As previously mentioned, the subsidies from local municipalities and ESKOM for Free Basic Electricity (FBE) and Free Basic Alternative Energy (FBAE) have fallen short on effectively meeting the basic energy needs of poor households (Masuku, 2024, 12). What was supposed to be a realization of these pro-poor energy policy by municipalities has led to only a few households benefiting from said subsidies. Consequently, in response to this situation, households without subsidies resort to informal and illegal means of connecting to the electricity grid and using unstable fuel sources like wood, charcoal, and paraffin.

Masakuk (2024) revealed that a minority of surveyed households rely on kerosene stoves for cooking and paraffin lamps for lighting. Mohlakoana et al. (2018) corroborates these findings, suggesting a persistent trend among households and vendors to switch between different energy sources (Masuku, 2024, 13). On the other hand, several factors influence the economics of a solar system, including the geographic location, the specific energy consumption tariff, and the slope and shading of the roof structure or the piece of ground where solar panels could be installed (SOLA-admin, 2021). This underscores the challenges encountered by a significant segment of the population in attaining more sustainable and dependable energy solutions.

Considering that built-in electric stoves are not commonly found in low-income households and portable counter-top plate stoves are more prevalent, the chosen household deviates from the common practice of using combustible fuels such as firewood and biomass for cooking. However, what this household mirrors is the customary dependence on paraffin during loadshedding, which is a specific type of combustible fuel, and reflects the prevailing cooking practices within the targeted demographic. Therefore, the criteria for selecting the host- household which occupies house shown in Figure 11, was primarily influenced by the convenience of accessing a host household based on familiarity, aiming to mirror what a typical household would resemble in terms of various criteria such as size, composition, income, and food choices. As such, the selection of the host household was methodically guided by four primary considerations: ensuring safety and familiarity for the researcher, having a female member to observe gendered roles in cooking, the use of paraffin especially during loadshedding and municipal power disconnections due to non-compliance and non-payments and finally having a roof that can be evaluated for the feasibility of installing solar panels.

Figure 11. Host-household in Alexandra township Source

3.6.2. Case study 2: Chebeng village

Public resistance and apprehensions surrounding the integration of RE technologies in proximity to residential communities are discussed in Nkoane's (2018) paper which investigates the acceptance challenges of RE transition in Limpopo. Opposition at the local level to the widespread implementation of RE is mainly motivated by various factors such as environmental considerations, including concerns about noise and visual pollution, as well as cultural issues tied to the protection of ancestral burial lands. Financial considerations, such as investor perspectives and the willingness of communities to contribute financially, also play a significant role. In addition, socio-political factors, such as concerns about job creation, mistrust, and perceptions of social injustice contribute to the overall resistance to large-scale deployment of RE technologies on land primarily supporting rural communities (Nkoane, 2018, 4)

Amidst these challenges, projects such as the one led by Richards Bay Minerals (RBM) have proactively addressed these concerns and engaged in a partnership with an international energy company to construct a solar power plant (Smith, 2022). Positioned as South Africa's largest mineral sands producer and predominantly owned by Rio Tinto with a 74% stake, RBM's initiative with the Bolobedu Solar PV renewable energy project was set to commence construction in 2023 in Limpopo (press release on the exact location is yet to be communicated). It is designed to provide RBM with sustainable energy, boasting of a 51% ownership by black economic empowerment (BEE) partners. Leveraging Chebeng village as a case study was primarily driven by Chebeng's energy-generating potential which was assessed from a technical standpoint and also from a socio-cultural and political lens. Another consideration was based on the fact that the influence of the local tribal authority is a critical and unique factor, as it shapes the community's reception and integration of land-use projects. Last, ensuring safety and familiarity for the researcher was also a deciding factor when choosing this site for investigation.

Figure 12 illustrates the house where tribal meetings take place, serving as a central hub for discussions that shape local governance and decision-making processes related to land use and community activities. This space is integral to community dialogue, with rural tribunals playing a critical role in shaping decisions around the future of the community.

Figure 12. House where rural tribunal meetings are typically held

3.6.3. Case study 3: PowerX

Eskom is a vertically integrated monopoly, controlling the generation, distribution and transmission levels of the electricity value chain in South Africa. IPPs play a small role at the generation level (5% of total generation in 2017), while municipalities participate in distribution, which serves as a vital source of revenue to local authorities licensed by NERSA. In reality, however, there is very little effective competition for Eskom at any level of the value chain due to the way that policy and regulatory environment has favored the state-owned provider (Robb & Mondliwa, 2018, 27). One player, PowerX, was awarded a trading license by NERSA, which allows it to purchase electricity from generators and sell it to municipalities and other customers. This requires it to wheel electricity over transmission and/or distribution networks owned and operated by other parties (Eskom or municipalities), and thus being in competition with Eskom. However, there are a number of factors limiting the expansion of these activities which will be discussed further below (Robb & Mondliwa, 2018, 27)

The PowerX case study provides a working example of how non-traditional energy traders can operate within a tightly regulated and monopolized electricity sector. As shown in Figure 13, in view of the emerging policy and regulatory environment, ability of PowerX to wheel power through existing networks provides an example of how innovative business models can carve out space in a market dominated by a single utility, such as Eskom. Experience of PowerX firstly highlights the importance of regulatory agility and market entry strategies, which are crucial for energy cooperatives looking to position themselves in a competitive yet state-controlled environment. Second, leveraging PowerX as a case study offers practical relevance and strategic depth to this study, especially because it is third party market operators who can serve the role of bridging between the generator and consumer cooperatives. This means that the cooperatives themselves do not have to directly engage with the complexities of the wheeling market. Lastly, in later chapters, PowerX is a crucial touchpoint for understanding the broader systemic and operational realities of introducing competition and innovation into South Africa's energy market

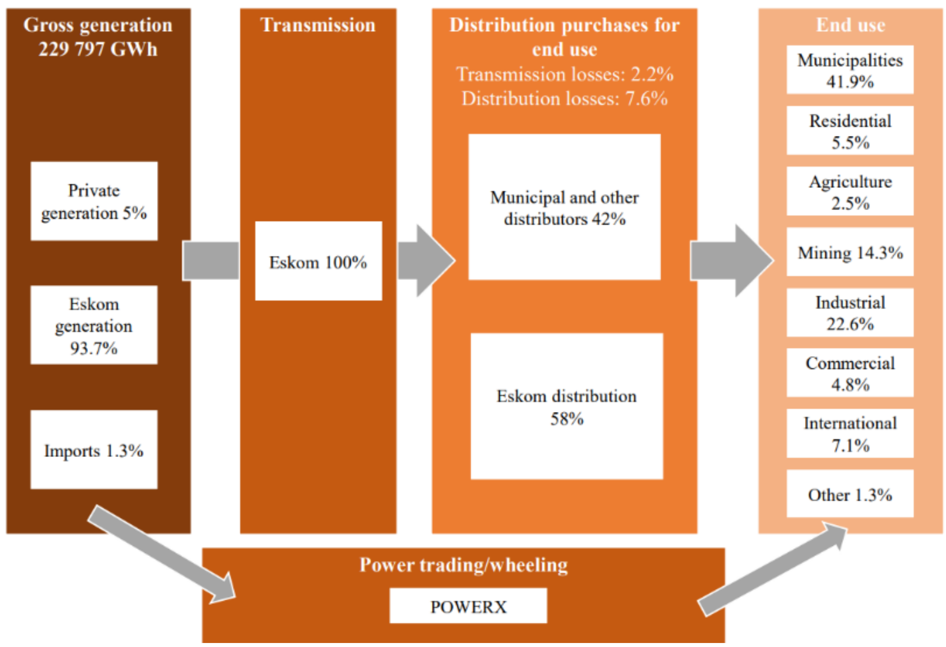

Figure 13: Electricity value chain. Source: (Robb & Mondliwa,2018, 27)

3.6.4. Case study 4: Ener-G-Africa

Ener-G-Africa (EGA) serves as a model for expanding the footprint of women in manufacturing plants, field distribution coordinators, and those holding managerial positions. Through its partnership with C-Quest Capital to enter previously underserved markets by leveraging carbon-based financing, EGA's product range is centered around sustainable and advanced technologies (EGA, nd). The company exclusively produces Advanced Biomass Stoves tailored for urban markets in South Africa. Additionally, EGA is the exclusive manufacturer of German TUV-certified small solar panels, covering a spectrum of capacities from 20W to 400W. With manufacturing facilities strategically located in Lilongwe, Malawi, and Cape Town, South Africa, EGA contributes to local economic growth and job creation. By focusing on urban markets in South Africa, the company addresses the energy needs of these regions, thus promoting sustainable practices and reducing carbon footprint (EGA, nd).

3.6.5. Case study 5: Mahlako Energy Fund

The Mahlako Energy Fund operates as a managed financial entity with a targeted portfolio size of R1.75 billion (Mahlako Financial Services, 2021) Its primary investment focus lies in projects and businesses within the energy value chain, specifically emphasizing areas such as renewable energy, gas, and energy services. Situated in Khathu, Northern Cape, the project strategically capitalizes on the region's substantial RE potential thereby contributing significantly to the broader objectives of fostering sustainable practices within the green economy (Mahlako Financial Services, 2021). The project in Khathu extends beyond environmental considerations as it actively addresses socio-economic aspects, emphasizing economic empowerment, inclusivity, and prosperity. An integral aspect of its approach involves the intentional involvement of underrepresented population groups. This reflects a commitment to equitable participation and the promotion of inclusivity in JET.

As a subsidiary of Mahlako a Phahla Investments, Mahlako Financial Services operates as an alternative investment fund manager in South Africa. Unique in its ownership, the company is a 100% black women-owned entity with a Level 1 BBBEE status (Mahlako Financial Services, 2021). This ownership structure aligns with broader empowerment objectives, aiming to transform historically disadvantaged groups. Mahlako Financial Services targets investment opportunities in developmental assets that drive transformative economic impact (Mahlako Financial Services, 2021). The contribution of this case study lies in its mission to contribute meaningfully to economic development through investments that enhance infrastructure and align with sustainable growth goals. By prioritizing both financial returns and social impact, the fund serves as a catalyst for advancing developmental and social objectives within its investment strategy. Moreover, if rural-urban women-led cooperatives can demonstrate effective organizational and operational capabilities, investor-fund firms such as Mahlako Energy Fund could emerge as potential investors. The fund’s commitment to economic and social impact would align with the goals of such cooperatives, thus making it a viable partner for financing projects that enhance energy access and sustainability. By successfully organizing and scaling their initiatives, these cooperatives could attract investment from firms such as Mahlako Energy Fund, thus allowing the firm to leverage its financial resources to further the impact of such cooperatives which would in turn contribute to the broader objectives of Just Energy Transition.

3.7. Ethical considerations

The study is a preliminary investigation into the potential for generating and wheeling green electricity from Chebeng Village in Limpopo (see Figure 1c) to Alexandra township in Johannesburg (see Figure 1b). In this model, a rural women's cooperative could lease land and develop PV-generation installations. These two locations are personally significant to the author, as Alexandra is their birthplace and Limpopo is their paternal home.

When conducting ethnographic observations and living among participants, several ethical considerations arise. These include issues of privacy, consent, power dynamics, confidentiality, reflexivity, community engagement, and the risk of misrepresentation. Addressing these ethical concerns was essential to maintaining integrity and rigor in the research process.

As a basis of ethics clearance application (see Appendix A for clearance letter), ethical concerns and risks were managed as follows:

- Invasion of privacy: Living among participants required access to intimate spaces. This called for a respectful approach to avoid intolerable intrusion. Transparency about the researcher's presence and activities helped establish trust and respect for personal boundaries from the outset.
- Clear boundaries and informed consent: Participants were made fully aware of the researcher's role and the study's purpose. Ongoing consent was sought throughout the research process, thus allowing participants to voice preferences for privacy or withdrawal at any point during the fieldwork.
- Covering personal costs: To prevent the host household from bearing financial burdens, the researcher purchased groceries and prepaid electricity, ensuring that their stay did not create additional strain on the household.
- Addressing power dynamics: To address the inherent power dynamics between the researcher and participants, several efforts were made to cultivate a more equitable relationship throughout the research process. The researcher actively engaged in reflexive practices, continually examining their own positionality and the potential influence of their authority on the participants. This included adopting a participatory approach to fieldwork, where participants were invited to actively contribute to shaping the research agenda and decision-making processes, ensuring their voices were not just heard but meaningfully integrated into the study. In addition, the researcher fostered an environment of mutual

respect by recognizing and valuing participants' lived experiences as legitimate sources of knowledge. Regular check-ins with participants allowed them to express any concerns or suggestions regarding the research direction, thereby promoting their autonomy and reinforcing a sense of shared ownership over the project. These efforts were also complemented by transparent communication, where the objectives and potential outcomes of the research were clearly outlined, thus providing participants with the opportunity to consent fully and participate with agency at every stage of the fieldwork.

- Confidentiality and anonymity: Protecting participants' identities and personal information was paramount. Pseudonyms were used, and identifying details were removed. All data, including field notes and audio recordings, were securely stored to safeguard confidentiality.
- Reflexivity and bias awareness: As a 'native' of Alexandra, the researcher critically reflected on personal biases and assumptions to minimize their influence on participants and ensure the credibility of the research. This reflexive approach enhanced validity of the study and ensured that the research process respected the community context.
- Ethical dissemination of findings: The researcher communicated to participants that the study aimed to contribute to academic understanding rather than provide immediate solutions to energy poverty in Alexandra. This transparency helped prevent misrepresentation and maintained the academic integrity of the research.
- Data storage: All collected data, including field notes, interview transcripts, and digital recordings, were stored securely in password protected drives to protect participants' privacy and comply with ethical guidelines. Access to the data was restricted to the researcher with plans for proper disposal upon completion of the research.
- Ethics approval number SOAP076/07/2023

Chapter Four

Status quo cooking practices and social acceptability of induction stove in Alexandra

4.1. Introduction

This chapter addresses the first sub-question which centers on the potential for low-income households in Alexandra township to embrace induction stoves as an alternative to prevailing cooking methods. Given the reality of cooking cultural preferences and limited access to alternative cooking technologies, the chapter commences with a re-contextualization of energy poverty followed by an overview of the complex dynamics associated with the adoption of induction stoves within this specific socio-cultural context. As highlighted by the Department of Energy (DME, 2012, 22), there is an enduring challenge of energy poverty faced by marginalized households in South Africa, even when connected to the electrical grid. As a consequence, a considerable number of households, numbering in the millions, continue to rely on substandard energy sources, particularly combustible fuels, for their cooking requirements.

On the other hand, induction stoves have been shown to significantly increase energy efficiency, utilizing between 28% and 79% less energy (depending on the meal prepared) compared to conventional electric stoves (Hager & Morawicki, 2013). When integrated with renewable energy technologies such as solar-PV, induction stoves can help in addressing the primary concern pertaining to the carbon-intensive nature of cooking. While these technologies might not hold the status of primary or leading solutions, they provide viable alternatives or supplementary approaches to ameliorate the detrimental health effects, notably respiratory disorders, attributable to carbon-intensive cooking practices, especially among low-income households (Haagsma,J.A., Graetz,N., Bolliger,I., Naghavi,M., Higashi,H.,Mullany,E.C., Abera,S.F., Vos,T 2016; Wolf, Prüss-Ustün & Vickers, 2016).

With reference to UN SDG7 (United Nations, n.d.), Zhang, Raufer, & Liu, (2020) reiterates that indoor air pollution due to dependence on combustible fuels under conditions of poor ventilation contributes to approximately 2.5 million premature deaths per year. Considering the significant energy demand for cooking and the detrimental health impacts caused by indoor air pollution due to smoke among low-income households, induction stoves, especially when combined with a green energy source such as solar-PV, would also confer enormous health benefits for such households. Although solar home systems (SHS) are typically ideal for supporting clean cooking with induction stoves, their installation limitations in low-income communities present a significant barrier to widespread adoption. For example, as demonstrated in

Figure 14, Shapurjee and Charlton (2013, 8) note the limited roof space and weak roof structure for most houses in townships. In addition, theft and vandalism pose further constraints to rooftop PV installation at the scale required to support induction stoves.

Figure 14. Backyard shack in Alexandra township, Johannesburg. Source: (Shapurjee & Charlton, 2013, 8)

Drawing from a three-day ethnographic observation, this chapter documents participants' experiences with their existing cooking practices. This involves a comparative analysis between the conventional stove currently in use and the modern induction stove, while considering factors such as user-friendliness, aesthetics, cookware and spatial requirements in the kitchen. The chapter then presents an assessment of challenges towards utilizing rooftop space for the installation of solar PV panels for localized generation of electricity for the induction stoves.

4.2. Data overview

This section presents a detailed overview of the data collected as part of the ethnographic investigation in Alexandra township. The investigation aimed to understand the existing cooking practices and the integration of an induction stove into existing cooking practices and assess the potential for its acceptance and practical implications. The host household made use of a wall-fixed 4-plate stove as well as a paraffin stove which is mainly used during load shedding. The induction stove used in this study is introduced subsequent to a thorough observation of the household's established cooking practices and norms based on existing equipment and appliances. The household comprised of four participants - two primary homeowners and their two backroom tenants, with shared ablution and kitchen facilities.

The concluding phase of the section presents data and analysis on the workings and customary norms of an existing *stokvel,* specifically for the purpose of evaluating its potential for transformation to a consumer cooperative to reciprocate the hypothesized power generation cooperative in Limpopo. Considering that the hypothesized business model aims to not only introduce sustainable energy solutions but also to create a supportive ecosystem across the urban-rural context for households, data related to the first sub-question are presented in Table 9 which focuses on energy consumption patterns, meal preparation times, cookware being used, and rooftop adequacy for PV installations.

Table 9. Data overview for sub-question 1

Sub-question 1	Primary data	Secondary data
What is the potential of adopting induction stoves as a substitute for combustible fuels among low-income households in Alexandra township when considering cultural preferences for traditional cooking methods and limited access to alternative technologies?	- Alexandra township will consist of ethnographic observations in Alexandra township for the purpose of observing social interactions and processes within the specific real-life setting of the participant. This approach will enable a comparison between prevailing cooking practices and induction stove usage for various meals, including breakfast, lunch, and dinner, as well as light meals and boiling water -Interview and ethnographic observations documenting women interactions within specific community- based organizations (CBO such as stokvels) that could transform into energy consumer cooperative -Visual documentation in the form of photographs, audio and video recordings, individual interviews, and direct observations will be key tools aimed at contributing to a more comprehensive understanding of the study area and its socio-political dynamics -Transect walk with at least 2 co-walkers for documenting insights on characteristics and dynamics of Alexandra's area, especially with regard to housing structures (mainly roof-space/structure) and sense of security (especially with regard to security-risk of solar-PV panels), as well as extent of unplanned cable network for illegal electricity connection to homes	- Data from the Pietermaritzburg Economic Justice & Dignity Group (PMBEJD) highlights how low wages and the National Minimum Wage (NMW) impact the affordability of cooking energy (2021,7) - The residential prepaid tariffs for COJ (City of Johannesburg, 2023, 2). - Roof-space adequacy and security concerns (theft of installations) in similar contexts (Shapurjee & Charlton, 2013, 8) - The energy stacking and energy ladder theories that challenge the view that economic growth solely determines household energy use (Masuku, 2024, 9).

4.3. Social constructs influencing household meal preparation

As established in the literature review (see Chapter 2, Section 2.3 and 2.4) women are significant consumers of fuels and energy services, with cooking being a primary example (Moniruzzaman & Day, 2020, 3). Despite their crucial role in energy use, women in low-income contexts are faced with a limited range of energy options, which further constrains their ability to make informed decisions about energy procurement and utilization. This disparity arises from several intersecting factors. Socioeconomic constraints, such as financial dependency and economic limitations, often hinder women's capacity to independently make energy-related choices. In support of this view, Participant 1, disclosed her responsibility for all cooking and meal preparation, underscoring her significant role in energy use despite having minimal decision-making power. She detailed her use of traditional slow-cooking methods, which involve extended simmering times integral to her culinary practices. Participants 3 and 4, who occasionally assist her, also noted the importance of prolonged cooking durations for enhancing the flavor and texture of their dishes. They expressed concerns on whether induction stoves could replicate these slow-cooking attributes, reflecting a broader apprehension about adopting new cooking technologies.

4.4. Average cooking time and estimated energy cost

The concept of 'energy stacking' stands out in opposition to the commonly discussed 'energy ladder.' Research on energy stacking argues against viewing economic growth as the sole determinant of household energy-use patterns, emphasizing the influence of factors such as affordability, energy technologies, cultural preferences, and local regulations (Masuku, 2024,9). This discussion is particularly relevant to understanding how households make decisions regarding cooking methods and energy consumption. These topics are further explored in the findings section of this chapter. As opposed to the commonly discussed energy ladder, 'energy stacking' model, suggests that an increase in household income does not necessarily lead to an immediate transition to modern fuels like electricity or LPG (Masuku, 2024,9).

Shifting focus, the ongoing service delivery protests in Alexandra, marked by severe housing backlog and lack of access to essential services, including electricity, are pertinent to the discussion on energy costs. City Power's electricity disconnections for non-paying residents that shows the challenges faced by communities in meeting their energy needs (Dlamini, 2023). The low percentage of businesses and residents in Alexandra paying for electricity further highlights the complex dynamics in energy consumption within low-income communities. Given these challenges, people like Participants 1 and 3, who work as general workers, face difficulties in meeting essential household expenses. This was pointed out in the data presented by the Pietermaritzburg Economic Justice & Dignity Group (PMBEJD) in 2021. As seen in Table

10, the data directly relates to the investigation into energy expenses. In this context inadequacies of low baseline wages and the meager levels of National Minimum Wage (NMW) raise questions about the affordability of energy sources for cooking. The prioritization of non-negotiable expenses, such as transportation and electricity over food, offers insights into the financial challenges confronting low-income households in meeting their energy needs for cooking — challenges that also resonate with participants in the study's host household.

Table 10. NMW and social grant data (PMBEJD, 2021,7).

General Workers: at NMW			**R21,69 an hour**
Income	**Wage scenario 1**	**Wage scenario 2**	**Wage scenario 3**
Number of days worked	19	15	15
Number of hours worked	8	8	5
Remuneration rate	R21,69	R21,69	R21,69
Wage income	**R3 296,88**	**R2 602,80**	**R1 626,75**

	Wage scenario 1		**Wage scenario 2**		**Wage scenario 3**	
Wage income	**R3 296,88**		**R2 602,80**		**R1 626,75**	
Household expenses		**% of wage**		**% of wage**		**% of wage**
Transport to work (2 taxi, return)	R1 140,00	34,6%	R900,00	34,6%	R900,00	55,3%
Prepaid electricity (350kWh)	R647,50	19,6%	R647,50	24,9%	R647,50	39,8%
Total for transport + electricity	**R1 787,50**	**54,2%**	**R1 547,50**	**59,5%**	**R1 547,50**	**95,1%**
Money remaining to secure all other expenses	**R1 509,38**		**R1 055,30**		**R79,25**	
Subtract: food (4 persons)	R2 950,76		R2 950,76		R2 950,76	
Minimum *surplus/shortfall on food costs*	**-R1 441,38**	**-48,8%**	**-R1 895,46**	**-64,2%**	**-R2 871,51**	**-97,3%**

In a document titled *Understanding Electricity Tariffs* released by the City of Johannesburg's Group Finance (City of Johannesburg, 2023, 2), City Power adopts NERSA's inclining block tariff system, where electricity rates increase as consumption surpasses set thresholds (350kWh for block 1, 500kWh for block 2, and exceeding 500kWh for block 3). As seen in Table 11, City Power raised residential prepaid tariffs by 7.47%, as per NERSA's recommendation. Consequently, customers using 350kWh or less monthly will now pay R1.8237 per kWh, up from the previous R1.6969. For those consuming exactly 350kWh, this equates to an additional cost of R44.37, resulting in a total charge of R638.29 compared to the previous R593.92 (City of Johannesburg's Group Finance, 2023, 2). For instance, if a customer purchases 350kWh at the beginning of the month, the charge will be R638.29. However, if they require an additional 350kWh midway through, the cost will rise to R790.51. This reflects the inclining block tariff principle, where higher electricity usage incurs higher costs beyond the initial block (City of Johannesburg, 2023, 2).

Table 11. COJ residential prepaid tarrif for 2021/22 and 2023/24. Source: (City of Johannesburg, 2023, 2).

Residential Prepaid

Prepaid 2021/22				
Assumed Monthly Usage (kWh)			700	
	Size	Tariff (c/kWh)	Rand (VAT Excl.)	Rand (VAT Inc.)
Block 1	350	169,69	R593,92	R683,01
Block 2	500	194,65	R291,97	R335,77
Block 3	>500	221,80	R443,59	R510,13
Sub-total			R1 329,49	R1 528,91
Basic charge			R0,00	R0,00
Total charge for the month			R1 329,49	R1 528,91
Average selling price (c/kWh)			189,93	218,42

Prepaid 2022/23				
Assumed Monthly Usage (kWh)			700	
	Size	Tariff (c/kWh)	Rand (VAT Excl.)	Rand (VAT Inc.)
Block 1	350	182,37	R638,29	R734,03
Block 2	500	209,19	R313,79	R360,85
Block 3	>500	238,36	R476,73	R548,24
Sub-total			R1 428,80	R1 643,12
Basic charge			R0,00	R0,00
Total charge for the month			R1 428,80	R1 643,12
Average selling price (c/kWh)			204,11	234,73

Increase of 7,47%

All the calculation is before consideration of VAT.

Table 12 triangulates the four key expenditures for the study participants, all of which are directly influenced by the tariff structure. Participants 1 and 3 are formally employed, Participant 2 is a taxi marshal earning a commission-based wage, and Participant 4 is actively job hunting.

Table 12. Income versus basic costs of living of the host-household.

	Participant 1	% of income	Participant 2	% of income	Participant 3	% of income
Wage/salary	R3400		R900		R3600	
Transport	R980	28%	-	-	R572	15%
Food	R1200	35%	R350	38%	R1200	33%
Policies	R600	17%	R154	17%	R890	24%
Prepaid electricity	R600	17%	R150	16%	R600	16%

While spending just below 20% on prepaid electricity may seem manageable at first glance, it underscores the economic fragility of low-income households and the broader implications of energy costs—especially in light of the City Power tariff structure—on their financial stability and quality of life. With limited disposable income, participants rely on each other to balance their energy expenditures with essential costs. Consequently, they may be forced to compromise on other critical areas of their lives such as healthcare, and education, potentially affecting their overall well-being and quality of life. Notably, the themes of healthcare and educational betterment did not emerge in the participants' discussions, suggesting that these areas are not even on their radar amidst their immediate financial concerns.

4.5. Exposure to pollutants during cooking activities

Zhang, Raufer, & Liu (2020) underscore the critical impact of indoor air pollution resulting from the use of combustible fuels in poorly ventilated environments which is a factor that becomes relevant once the host household uses their paraffin stove. This factor becomes particularly pertinent when households similar to the one under investigation in Alexandra face challenges such as load shedding and disconnections from municipal supply due to non-payment or illegal connections and then resort to using their backup paraffin stoves. Participants, whose status quo cooking practice relied on electrical stoves, found themselves compelled to turn to paraffin as the sole source of fuel for cooking and boiling water under such circumstances. Figure 15 shows the electric stove used for day-to-day meal preparation. In contrast, Figure 16 serves to illustrate the household's recourse to a paraffin stove as a contingency during instances of load shedding and City Power disconnections.

Figure 15. Host household's electric cookstove.

Figure 16. Host household's paraffin cookstove.

4.6. Existing cultural preferences for cooking

The three days ethnographic observations in Alexandra gave a window into the cooking practices of the host household as they adapt to the dual factors of high electricity costs and change inertia within the income group. Balmer (2007) highlights that in low-income households in developing countries, nearly all energy is directed towards cooking, with minimal allocation to lighting. Cooking times and the necessary rate of heat input for staples and other foods vary. Figure 17 provides an illustration of the energy consumption per meal for a family of four based

One of the key fieldwork findings indicates that while the adoption of induction stoves in low-income households offers potential benefits in terms of energy efficiency and safety, acceptance of the technology would be contingent on factors such as reliable access to suitable cookware. The cookware used by the host household did not exhibit compatibility with the induction stove as it is composed of aluminum or anodized aluminum (see Figures 17 and 18). Conversely, most other materials, notably stainless steel and cast iron, are amenable to induction cooking. Figure 17 shows the cookware used for daily cooking on both the electric stove and the paraffin stove, while Figure 18 shows the cookware purchased by the researcher specifically to ensure compatibility with the induction stove. Finally, Table 13 is a cost breakdown between the conventional stove, induction stove, and required cookware for each.

Figure 17: Cookware currently in use.

Figure 18. Compatible cookware for induction stove.

Table 13. Conventional electric, paraffin versus induction stove and cookware costs (adapted from Univca and Takealot)

	Conventional electric stove	Paraffin stove	Induction stove
Stove price	R3200	R300	R1100
Required cookware cost	R1300 (for a set of 7 pots)	Uses the same pots as conventional stove	R700 (per pot)

Table 14 provides a summary of the durations required for meal preparation of staple foods during breakfast, lunch, and supper, along with insights from a three-day ethnographic observation. This table consists of figures 19 -21 that show the staple foods prepared on the household's electric/conventional stove. The primary aim of this analysis was to address the initial sub-question regarding the patterns and efficiency of meal preparation in the observed households. The data forms the basis for understanding current cooking practices which serve as the foundational component of the study.

Table 14. Ethnographic observations on existing energy consumption patterns in the host household using conventional electric cookstove

Primary data	Description	Key observation
 **Figure 19:** Breakfast being prepared by Participant 1	Meal preparation of breakfast for 4 people on the paraffin stove due to loadshedding.	Meal preparation during weekday: breakfast for 1 person typically took 17 minutes prepared by Participant 1. The meal consisted of soft maize meal porridge. The meal preparation for a weekend day: breakfast typically took 19 minutes prepared by Participant 1. Figure 19 shows Participant 1 preparing to boil water for tea with *vetkoeks* due to loadshedding In some instances porridge was prepared on the conventional stove before loadshedding started. Paraffin stoves typically have a single small plate for cooking, This limitation can lead to inefficiencies in terms of time, energy, and resources. In the context of this household, participants considered paraffin cooking wasteful because it requires more time and effort to prepare meals compared to using conventional electric stove with multiple working plates. Limited capacity of a paraffin stove may restrict the types of dishes that can be cooked efficiently. This real-time impact of external factors on daily routines underscores the practical and adaptive approaches individuals in low-income households adopt in response to challenges like load shedding.
 **Figure 20:** Week-day lunch being prepared by Participant 1	Meal preparation for lunch on electric stove	On weekdays, lunch preparation usually consumed 90 minutes as Participant 1, the primary person responsible for cooking, prepared meals for herself and Participant 4. Cooking lunch during the week is infrequent in this household due to the work commitments of Participant 1, who holds a key role in cooking activities. Limited time is spent during the week in the kitchen since the main participant responsible for cooking is employed as a general worker. In the event where lunch was prepared during the day owing to a day-off, lunch typically consisted of white pap with chicken feet and an onion-tomato salad. The meal preparation for the weekend: lunch typically consisted of a local meal called *"kota"* which consists of bread, fried chips, Vienna and side salads. The cost of this meal is much cheaper and requires minimal use of electricity over the weekend.

 **Figure 21:** Week-day supper prepared by Participant 1	Meal preparation for supper on electric stove	The meal preparation for week-day: supper typically took 30 minutes. Due to increased load-shedding schedule, enough food is prepared in the afternoon so that the family only warms up the food in the evenings. On this particular day, only pap was prepared and the leftover meat from the afternoon was used to complete the meal. The meal preparation for weekend-day: supper typically took between 40 -60 minutes. Suspended loadshedding schedules over the weekend meant that longer cooking times could be spent in the kitchen. Participant 1 and 3 prepared rice, tinned fish and salads on the side.

4.7. Introduction of the induction stove in the host-household

Following careful observation of existing cooking practices, the procurement of an electric induction stove (see Figure 22) and compatible pot was undertaken at a cost of R1 100 followed by training sessions to familiarize participants with its usage. A noteworthy finding during fieldwork was that while integrating induction stoves in low-income households holds potential for enhanced energy efficiency and safety, its efficacy is contingent upon factors such as affordable access to compatible cookware. This introduces an additional layer of costs, thereby diminishing social acceptability. Significantly, a majority of the cookware used by the household in this study exhibited incompatibility with the induction stove. Household's cookware is primarily composed of aluminum or anodized aluminum. Apart from the financial implications associated with acquiring suitable cookware, the nature of meals required extended preparation time which added complexity to the acceptance of the induction stove.

Figure 22: Induction stove used for the study

Furthermore, the introduction of new cooking technology alongside the conventional electric stove posed logistical challenges in the confined cooking space. The smaller space needed for a counter-top induction stove might not be an advantage because regular stoves usually come with an oven. So, the smaller size of the induction stove may not matter if you value or use the extra oven space provided by a regular stove. Put differently, the space efficiency of the induction stove may not necessarily translate into a practical advantage for those who value or use the additional features offered by a conventional stove, such as the oven. In this sense, the cramped quarters made it difficult to integrate additional appliances like the induction stove, especially when the conventional stove had proven reliable over the years, and there was no compelling reason to replace it. This spatial constraint was particularly pronounced in the host household under observation. In such settings, the allocation of space for cooking represented a delicate balance, with participants frequently having to prioritize essential cooking tools and necessities within the confined kitchen area. Table 15 presents an overview of the cooking experience when using the induction stove and consist of Figures 23 -25 that show the staple foods prepared on the Sokany induction stove.

Table 15. Observation data on cooking patterns using the induction stove

Primary data	Description	Key observation
 **Figure 23.** Meal preparation for breakfast.	Meal preparation for breakfast using the Sokany induction stove.	Meal preparation for week-day: breakfast typically took 11 minutes prepared by Participant 1. The meal consisted of soft maize meal porridge. Meal was prepared in the backroom due to space constraint. Induction stoves are typically plug-and-play devices and do not demand heavy-duty electrical connections required for conventional electric stoves with ovens. This ease of use and flexibility in electrical requirements would play a significant role in the decision to switch. Meal preparation for weekend-day: breakfast typically took 14 minutes prepared by Participant 1. The meal consisted of deep-fried dumplings, tea and polony. The induction stove was used to prepare the polony and boil water for tea.

 **Figure 24.** Meal preparation for lunch.	Meal preparation for lunch using induction stove	Meal preparation for week-day: lunch typically took 40 minutes prepared by Participant 1. The meal consisted of white pap (prepared with maize-meal) with fried fish and salads on the side. Due to the fact that the induction stove has 1 plate which meant that one-plate was a constraining factor, especially when more household members are to be catered for, only pap was cooked on the stove. Meal preparation for weekend-day: lunch typically took 90 minutes prepared by Participant 1. The meal consisted of pap and chicken feet stew. The induction stove was used to prepare the chicken feet stew.
 **Figure 25.** Meal preparation for supper	Meal preparation for supper using induction stove	Meal preparation for week-day: supper typically took 40 minutes prepared by Participant 1. The meal consisted of chicken portions, pap and baked beans. The induction stove was tested for efficiency in cooking chicken pieces. Meal preparation for weekend-day: supper typically took about 42 minutes, prepared by Participant 1. The meal consisted of rice, meat, baked beans and salads on the side. The induction stove was tested in cooking rice.

4.8. Affordability as a percentage of household income

SEA (2018, 27) reveals that 76% of all South African households have embraced electricity as their predominant form of energy for cooking. However, low-income households have continued using paraffin stoves as well as other combustible fuels which entail indoor air pollution and resulting in respiratory ailments. The induction stove, characterized by its clean and efficient operation, mitigates such pollution and health risks. Consequently, the financial burden imposed by medical expenses and treatments stemming from cooking-related health issues can be mitigated thus reflecting the need for a broad-based assessment of viability and affordability.

Furthermore, a reduction in cooking-related expenses translates into a potential catalyst for economic mobility within low-income households. As less of household income is apportioned to cooking, opportunities arise for savings or investment in education and skills development. This investment, in turn, could augment employment prospects and income levels, thereby perpetuating an upward trajectory of economic well-being. These considerations become particularly significant when introducing front-runner cooking technologies such as the induction stove, while emphasizing the crucial factor of affordability. In the case of the host household, the proportion of affordability relative to their income emerged as a pivotal determinant based on the following factors:

4.8.1 Energy efficiency and cost reduction

In the context of the host household, prevailing cooking methods are recognized for incurring substantial energy costs. An illustration of this phenomenon was evident in the significant expenditure earmarked for paraffin and matches, which are utilized to fuel the paraffin stove as depicted in Figure 26. These expenses often constitute a considerable proportion of a household's financial resources, consequently restricting availability of funds for other essential necessities. Adding to this financial constraint is the joint expenditure for the household, which amounts to R7 900, with the cost per liter for paraffin sitting at 1 981.0c/l (SABC News, 2024), and prepaid electricity expenditure at about R1 700. The adoption of induction stoves, renowned for their intrinsic energy efficiency, presents an opportune avenue to markedly curtail electricity bills. Consequently, a smaller fraction of the household's income would be allocated to cooking-related expenses, thereby enhancing overall affordability.

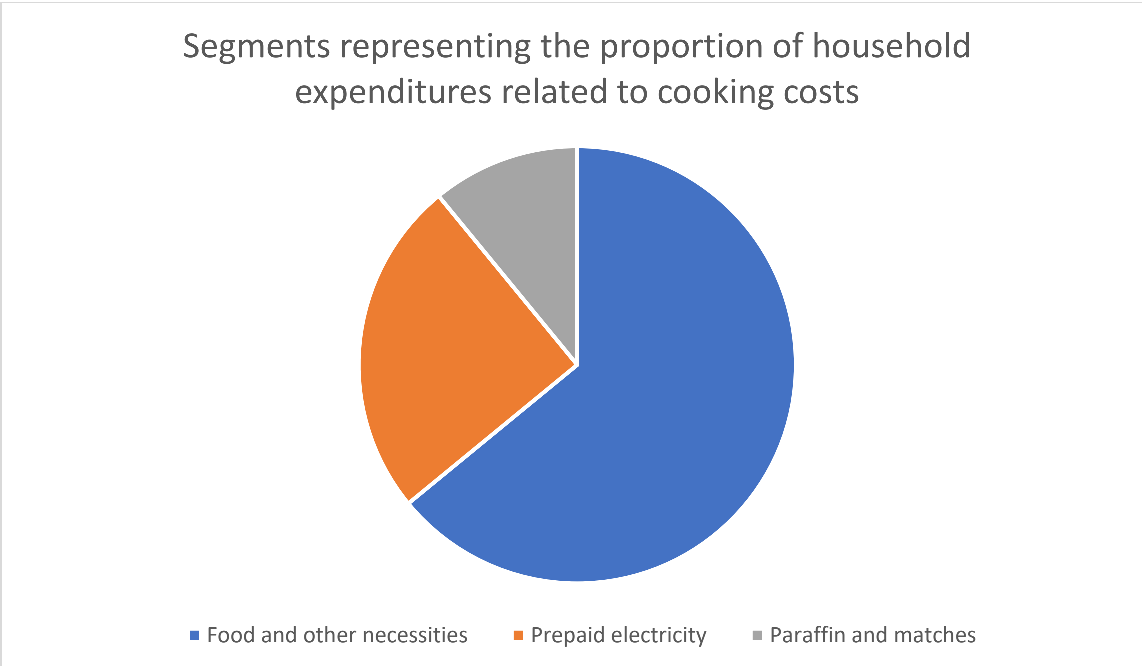

Figure 26. Segment breakdown of host-households expenditure.

Data presented in the figure above are estimates obtained through various methods, including interviews, phone records, and observations, as precise records are not available in this low-income household because they do not have a record-keeping system. These estimates are intended to provide a general understanding of energy-related practices within the community.

The electricity prepaid electricity consumes a large portion of the household's overall expenditure which amounts to about R1 700 monthly. Most of that consumption goes to the fixed electric stove which is used for most of the cooking. The segment dedicated to paraffin and matches, totaling R800 per month, emphasizes the considerable expenses associated with the secondary paraffin-stove used during load-shedding. This segment not only brings to the fore the financial commitment but also prompts a broader discussion on the elevated costs tied to essentials such as food, various *stokvel* contributions, and more. As such, this part of the investigation prompted a compelling discussion of the economic advantages and considerations associated with different cooking technologies. It highlighted the potential financial benefits of embracing induction stoves, not only in terms of direct electricity costs but also in the broader context of overall household expenses.

4.8.2. Initial investment and long-term benefits

While it is widely recognized in existing literature that induction stoves may require a higher upfront investment compared to certain conventional cooking appliances, the economic rationale should extend to long-term considerations. Low-income households often find themselves trapped in a repetitive cycle of purchasing inexpensive yet energy-inefficient appliances, resulting in significant cumulative costs over time. As one participant revealed, the paraffin stove currently in use is the second one bought this year. The first one failed to maintain a consistent flame, and it was retained as a backup in case the current one malfunctions. In this context, the initial investment in an induction stove can be regarded as a financially practical choice, given its energy efficiency and durability. Over the stove's operational lifespan, substantial savings on energy consumption can be achieved, thereby reducing the portion of income allocated to cooking-related expenses as shown in Table 16.

Table 16. Upfront costs versus operational costs of the two modes of cooking.

Cost Category	Traditional Cooking (Status Quo)	Induction Stove Cooking
Upfront Costs	Paraffin Stove: Approx. R300, requiring replacement every 2-3 years. Electric Stove: Approx. R3200, a higher initial cost but potentially longer-lasting.	Induction Stove: Approx. R1100 for a 2-plate stove.
Operational Costs	Fuel Costs: Paraffin at approx. R18 per liter. Other Consumables: Matches at approx. R10 per pack of 10. Electricity: Prepaid meter costs for electric stove usage vary based on usage and local tariffs.	Consumption: Costs would be determined by kilowatt-hour (kWh) rates imposed by the hypothesized solar generation cooperative in Limpopo, thus contributing to more predictable energy pricing. Maintenance: Minimal, though regular checks on the stove and the electric grid infrastructure would be required.

4.8.3. Environmental implications

Apart from energy-savings and financial benefits, adoption of induction stoves carries notable environmental importance, especially in the event of increased load-shedding schedules where paraffin stoves are used to cater for cooking needs. This is a matter of heightened concern in low-income communities, which frequently bear a disproportionate burden of environmental degradation due to use of combustible fuels for cooking. Furthermore, due to the close proximity of the host household to their neighbors, it was observed that the smell of paraffin fumes quickly spreads during load shedding, which was at level 5 at the time of fieldwork for data collection. The combination of these findings underscores the urgency and significance of addressing the challenges posed by both load shedding and the resulting fumes (indoor and outdoor - due to use of combustible fuels such as paraffin) in Alexandra Township.

4.9. The existing urban consumer-based organization

Bisaga, Campbell, Bellanca, Kleijn and To (2022, 8) assessed the willingness of households in Uganda to invest in the ECOCA solar-PV based induction stove. Their study compared the appeal of the stove to other clean cooking alternatives. Initial findings from the pilot study indicated a strong inclination to invest in the ECOCA stove. This was primarily driven by the stove's unique feature, especially its ability to provide electricity access and its multi-functionality. The ECOCA stove can also support lighting and charging of electronic devices through USB ports also powered by the solar-PV thus making it especially attractive.

In the case of Alexandra township, consumer behavior and preferences within the existing consumer cooperative network known as *stokvels* have historically played a significant role. One example provided by Participant 1 is the use of a *stokvel* to distribute a pap cooker introduced by a Chinese entrepreneur that allowed users to prepare pap in just 20 minutes (see Figure 27).

Figure 27. Pap-cooker.

Stokvels are founded on social capital, as members trust each other with their finances (Orlu & Rambe, 2022, 13). This trust can help overcome skepticism or uncertainty regarding new technologies like solar stoves and facilitate knowledge sharing and adoption within the community. Acting as coalitions of entrepreneurs, cooperative organizations have the potential to enhance financial sustainability for their members. Figure 28 shows anonymized *stokvel* members meeting in Alexandra township held for a December grocery savings plan. Key insights gained from the existing *stokvel* network in Alexandra includes:

- *Stokvels* can pool resources from their members, making it more accessible for individuals who might not have access to affordable conventional financing options to afford a solar induction stove. They have the potential of addressing the affordability barrier which is a significant hindrance to the adoption of clean energy technologies.
- *Stokvels* involve collective decision-making processes which can enable members to discuss and collectively decide on the purchase of solar induction stoves as a group. This would ensure that the technology aligns with the community's specific needs and preferences.
- The use and maintenance of induction stoves may require skills development and training. This presents an opportunity for skills-building within the community, which can lead to job creation and entrepreneurship opportunities in appliance repair, maintenance, and training.

Figure 28. Members of the *Matsogo* stokvel in Alexandra township.

While the existing *stokvel* network in Alexandra Township may predominantly operate on trust, there is an observable blend of formality and adherence to common rules. Participants frequently enter into collective agreements and informal regulations to guide the *stokvel's* operations. However, the degree to which formal rules or regulations are instituted varies based on the specific objectives at the time and the scale of the agreement, particularly when pooling funds for communal financial support, such as emergency loans and funeral expenses.

Observations conducted on the existing *stokvel* networks suggest that, despite the prevalence of informality and flexibility, there exists a plausible trend toward heightened formalization and adaptability. The key transitions that were identified include:

- **Initial Stage:** Informal, trust-based operations.
- **Structural Trigger:** The growing need for formal mechanisms, such as joint bank accounts and legal agreements.
- **Operational Action:** Implementation of regular contributions, systematic record-keeping, and enhanced accountability.
- **Full Formalization:** External pressures, notably energy costs, propel *stokvels* to evolve into fully formalized energy cooperatives, which would allow them to access funding and participate in larger-scale projects.

The transition from *stokvels* to formal cooperatives in South Africa, presents a compelling yet challenging opportunity to reshape economic dynamics and address endemic development constraints. Central to this transformation is the Cooperatives Act 14 of 2005, which not only establishes a legal framework for cooperative governance but also embodies internationally recognized cooperative principles (DTIC, 2010, 3). The 2013 amendments and the introduction of a Code of Good Practice were intended to refine cooperative operations (DTIC, 2010, 3). Within this context, the broader critique is the sufficiency of these measures to catalyze the shift from informal to formal cooperative models. The involvement of the Department of Social Development (DSD) in social welfare initiatives underscores a complex aspect of welfare support and donor dependency. While informal *stokvels* have a significant economic impact, their transition to formal cooperatives encounters substantial challenges, such as governance issues and high failure rates. Overcoming these challenges necessitates more than just incremental policy changes. In particular, it requires a fundamental rethinking of cooperative support and development. To effectively address the urban-rural divide and energy poverty, it is crucial to reevaluate the roles of government bodies and state-owned enterprises (SOEs), to ensure their support is strategically aligned with economic equity goals and capable of nurturing resilient and sustainable cooperative models (DTIC, 2010).

The Department of Trade, Industry, and Competition (DTIC) is tasked with overseeing this complex landscape, confronting the reality of fragmented support systems and alarmingly high failure rates among cooperatives (DTIC, 2010, 36). This situation raises a critical issue around the systemic changes that are necessary to ensure that cooperative policies translate into meaningful support rather than merely theoretical policy frameworks. The Companies and Intellectual Property Commission (CIPC) facilitates the registration and legal compliance of cooperatives, yet their role prompts scholars to consider whether the bureaucratic processes adequately address the unique challenges faced by emerging cooperatives (DTIC, 2010, 36)

The National Empowerment Fund (NEF) plays a crucial role by providing financial support through mechanisms such as the Rural and Community Development Fund, which offers substantial funding to foster economic development in rural areas (National Empowerment Fund, n.d.). However, the effectiveness of this support needs to be critically assessed to determine whether the funding is truly transformative, or if it merely scratches the surface of deeper economic and structural constraints. On the other hand, other state-owned enterprises (SOEs) such as Eskom, Transnet, Telkom, and Airports Company South Africa (ACSA) would be pivotal toward providing the necessary infrastructure and logistical support for cooperatives (DTIC, 2010, 48). Yet, their involvement would prompt an inquiry into whether their current models of support align with the broader objectives of equitable economic development and sustainability. Considering the interplay of various government bodies, formal mechanisms become essential at each critical stage of cooperative formalization, thus necessitating government support to facilitate scaling operations, as illustrated in Figure 29.

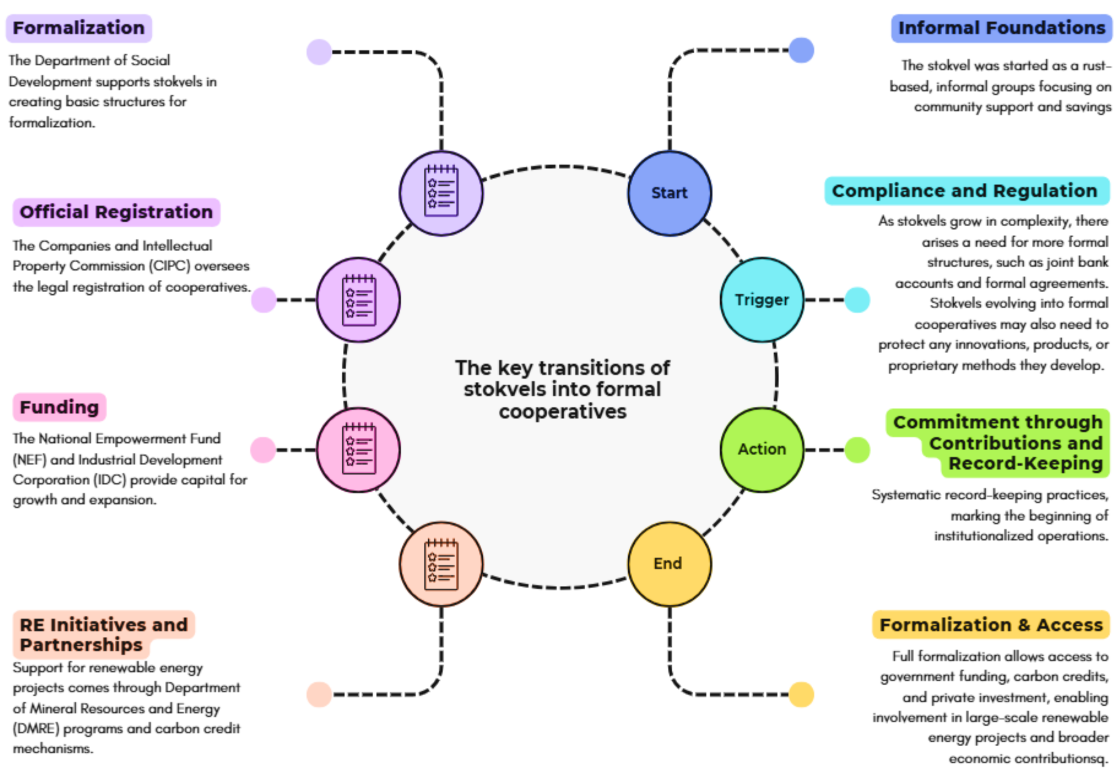

Figure 29: Schematic representation for the key transitioning stages of *stokvels* into formal cooperatives also highlighting government's role at each stage.

4.10. Constraints and challenges of installing roof-top solar-PV systems on low-income houses

Acknowledging the limited engagement of low- and middle-income households (LIHH & MIHH) in the increasing adoption of rooftop solar PV within the residential sector of the South African market, SEA, (2019, 4) conducted an initial investigation to identify the diverse barriers impeding the adoption in this sector. As part of the process of seeking viable solutions, a bespoke spreadsheet model was developed to facilitate assessment of potential long-term electricity cost savings for households, contingent upon access to affordable loans for grid-tied rooftop PV systems. Central to the model was the determination of whether the accrued savings would sufficiently cover loan repayments, contingent upon changing electricity tariffs. The model incorporated a spectrum of variables and assumptions, encompassing tariffs and household demand profiles, thus offering flexibility in examining the impact of these factors on financial viability.

Findings by an earlier iteration of the model specifically scrutinized Tshwane and Johannesburg municipalities, in addition to Cape Town, and based on 2017/2018 tariffs - SEA (2019, 10). Outcomes of the analysis can be summarized as follows:

- The model consistently projected a substantial increment in income for municipalities, relative to the default 'without SSEG' scenario, across nearly all cases.
- Conversely, households encountered challenges in achieving financial parity within any plausible loan repayment timeframe, even when extended to a 20-year period.
- This financial predicament was notably conspicuous among low-income households, who, despite benefiting from tariff subsidization at the lowest consumption levels (typically < 350 kWh/month), faced difficulties in breaking even.

These findings emphasize the critical need to address financial barriers that hinder the engagement of low- and middle-income households in the adoption of rooftop solar PV. There is evidence for urgency in the development of targeted interventions designed to enhance accessibility of sustainable energy solutions for these specific demographic segments. The primary variable behind these findings is the SSEG tariffs applied to all three municipalities. The tariffs are mainly characterized by high fixed monthly charges and relatively low feed-in tariffs which resulted into negative net savings for households after accounting for loan repayments on the PV system. This remained the case even when households reduced municipal electricity consumption by up to 33% through practices such as shifting hot water heating to daytime hours using PV power.

The financial impracticality persisted even when modeling relatively high tariff escalation rates (such as 5% above CPI) throughout the entire loan-repayment period. Given the absence of an equivalent 'low-income' SSEG tariff for households eligible for tariff subsidization, the more rational choice for them remains to utilize 100% municipal energy at the subsidized tariffs. Notably, one of the valuable outcomes of the modeling exercise was the identification of several factors that could contribute to a more appealing investment case for low-income rooftop PV systems in the future (SEA, 2019, 13). The key factors are:

- Escalating Eskom tariffs well above inflation for the foreseeable future
- Fundamental changes in municipal tariff structures enabled by smart meters so that municipalities can offer Time-Of-Use (TOU) tariffs to domestic end-users (in alignment with their input costs of supply)
- PV affordability due to ongoing competition in the rooftop PV industry (internationally, at R&D level, and locally, as more installers and suppliers enter the market) and resultant cost reductions in PV system installations
- Innovative approach to capital financing such as integrating the hardware loan into a home-loan facility, leveraging the extended lifespan of well-maintained modern rooftop PV systems, which typically exceeds 25 years. Additionally, government-funded financing options, such as Property Assessed Clean Energy (PACE) which is used in the US enables property owners to fund energy efficiency, renewable energy, and water conservation improvements on their properties. This mechanism for financing offers an alternative avenue for addressing consumers' financial constraints towards adopting rooftop solar PV
- Storing energy, especially using technologies like a large Vanadium Redux Flow Battery (VRFB), where initial calculations show that relying solely on tariff arbitrage savings (the price difference between peak and off-peak rates) is not financially practical. Levelized Cost of Storage (LCOS), make storage financially appealing mainly during winter weekdays when peak and off-peak rate differences are high. However, this type of battery tech is still in development. As storage costs decrease over time, it is expected that the difference between peak and off-peak rates, even in low-demand periods, will eventually be greater than storage costs, making large-scale storage investments more sensible. Apart from cost savings, local storage can also bring other advantages, such as better management of energy frequency, having standby reserves, responding to changes in demand, and reducing charges tied to high energy-use
- In the context of apartment blocks, centralization (implementation of collective schemes strategically designed to leverage economies of scale, aggregate demand profiles for enhanced self-consumption, optimize efficiencies and mitigate project risks) opens avenues for larger-scale investment opportunities

Within the context of this study, load shedding has precipitated an upsurge in demand for solar panels, leading to the emergence of an extensive black market for these energy devices, as highlighted in the *Daily Maverick* (Moodley, 2023). The panels are either disassembled to extract valuable components, like copper, or they are sold as they are. Gaylor Montmasson-Clair (facilitator of the South African Renewable Energy Masterplan and assistant program manager for sustainable growth at Trade & Industrial Policy Strategies), noted that between 2010 and 2022, South Africa imported solar panels worth R31 billion (Moodley, 2023). This has given rise to an environment for thriving criminal enterprises. It is also essential to recognize that these concerns extend far beyond South Africa and have a global reach. For instance, according to PV magazine, the UK experienced a significant 93% surge in reports of solar panel-related crimes from 2021 to 2022 (Moodley, 2023).

Beyond these security-related concerns, ethnographic observations in Alexandra Township unveiled constraints that uniquely impact the potential of having solar panels installed directly on most roofs. The key factors identified during the transect walk were as follows:

- Limited roof area due to small size of units per household.
- Participants also raised security concerns regarding such installations especially within highly insecure townships such as Alexandra. High vulnerability to theft and damage by disasters such as fire profoundly diminishes long-term sustainability and economic viability of self-generation installations within low-income neighborhoods
- Inappropriate pitch and orientation: Low-pitch and off-north roof orientations would undermine performance levels of PV-systems. In most low-income homes, this would necessitate correction measures which would entail additional costs of installation
- Figure 30 shows the ceiling (underside of roof) of the host household's home which displays structural inadequacy of the existing roof in accommodating the additional loading of solar panels and related accessories on the roof. The images further show poor roof quality which contributes to leaks and water damage inside the home. Installing solar panels on a roof with existing leaks can exacerbate these issues, as the installation process may further compromise the roof structure and waterproofing

Figure 30. Exterior and interior views of the host household's roof.

The transect walk illustrated that a significant number of low-income residents live in aging homes or buildings with roofs that have markedly deteriorated over time. As shown in Figure 31, the transect walk, conducted along a route stretching from 28 10th Avenue, Alexandra Extension 62, to 1 Roosevelt Street, Alexandra East Bank, was strategically chosen to capture a cross-section of the quality of the housing units. The route was selected because it traverses both older, more densely populated areas of Alexandra, where infrastructure challenges are particularly acute, as well as newer and slightly better-off sections. Figure 30 shows why roof area and structural stability pose critical limitations on installation of roof-top solar PV systems

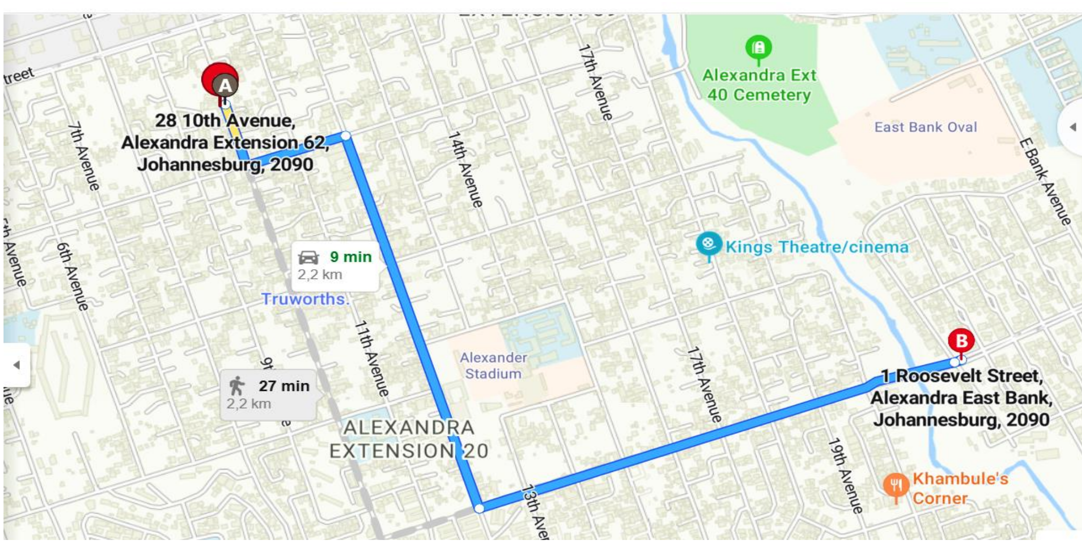

Figure 31. Transect walk conducted along 28, 10th Avenue, Alexandra Extension 62, to 1 Roosevelt Street, Alexandra East Bank, Johannesburg. Source: (Bing maps, 2024: [28 10th Avenue, Alexandra Extension 62, Johannesburg, 2090 - Bing Maps])

By following this path, the transect walk aimed to document variations in housing conditions, focusing on critical issues such as roof deterioration. The widespread occurrence of decaying roofs—exhibiting signs of cracked or sagging beams (see figure 32)—was evident throughout the route, severely limiting the potential for rooftop solar installations. Given the financial strain on residents, addressing these structural deficiencies takes precedence, as ensuring the habitability and safety of the homes is critical before any further steps, such as solar panel installation, can be considered.

Figure 32. Exterior and interior views of the host household's roof.

4.11. Sub-findings in relation to sub-question 1

Despite being connected to the electrical grid, marginalized households in South Africa, particularly in areas like Alexandra Township, continue to grapple with persistent energy poverty. This creates a paradox where grid access does not translate to energy security, thus forcing households to rely on inferior energy sources like paraffin that carry serious health, safety, and environmental risks. The introduction of induction stoves offers a technically superior and cleaner alternative which promises improved energy efficiency and reduced environmental impact. Yet, several deeply entrenched barriers threaten to prevent this innovation from gaining traction in low-income households, raising fundamental questions mechanisms of effectively tackling energy poverty under JET.

One of the most immediate obstacles are economic and financial constraints. While induction stoves may reduce long-term energy costs, the initial outlay for procurement and installation of the system are considerably higher than for traditional stoves. Low-income households are particularly sensitive to upfront costs, especially when existing electric stoves — though less efficient — are still functional and affordable. This challenge is further amplified by the requirement for compatible cookware, which not only adds to the expense but also relates to the broader issue of accessibility to energy-efficient technologies.

Beyond the upfront costs of the installations, limitations of available induction stove models reveal deeper systemic inequities. Most of the induction stoves on the market are single-plate models, which fall short of what larger households are accustomed to when cooking multiple dishes simultaneously. The need for multi-plate stoves, which are priced significantly higher, exposes the disproportionate burden placed on low-income households to adapt to new technologies without adequate support. This transition would be further constrained by lack of infrastructure for maintenance and repair, meaning that any malfunction could render these stoves unusable for extended periods. In an environment where even minor setbacks can have outsized impacts, these issues become insurmountable barriers for many.

However, despite these challenges, ethnographic data suggests that there is latent potential for induction stoves to become part of the cooking landscape in Alexandra Township. The ability of the stoves to heat quickly and cook more efficiently appeals to households juggling multiple responsibilities, especially in settings where time is a precious commodity. Even though this aligns with broader trends toward modernization and convenience in urban kitchens, without strategic interventions from policy and industry, this potential may remain unrealized.

The Government of National Unity (GNU) plays a pivotal role in this dynamic. The GNU's current energy policies, particularly around pricing structures like NERSA's inclining block tariffs, exacerbate the financial difficulties already being faced by low-income households. The recent 7.47% increase in residential prepaid tariffs reflects a broader misalignment between energy policy, energy justice and realities of those living in energy poverty. For households in Alexandra, where electricity costs already consume a significant portion of their income, these tariff hikes undermine any potential gains from adopting energy-efficient appliances like induction stoves. Such policies inadvertently deepen energy poverty by making it harder for households to invest in solutions that could reduce their dependence on hazardous fuels.

The Government of National Unity (GNU) emerged in South Africa following a significant political shift when the African National Congress (ANC) lost its majority in the national elections. This new political landscape necessitated a coalition government, aiming to foster collaboration and navigate the country's pressing social and economic challenges. Among these challenges is the persistent energy inequality, where many low-income households face high costs, unreliable supply, and limited access to modern technologies, that could enhance their living standards. At this critical juncture, the GNU faces a decision: continue with policies that uphold existing energy disparities, or implement reforms that enable disadvantaged communities to benefit from modern energy solutions. One promising reform path is the concept of wheeling, which allows for the transmission of renewable energy across the national grid.

By facilitating the transmission of renewable energy through the national grid, wheeling offers a way to stabilize energy supply without overburdening the most vulnerable households. It presents a vision of energy democracy — where access to clean, renewable power is not restricted by geography or socio-economic status. In this context, the adoption of induction stoves becomes not only a question of technological feasibility but also one of political will and equity.

At the grassroots level, *stokvels* in Alexandra Township offer a promising counterpoint to the limitations of top-down policy approaches. Transforming these community-based savings groups into energy consumer cooperatives could empower households to collectively navigate the high costs and logistical challenges of adopting induction stoves. With formal backing from the GNU in the form of legal recognition, financial incentives, and capacity-building initiatives, these cooperatives could negotiate better energy rates, access subsidies, and even serve as pilot programs for broader energy reform.

Dr. Kgosientsho Ramokgopa, South Africa's Minister of Electricity, has taken on the challenging task of navigating the country's energy crisis amid economic constraints and persistent social inequities. Appointed to address electricity supply issues and help reform the energy sector, Ramokgopa's administration is grappling with a range of structural challenges, from unreliable power generation to the escalating costs of energy. His leadership plays a crucial role in shaping energy policies, reforming the electricity market, and fostering community-based solutions that empower marginalized communities. The feasibility of transitioning to induction stoves as a substitute for traditional fuels in Alexandra Township is not merely a matter of individual preference but is embedded within a complex matrix of socio-political and economic dynamics. Under Ramakgopa's administration, energy policies, the structural framework of the electricity market, and the role of community-led initiatives such as cooperatives are pivotal towards transforming the future energy landscape of marginalized urban areas and communities. This complexity suggests that the path toward cleaner, more efficient cooking technologies must be multifaceted — requiring not just technological innovation but also bold policy reforms that recognize the intertwined nature of energy, poverty, and inequality.

The sub-findings confirm that the successful adoption of induction stoves would be closely tied to systemic shifts in energy production, pricing, and distribution. Crucially, social acceptability is significantly elevated when these stoves are positioned as an alternative to cooking that depends on City Power's ongoing infrastructure failures. By presenting induction stoves as a reliable alternative that can bypass the effects of frequent power outages and thus ensure timely meal preparation, the technology becomes more than just a modern innovation — it is seen as a practical and necessary response to the deepening energy crisis in Alexandra Township. This narrative would enhance community buy-in by framing the stoves as both an empowering tool and a remedy to the shortcomings of the current energy infrastructure. Wheeling emerges as a particularly promising mechanism for addressing the energy crisis in Alexandra, offering a way to bypass the structural limitations of City Power while fostering a more equitable energy landscape. For the GNU, this moment presents an opportunity to rethink the energy paradigm—moving beyond short-term fixes and tariff adjustments to embrace a future where energy justice and sustainability are at the core of national policy.

Chapter Five

Leveraging wheeling as a mechanism for powering solar-PV induction stoves in low-income households

5.1. Introduction

This chapter shifts focus to Chebeng village in Limpopo Province as the case study on land governance in the establishment of energy generation cooperatives. Chebeng is identified as an ideal site for a solar energy cooperative due to its significant solar potential. In solar energy planning, spatial zones are analyzed and evaluated in order to identify zones of strong solar radiation profiles. Other critical considerations in the selection process for solar energy project sites include proximity to infrastructure like transmission networks, roads, and water sources, as well as land use efficiencies (LUE, %) or power densities (km2/GW) (Duvenhage, Brent, Stafford, and Van Den Heever, 2020, 2).

In light of these factors, this chapter starts with an assessment of the suitability of Chebeng's terrain for solar-PV generation, which positions it as a potential catalyst for capacity development in renewable energy projects. Chebeng's alignment with broader solar PV trends presents a unique opportunity to explore innovative energy solutions that can address both local and global challenges. When implemented through a sustainable, community-based cooperative model, such solutions could contribute to a Just Energy Transition (JET). However, a crucial aspect on the suitability of Chebeng for renewable energy projects is the significant influence of tribal authority on land access, which would particularly influences the involvement of rural women as land lessees for the generation of green electricity for urban consumers.

As observed during a three-day ethnographic study in Chebeng, the role of tribal authority is explored alongside an analysis of the village's *stokvel* network, thus providing insight into its foundational and operational aspects. This chapter also draws on secondary data to assess solar-PV plant potential, focusing on regulatory frameworks governing wheeling of clean electricity in South Africa and available financing mechanisms. It also explores the regulatory environment wheeling in relation to solar-PV-powered induction stoves.

5.2. Data overview

Primary data were derived from ethnographic observations conducted in Chebeng which was identified for its significant potential for solar-PV electricity generation, and thus addresses the second sub-question. The main objectives were to gather data on the local geography, evaluate the availability of land for energy generation projects, and examine the processes of access to land for large-scale RE projects. The influence of tribal authorities on land use and access rights in the region also constituted a critical focus of the data collection and analysis. Data collection also covered structure and operations of existing *stokvel* models in the area. Alongside the ethnographic data, secondary data sources such as relevant reports and case studies were also accessed to provide context and theoretical foundations to further address the sub-question. Table 17 consolidates the research sub-question and the primary and secondary data for this chapter.

Table 17. Data overview for sub-question 2

Sub-question 2	Primary data	Secondary data
To what extent can rural-urban women-led cooperatives leverage wheeling as a business model to address operational cost barrier associated with the adoption of solar-PV induction stoves among low-income households, given prevailing low levels of commercialization?	- Chebeng will also consist of ethnographic observations for the purpose of documenting women interactions within specific community-based organizations (CBO such as stokvels) that could transform into energy generation cooperative - Visual documentation in the form of photographs, audio recordings, video recordings, individual interviews, and direct observations will be key tools that also serve as a permanent and unbiased reference for later analysis and contribute to a more comprehensive understanding of the study area and its sociopolitical dynamics - Transect walk (or possibly drive-by) with at least 2 co-walkers for documenting insights on characteristics and dynamics of Chebeng especially with regard to land-availability and various land-uses in order to document a comparative case where access to a large parcel of land has been previously/recently secured for projects such as farming, mining or renewable energy generation Interview with leader of tribal authority responsible for granting access to land for long-term development projects -	- An examination of the impact of geo-environmental variables on the selection of sites for solar-PV farms (Mierzwiak & Calka, 2017, 3). - An examination of the annual mean Solar Shortwave Flux (SWFlux - radiant energy emitted by the sun and reaching the Earth in the form of shortwave radiation) (Singh, 2016, 4) - An examination of the technical and infrastructural land attributes integral to the decision-making process for solar farm placement (Mierzwiak & Calka, 2017, 3) - An analysis on the South Africa's tribal authority constituents on on spatial justice (Pycroft, 1998, 151; Ntsebeza, 2004, 3). - An analysis on the potential loss of cultural heritage and landscape, impacting land tenure and land acquisition processes (Lamhamedi & de Vries, 2022, 8). - The role of traditional authorities as custodians of rural land acting on behalf of the state (Muthambi, Cloete, & Cook, nd, 362) - Business model canvas (Osterwalder et al, 2010, 44 cited in IEA PVPS, 2014, 8)

5.3. Geographic terrain

Lamhamedi and de Vries (2022, 9) note that the connection between land and energy is not adequately integrated into development policies and political discussions when deciding on renewable energy projects. Topography of the area surrounding a generation facility significantly influences the positioning and layout of solar panels to optimize exposure to solar radiation. A challenge in land utilization for renewable energy lies in its site-specific nature and relatively high land requirements, especially when compared to nonrenewable electricity generation sources (Lamhamedi & de Vries, 2022, 9). Although fossil-fuel generation plants occupy relatively smaller land pieces, ongoing supply of fuel requires extraction and handling which entails far larger land parcels. Once installed, wind and solar generation plants do not require additional land for ongoing operation.

The development of renewable energy affects land use at various project stages, from site preparation and on-site construction to grid connection wayleaves and space for future expansion. In particular, generating electricity from renewable sources also entails building powerline corridors, roads, service buildings, and other infrastructure, which is part of standard power development, extraction, or transmission projects. These linear land-cover features are more in line with industrial and urban land-use patterns and are arguably less compatible with rural land-use patterns such as agriculture, rangelands, and forested areas (Lamhamedi & de Vries, 2022, 10).

Limpopo's high solar radiation potential is highlighted by Singh (2016), who notes a substantial SWFlux value of 257.95 ± 6.16 Wm-2, making the region particularly promising for solar energy projects. Latitude plays a pivotal role in determining solar radiation levels, and Chebeng's coordinates, approximately 23°53'44"S and 29°26'44"E, are particularly significant (Road on map, nd). These coordinates position Chebeng within a geographic zone that receives abundant solar radiation year-round. Located near the Tropic of Capricorn, this region experiences consistent sunlight, with high solar insolation levels that make it particularly well-suited for solar photovoltaic (PV) energy generation. The latitude influences the angle at which sunlight reaches the earth's surface, affecting the intensity and duration of solar exposure. In this case, the southern hemisphere location means Chebeng benefits from longer daylight hours during the summer months and a relatively mild winter, contributing to more predictable and efficient solar energy production. These factors make latitude a crucial determinant for the feasibility and economic viability of solar PV projects, as higher solar radiation levels translate into greater potential energy output from the same installation compared to regions further away from the equator. Figure 34 below is a map showing Chebeng village.

Figure 34. Map of Chebeng village. Source: (Google maps., nd)

The terrain around Chebeng Village (see Figure 35) typifies a rural savannah landscape, featuring a mix of rolling hills, flatlands, and scattered elevated outcrops. The photographs of Chebeng village below show pockets of land that are characterized by bare, vacant, and open spaces. The area as a whole, experiences semi-arid conditions, with dry land shaped by the broader climate across the province. The soil ranges from sandy to clayey textures, supporting small-scale agriculture but unsuitable for intensive farming. Vegetation is sparse, primarily consisting of hardy grasses, shrubs, patches of bushveld, and occasional clusters of trees. The area has limited water resources, with small seasonal streams that may run dry during periods of drought. Irrigation is mostly limited to subsistence farming, with reliance on boreholes or rainwater harvesting.

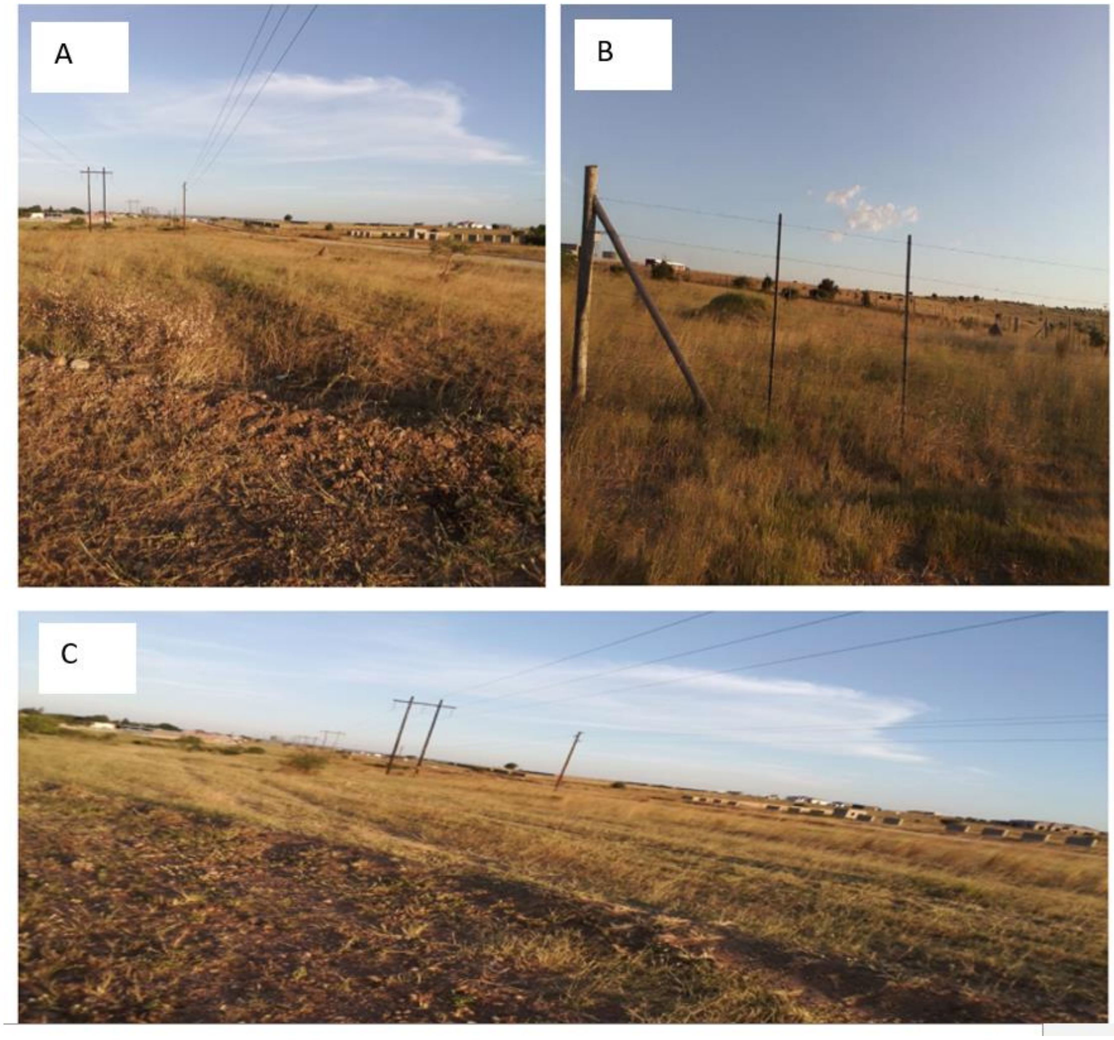

Figure 35. Landscapes in Chebeng village– (a) Bare landscape, (b) Open ground, (c) Vacant land

There are many parts of Chebeng that can classify it as a village proper - the core area where most residential and communal activities occur. The transect walk through the village revealed sections within Chebeng that primarily consist of houses and community infrastructure that classify the settlement as a village proper. Areas where community events, meetings, and cultural activities take place can also be seen as part of the village proper, fostering social cohesion among residents are shown in Figure 36 below.

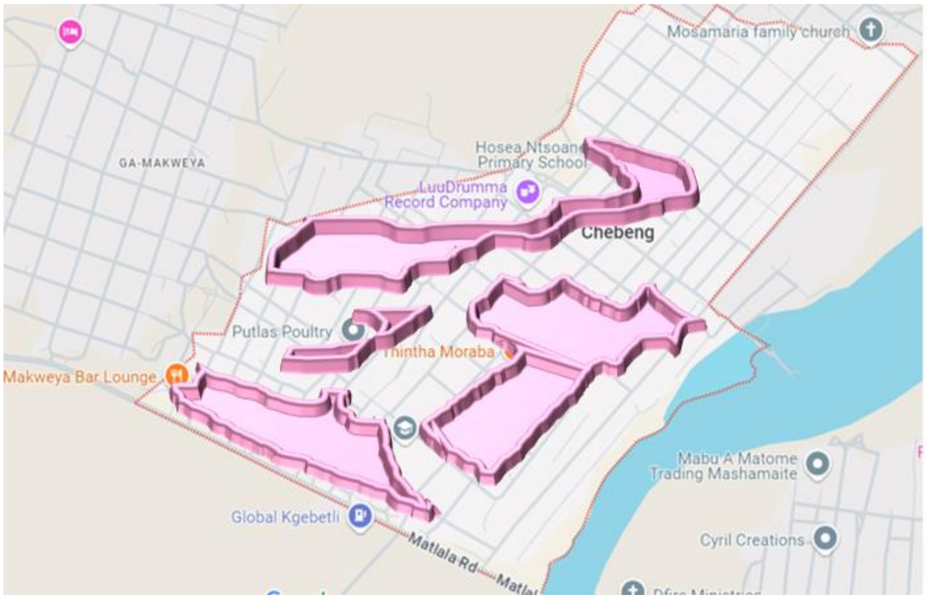

Figure 36. Area where most residential and communal activities occur. Source (Adapted from Google maps, nd)

A detailed mapping approach that distinguishes the inhabited areas from the surrounding territories is necessary to identify optimal sites for solar development. It is also worth noting that the study's scope was limited by a three-day timeline, which precluded a more in-depth mapping process that a longitudinal study could have provided. However, the potential areas near Chebeng that could support solar development include:

- **Ga-Dikgale**

  Figure 37 shows that Chebeng village and Ga-Dikgale are separated by a distance of 70 km, and the latter has the coordinates of approximately 23°82'02"S latitude and 29°84'27"E longitude (Google maps., nd). Ga-Dikgale consists of numerous rural settlements where renewable energy initiatives could be piloted. The area’s land, mostly used for subsistence agriculture, presents opportunities to integrate renewable energy into agricultural practices (e.g., solar-powered irrigation). Community engagement would be key in navigating land use agreements, as well as ensuring that local residents are directly involved in the benefits, such as job creation and energy cost reductions.

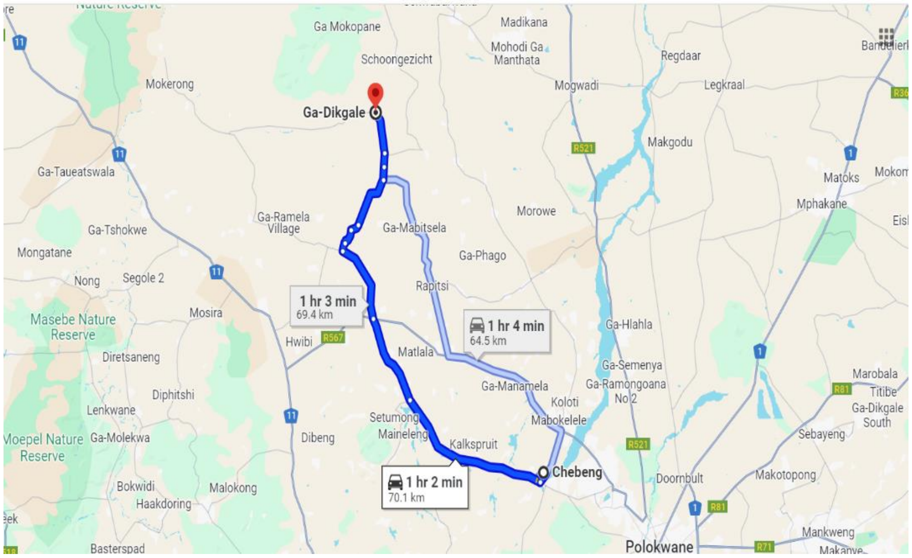

Figure 37. Distance between Chebeng village and Ga-Dikgale. Source: (Google maps., nd)

- **Mankweng**

  As shown in Figure 38, Chebeng and Mankweng are separated by a distance of approximately 58km, with the latter having coordinates around -24°08'74"S latitude and 28°90'63"E longitude (Google maps, n.d.). Mankweng is an urban node that also includes rural peripheries. Given Mankweng's relative proximity to the University of Limpopo, collaborations could be fostered for research and development in renewable energy technology, providing a knowledge-sharing platform to train locals in renewable energy skills and innovations.

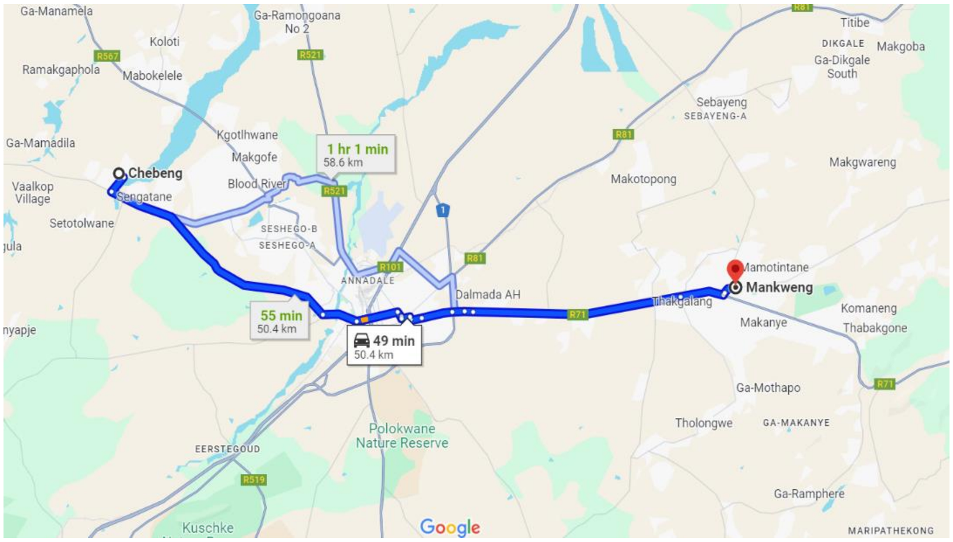

Figure 38. Distance between Chebeng and Mankgweng. Source: (Google maps., nd).

The above areas (Mankweng and Ga-Dikgale) are not only geographically well-positioned but also represent strategic sites where renewable energy projects could enhance local economic development, and promote environmental sustainability. The deployment of renewable energy infrastructure in these locations could also support broader Just Energy Transition (JET) objectives by empowering rural communities through ownership, training, and job creation in the green economy. Land-use considerations, legal requirements, and community consultations would need to be carefully navigated to ensure the social and economic benefits are maximized and equitably distributed.

5.4. Land availability and key topographic considerations for solar farms

Mierzwiak & Calka (2017, 3) examine the impact of geo-environmental variables on the selection of sites for solar-PV farms. Both for photovoltaic (PV) installations or concentrating solar power (CSP), the effectiveness of solar projects depends on datasets on key parameters such as global horizontal irradiance (GHI) for PV and direct normal irradiance (DNI) for concentrating solar power. South Africa encompasses four primary climatic zones: desert (Northern Cape, North-Eastern parts of Western Cape); arid (Limpopo, Mpumalanga, North-West, Free State, the western parts of KwaZulu-Natal and the Eastern Cape); sub-tropical wet (coastal strip of KwaZulu Natal and the Eastern Cape); and Mediterranean winter rainfall (south-western coastal strip of Western Cape) (JWAF, 1999) (Singh, 2016, 3). Understanding the intensity and direction of solar radiation in each climatic zone plays a crucial role in identifying suitable locations for these projects.

The examination of the annual mean Solar Shortwave Flux (SWFlux - radiant energy emitted by the sun and reaching the Earth in the form of shortwave radiation) from 1980 to 2009, provides essential insights into the regional distinctions in solar radiation levels. SWFlux, essentially measures the amount of solar radiation energy received per unit area, and serves as a key metric in assessing the feasibility of solar projects. Singh (2016) brings attention to Limpopo which stands out due to its significant SWFlux value (257.95 ± 6.16 Wm-2). As shown in Figure 39, solar radiation patterns in Limpopo were documented as follows (Singh, 2016, 4):

- Limpopo experiences higher SWFlux during autumn (235 ± 4.61 Wm-2) and winter (201.60 ± 4.7 Wm-2).
- During different seasons, Limpopo records the maximum SWFlux (235 ± 4.61 Wm-2) in autumn and the minimum in winter.
- Limpopo consistently demonstrates higher SWFlux during winter and autumn months compared to other provinces.
- SWFlux in Limpopo tends to be higher in December and lower in June

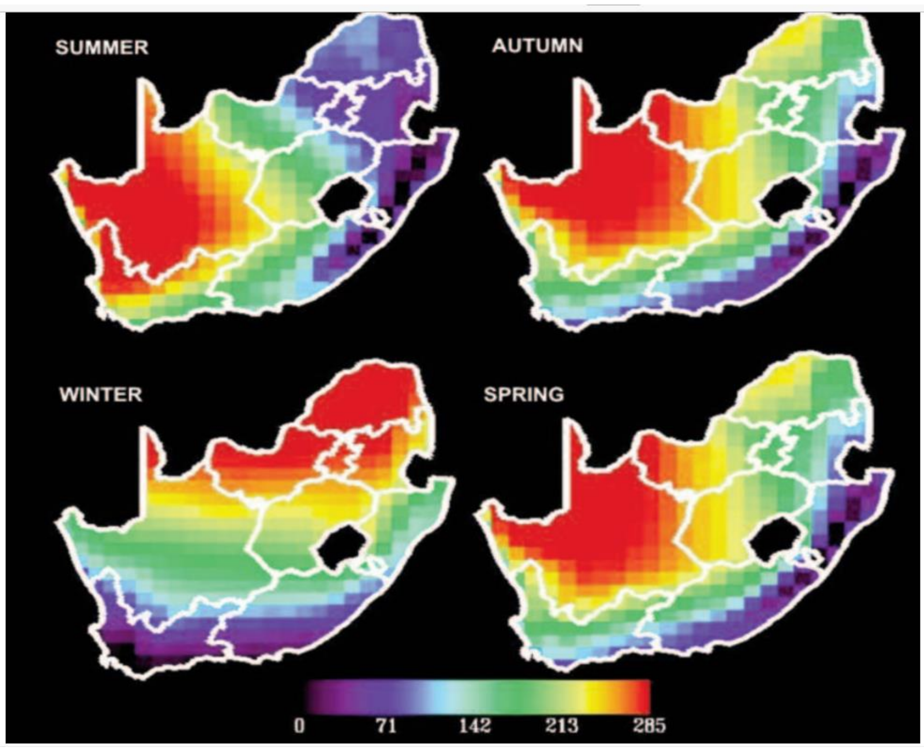

Figure 39. Climatological mean of monthly means of SWFlux (surface shortwave incident flux, W/m2) from MERRA 2D reanalysis (1980–2009) across the nine provinces. Source (Singh, 2016, 4).

Spatial analysis of SWFlux was performed across three decades – the 1980s, 1990s, and 2000s (see Figure 39). Northern Cape consistently demonstrated higher SWFlux values compared to all other provinces throughout these three decades. The spatial distribution patterns of SWFlux unveiled a consistent decline in solar radiation levels over each successive decade, a trend mirrored in five additional provinces (North West, Limpopo, KwaZulu-Natal, and Eastern Cape) (refer to Table 18). The decline might be ascribed to an escalating presence of air pollution, as it is a factor known to curtail the amount of solar radiation reaching the Earth's surface (Singh, Bhattacharya & Kumar, 2012).

Table 18. Mean SWFlux (surface incident shortwave flux, Wm-2) with a standard deviation in the last three decades over South Africa. Source: (Singh, 2016, 6)

Province	***1980s***	***1990s***	***2000s***
		(Mean ±SD)	
Free State	259.27 ± 11.90	260.00 ± 4.93	258.34 ± 4.66
Northern Cape	269.44 ± 5.60	267.21 ± 3.26	265.49 ± 2.33
Western Cape	245.47 ± 4.73	244.17 ± 2.04	243.37 ± 1.40
Gauteng	251.46 ± 9.88	254.19 ± 5.94	252.69 ± 6.51
Mpumalanga	246.46 ± 8.50	249.48 ± 4.85	246.53 ± 5.71
North West	265.56 ± 9.66	262.62 ± 5.82	261.92 ± 5.33
Limpopo	259.98 ± 5.05	259.61 ± 6.08	254.24 ± 6.07
Kwa Zulu-Natal	233.48 ± 11.12	233.90 ± 4.07	231.59 ± 3.98
Eastern Cape	237.12 ± 9.22	237.29 ± 2.98	233.76 ± 3.57

Mierzwiak and Calka (2017, 3) also highlight technical and infrastructural land attributes integral to the decision-making process for solar farm placement. Key attributes include proximity to the built environment which plays a role in reducing transmission losses and streamlining the distribution of electricity generated as well as availability of power lines and accessibility to road networks. These factors facilitate the connection of the solar farm to the existing energy grid and concurrently reduce the costs associated with infrastructure development. The combination of these criteria aids in the efficient delivery of solar energy to end-users (Mierzwiak & Calka, 2017, 3).

The Provincial Land Use Legislative Reform Limpopo Province: Status Report of 2011 concurs with this sentiment as it specifically addresses the involvement of traditional councils in land use decisions as development in rural areas can be hindered by land ownership constraints and uncertainties about rights. In Limpopo, there are indications that critical permissions from various departments often impede the outcomes of permitting applications for most land uses (Baylis, 2011, 40).

Within the context of Chebeng, ethnographic observations revealed the perspective of the tribal authority on spatial justice which emerges as a significant factor. This perspective prioritizes indigenous socio-spatial values, which encompass cultural, historical, and community-specific needs over purely commercial uses of land. This underscores the critical significance of preserving the cultural and social fabric of communities when considering the implications of energy projects. In light of these observations, even with the current state of land availability and the high potential for solar energy generation, there is still no prioritization of land for renewable energy projects in Chebeng. However, this trend may not apply uniformly across the Limpopo province, as ongoing projects like the Bolebedu renewable energy initiative indicate a growing interest in such developments elsewhere in the region.

5.5. Role of traditional authority in land administration in South Africa

The constitutional framework in South Africa establishes a three-tiered governmental structure comprising national, provincial, and local spheres. Within this structure, municipalities play a crucial role, extending their reach even into rural areas (Ntsebeza, 2004, 11). The Constitution safeguards municipal autonomy, emphasizing their unhindered exercise of powers and functions. Post-1994, local governance adopts a 'developmental' approach, necessitating integrated development planning to coordinate activities within municipal jurisdictions. Despite these strides, historical legacies persist, especially in rural areas, where land ownership is predominantly vested in the state and managed by tribal authorities. The permit-to-occupy (PTO) system, although indicating effective ownership by rural inhabitants, lacks the legal security associated with freehold title (Ntsebeza, 2004, 11).

While the acknowledgment of traditional authorities in the Constitutions of 1993 and 1996 triggered investigations into their roles in rural governance and land administration, constitutional texts lack precision concerning the specific functions of traditional authorities in rural local government or land administration (Pycroft, 1998, 151; Ntsebeza, 2004, 3). A lasting legacy from the colonial and apartheid eras is the predominant state and Development Trust ownership of land in rural areas formerly designated as Bantustans. This land was administered and managed, particularly during apartheid, by government-established tribal authorities. Despite rural inhabitants effectively residing on and utilizing the land over extended periods, the permit-to-occupy (PTO) system fails to confer legally secure titles comparable to freehold titles. The notable consequence of this insecurity of tenure is the systematic exclusion of rural inhabitants from the administration and management of the land that fundamentally belongs to them (Ntsebeza, 2004, 4).

Despite many traditional authorities collaborating with colonial and apartheid systems, South Africa's 1993 Interim Constitution and 1996 Final Constitution recognized the institution of traditional leadership. However, these constitutional documents lacked clarity regarding the specific roles, functions, and powers of traditional authorities in rural local government or land administration (Ntsebeza, 2004, 11). In the early months of 1998, the Department of Land Affairs (DLA) took a significant step by formulating principles intended to guide its legislative and implementation framework. These principles encompass various aspects aimed at shaping a fair and inclusive system of land administration.

One crucial aspect of these principles is the emphasis on vesting land rights in the hands of the people rather than institutional entities like tribal or local authorities. This recognition reflects a shift towards acknowledging the individuals, families, or groups as rightful holders of land, signaling a departure from historical custodianship. The principles further delve into the nuanced scenarios where underlying rights may belong to groups, individuals, or families. In instances where rights are held collectively by a group, the principles advocate for granting the rights holders the autonomy to choose the system of land administration that aligns with their preferences on a day-to-day basis (Ntsebeza, 2004, 11).

Protection of basic human rights emerges as a cornerstone of these principles, particularly for scenarios involving group-held land rights. This protection extends to democratic decision-making processes and equality, ensuring that the voices of all members are heard in matters pertaining to their land rights. In addition, the principles recognize the importance of maintaining systems of land administration that are both fair and functional. In rural areas where breakdown in land administration has been observed, adhering to these principles becomes crucial. The aim is not to undermine viable and representative institutions but rather to provide transparent legal mechanisms for their continuity.

DLA principles draw a distinction between the concepts of land ownership and governance. Under these principles, members of specific communities are envisioned as co-owners of the land, giving them the authority to determine the administration of their land. This distinction challenges historical practices where tribal authorities held a fusion of functions and proposes a clear separation of roles. In this transformed landscape, the four main actors are as follows:

- landowners representing the broader community,
- land administrators or managers serving as officials or bureaucrats,
- traditional authorities,
- local government.

The latter two entities do not hold ownership rights to the land and may not inherently possess the authority to allocate land unless explicitly requested to intervene by the landowners. Despite the DLA's intention to subject traditional authorities to a system promoting representation and accountability, a fundamental contradiction is apparent. Establishing democratic structures while recognizing an institution of traditional leadership which is inherently undemocratic as it is inherited from the apartheid past, warrants careful consideration (Ntsebeza, 2004, 12)

In light of this contextual backdrop, sustainable land use encompasses the careful management, utilization, and conservation of land resources within specific spatial and temporal contexts (Lamhamedi & de Vries, 2022, 10). Viewed through this lens, renewable energy projects can be seen as agents that transform rural landscapes into extensive outdoor industrial energy production facilities, potentially depriving local vulnerable communities of access to their land and means of livelihood (Lamhamedi & de Vries, 2022, 5).

In particular, concerns arise over the potential loss of cultural heritage and landscape, leading to conflicts as energy production becomes more visible, thereby significantly impacting land tenure through land acquisition processes (Lamhamedi & de Vries, 2022, 8). In line with these apprehensions, ethnographic observations in Chebeng village highlighted specific stipulations aimed at ensuring that individuals seeking to access land for energy generation and large-scale developments adhere to certain prerequisites. The rural tribunal, referred to as the *'kgoro'* (meaning entranceway or the place of welcome), represents the initial sphere of governance for anything related to land. In line with the perspective presented by Muthambi, Cloete, and Cook (nd, 362), which emphasizes the role of traditional authorities as custodians of rural land acting on behalf of the state, a representative member of the *kgoro* council listed the following requirements for considering applications for access:

- Proof that the project will not directly lead to the loss of access rights to pasture and water resources for the primary users of the land
- To counteract the potential loss of young residents, it is essential that at least one business owner of the facility is located within the village
- Prioritize job creation within the immediate community
- Consider the nativity of individuals involved in the project to ensure a connection to and understanding of the local context
- Require the facility owner to contribute to the community's social capital through community service, such as participation in weddings and burials
- Figure 40 was taken to observe the *kgoro* council in a meeting where aforementioned discussions take place

Figure 40. *Kgoro* meeting observed from a distance

The tribal land acquisition process operates through a complex and intricate framework shaped by the diverse needs and preferences of stakeholders and tribal authorities, and therefore varies significantly from one region to another. This complexity makes it challenging to devise a standardized procedure that can be universally applied for renewable energy projects. Typically, the process unfolds in a series of five stages, each with its own set of tasks and considerations as presented in Figure 41.

Action/Stage	Role Player/s	Output
1. Land Identification		
Applicant identifies the portion of land they are interested in acquiring	Applicant and/ or Induna	Site selection and identification.
2. Land Application		
The Induna conducts a site visit with the applicant and issues an application form to the applicant.	Induna and applicant	Completed Application Form submitted to the tribal council.
3. Land Negotiations		
Application is scrutinised, initiation of land negotiations and the applicant pays the levies to the tribal council.	Applicant, tribal council and Chief.	Tribal Approved Application Form
4. Land adjudication and planning		
The approved application form is submitted to the municipality for processing.	Municipality	Municipality Compliance Certificate.
The process of land demarcation is initiated for land which is not demarcated.	Tribal council coordinates with COGTA.	Survey General Diagrams.
COGTA coordinates with other stakeholders to ensure that the application is checked and signed.	COGTA, Department of Health, DRDLR and DPW.	Committee Approved Application Form.
5. Land Allocation		
The Provincial Minister of DRDLR approves the application.	Provincial Minister of DRDLR	Provisional PTO Certificate.
Applicant is notified of the status of the application and issued a provisional PTO.	Local government and tribal councils.	PTO Certificate.

Figure 41. Tribal land allocation process. Source: (Muthambi, Cloete & Cook, nd, 372)

5.6. Existing rural community-based organization

Community based organizations such as *stokvels* are structured with specific goals such as systematically saving a portion of members' monthly income, ensuring responsible financial management, and fostering mutual support (Ramagoshi, 2016, 51). Various *stokvels* address diverse financial needs. Notably, there is a common practice of addressing the material needs associated with *stokvel's* functions in the form of a rotating cash payout to each member, referred to as *'mogodisano,'* (Ramagoshi, 2016, 51). The *Chebeng Kgomo-Phomolo stokvel* ("Kgomo-Phomolo" meaning "Cattle for Rest" in Sepedi) is a traditional burial stokvel established in 2010 in Chebeng village. The stokvel was founded by a group of families who saw the need to provide mutual support for funeral expenses while maintaining cultural practices around burials. The central focus of the stokvel is to ensure that every member's family can afford a dignified burial, which includes contributing towards a cow for each funeral, aligning with local customs. The *Chebeng Kgomo-Phomolo stokvel* functions not just as a financial safety net, but also as a vital form of social currency within the community. Social currency refers to the intangible benefits individuals gain from being part of a community, such as trust, reputation, influence, and mutual support. In the context of the stokvel, social currency is earned and exchanged through active participation, shared experiences, and the fulfillment of cultural and communal obligations, like providing for funerals and supporting one another in times of need. In addition to contributing a cow for each funeral, the stokvel upholds the spirit of *mogodisano* by providing a cash payout to assist with various funeral-related expenses, such as catering, transportation, and burial fees. This financial assistance is funded through monthly contributions made by members, which are specifically earmarked for funeral support.

When it comes to the structure and operations of the *Chebeng Kgomo-Phomolo stokvel*, its members meet on the last Saturday of every month at the community center. During these meetings, members make their contributions, discuss any recent or upcoming funerals, and review the financial status of the stokvel. The stokvel is governed by an elected committee, which includes a chairperson, treasurer, and burial coordinator. These positions rotate every two years to ensure shared leadership and transparency. Members must be up to date with their contributions to qualify for the full funeral assistance package. New members must undergo a six-month waiting period before being eligible for the cow and cash payout, to ensure the stokvel's financial stability. The *Chebeng Kgomo-Phomolo stokvel* is registered with the local tribal authority, giving it a form of communal recognition and legitimacy within the community. This registration with the tribal authority acknowledges the *stokvel's* role in local social and cultural practices, granting it a respected status among community members. However, the *stokvel* has not yet undergone the formal legislative processes required for recognition as a cooperative under South African law. While the tribal registration provides a level of informal governance and social credibility, the *stokvel* lacks the legal framework that a registered cooperative would offer, such as formalized agreements, legal accountability, and access to government support programs. Nonetheless, its recognition by the tribal authority reflects its alignment with local customs and norms, particularly in upholding communal practices like *mogodisano* and collective funeral assistance.

In Limpopo Province, various institutions contribute significantly to transitioning *stokvels* into cooperatives. While both *stokvels* and cooperatives stress community collaboration and financial cooperation, *stokvels* typically adopt an informal approach rooted in traditional kinship practices. In contrast, cooperatives are more formalized entities governed by legal mechanisms. Some of the entities with potential for contributing to evolution of *stokvels* into cooperatives are outlined as follows (Department of Economic Development, Cooperatives, Environment and Tourism, 2007, 11):

- In collaboration with the Limpopo Economic Development, Environment, and Tourism (LEDET) and the Limpopo Business Support Agency (LIBSA), the University of Limpopo plays a pivotal role in enhancing the capacity of cooperative members. Their training programs encompass five key modules: Cooperative Act, Business Management, Organizational Development, Production Management, and Computer Literacy

- Small Enterprise Development Agency (SEDA) is dedicated to promoting and sustaining cooperative growth. Its support extends to both financial and non-financial aspects. SEDA assists cooperatives in developing comprehensive business plans, conducting feasibility studies, crafting production strategies, marketing plans, and creating organizational and management frameworks.
- Through its social responsibility program, ABSA actively supports community initiatives with the aim of uplifting individuals and fostering thriving communities. This initiative is aligned with the broader goal of building strong and sustainable economy. ABSA extends both financial and non-financial assistance to community projects, including cooperative development.
- As a government-mandated statutory body under the provincial government, LIBSA (Limpopo Business Support Agency) plays a significant role in the development of cooperatives. It provides holistic support to cooperatives, including assistance with registration, business planning, feasibility studies, marketing strategies, comprehensive training, funding as well as monitoring and evaluation of funded cooperatives

5.7. Similar land-use project: The Bolobedu solar power plant

Chebeng Village shows limited progress in the implementation of renewable energy projects. However, an exception can be found in Limpopo Province with the Bolobedu solar power plant. Voltalia, known for its expertise and diverse portfolio, operates across various renewable energy sectors, including wind, solar, hydro, biomass, and storage facilities (Voltalia, 2022). As an international renewable energy company, Voltalia has engaged in a significant agreement known as the Contract for the Purchase of Power Agreement (CPPA2) with Richards Bay Minerals (RBM), a subsidiary of Rio Tinto, a globally established British-Australian metals and mining conglomerate and the largest mineral sands producer in South Africa. This agreement spans 20 years and aims to supply approximately 300 gigawatt hours of renewable energy annually to RBM's production facilities in KwaZulu-Natal. Notably, this represents the establishment of the largest South African renewable power plant specifically catering to the energy needs of a corporate entity (Voltalia, 2022). Its projected output is equivalent to the annual electricity consumption of 425,000 inhabitants, thereby helping to mitigate over 237,000 tons of CO_2 emissions. In addition to generating capacity exceeding 2.6 GW and ongoing projects set to expand this to 13.6 GW, Voltalia (2022) also offers comprehensive services to investor clients, assisting them in all phases of renewable energy projects from inception to operation and maintenance.

Comparing the extensive land use of solar farms highlights the significance of effective land management and sustainable development in the renewable energy sector. Drawing connections between solar farms and other land uses, several distinct characteristics emerge:

- Scale and sustainability: Similar to other solar projects, the Bolobedu solar farm, will utilize vast areas of land to generate renewable energy sustainably. The deployment of large solar arrays maximizes energy production while reducing the overall cost of energy generation.
- Economic impact: Solar farms have a significant economic influence, contributing to regional economic growth through activities such as job creation. Bolobedu solar farm, in particular, will play a crucial role in bolstering economic prospects within the region.
- Environmental considerations: Solar farm installations require careful consideration of their environmental impact, especially regarding extensive land use. Developers are required to implement land management strategies to mitigate ecological disruption, such as integrating native vegetation with solar panels.
- Community involvement: It remains unclear whether the company responsible for the Bolobedu solar farm is employing local workers or bringing in its own employees for the project. However, solar farm developers tend to actively engage with local communities, thus fostering infrastructure development and enhancing economic opportunities for regions in proximity to their sites.
- **Figure 42** is the distance between Chebeng village and the Bolebedu solar power station, for which the aforementioned coonections were derived

Figure 42. Distance between Chebeng and Bolebedu solar-PV plant. Source: (Google maps, nd)

5.8. Sub-findings in relation to sub-question 2

Sub-findings in this chapter highlight the interplay between the technical potential for solar energy generation and the gender-nuanced socio-political realities of land governance in Limpopo. The region's substantial solar shortwave flux (SWFlux), combined with high global horizontal irradiance (GHI) and direct normal irradiance (DNI) levels, confirms Limpopo's remarkable suitability for solar energy projects, particularly within the framework of wheeling initiatives aimed at broadening access to clean energy. However, this potential is not merely a matter of technology; it requires navigating the intricate socio-political landscape that governs land use in rural South Africa.

The specific requirements set forth by rural tribunals, including the protection of water and pasture resources and the prioritization of local employment and community engagement, highlight the deeply rooted socio-cultural dimensions of access to land. These requirements reflect a broader understanding that land in these communities is not just a resource but a central element of identity, livelihood, and cultural heritage. These criteria for land acquisition also align strongly with a cooperative approach, as opposed to a corporate venture approach, for energy projects. While these traditional governance structures lack formal legal recognition, the involvement of the tribal authority in recognizing stokvels adds an additional layer of accountability. This contrasts with stokvels in urban areas, which operate with full autonomy and without the same level of oversigh. The exclusion of women from key decision-making processes, particularly in areas like Chebeng, reveals persistent gender disparities that could undermine the inclusiveness and sustainability of land related development initiatives.

The development of the Bolobedu solar farm represents a significant shift toward renewable energy in Limpopo, thus symbolizing the potential for transformative change. However, uncertainties surrounding its local employment strategies and its impact on communities in its proximity suggest that energy projects must carefully balance economic development with the preservation of local rights and traditions. This calls for a reimagining of land use through the lens of a Just Energy Transition (JET), where economic growth, social equity, and environmental sustainability are addressed not as conflicting objectives but as interdependent goals that must be pursued in tandem. Social and cultural implications of the project must be as carefully considered as technological and financial viability. Solar farms often disrupt traditional land uses, such as agriculture and grazing, which hold deep cultural significance for local communities. Without meaningful community engagement and ownership models, projects like the Bolobedu solar farm risk marginalizing residents, particularly women and traditional land users. Such lack of community involvement, and in the extreme, disregard of gender inequalities, can exacerbate existing inequalities and alienate those most directly affected by land reallocation.

While renewable energy is generally seen as sustainable, the unintended consequences on local ecosystems, water resources, and biodiversity can be significant, particularly in water-scarce regions like Limpopo. Ensuring that the solar farm balances energy generation with resource conservation would therefore be crucial for the long-term sustainability of both the project and the local environment. If the benefits of this transition are not fairly distributed, the project risks reinforcing existing power dynamics, with corporate interests and external actors benefiting at the expense of vulnerable groups within the community, especially women. This challenge is particularly evident when considering the gender inequities in land use and ownership, which often place rural women at a disadvantage in energy transition strategies.

Furthermore, the role of Alexandra women in providing first-line support for stove maintenance and repairs would reinforce the sustainability of the wheeling model. Their involvement would ensure reliability of the stoves and while also generating additional income, thus aligning with Minister Ramokgopa's vision of localized solutions that promote sustainable energy development. Catalytic organizations such as Mahlako Energy, the National Empowerment Fund, and the Industrial Development Corporation (IDC) could play a crucial role in supporting such a model. Their financial and logistical backing would help reduce capital constraints for scale-up of solar infrastructure, thus promoting the pursuit of energy transition objectives. Tax rebates under Section 12B and 12BA of the Income Tax Act would further enhance the feasibility of solar investments, thus making clean energy more accessible and affordable.

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Chapter six

Women-led entrepreneurship in the broader energy value-chain for just energy transitioning

6.1 Introduction

This chapter provides a comprehensive exploration of the entire value chain through the lens of the *imbokodo*-inspired model, demonstrating the strategic potential of integrating electricity wheeling in South Africa to foster equitable energy access. The *imbokodo* approach in this context champions energy democracy through a wheeling approach that is centered on inclusivity and local empowerment, making it an ideal framework for transforming the energy sector. Electricity wheeling in South Africa— broadly defined as the process of transporting electricity from a generator to an end user via the national grid—plays a critical role in this transformation, but it remains tightly regulated, with formal approval required from the National Energy Regulator of South Africa (NERSA). Collaborative efforts between the Department of Minerals and Energy, NERSA, and Eskom have led to the deregulation of the country's electricity sector, opening doors for increased participation of private-sector entities. Despite attempts to introduce independent power producers (IPPs) into the generation sector, their contribution remains limited (approximately 5% of total generation in the year 2017) (Robb & Mondliwa, 2018, 27), while municipalities play a significant role in distribution, generating revenue for local authorities. Eskom, currently undergoing restructuring into three separate entities handling generation, transmission, and distribution, has traditionally maintained a monopolistic position, controlling various stages of the electricity value chain. However, effective competition against Eskom is minimal across the value chain due to biased policies and regulations in favour of the state-owned provider.

One notable exception is PowerX, which has obtained a wheeling license from NERSA, enabling it to purchase electricity from generators and distribute it to municipalities and other customers, necessitating the process of electricity wheeling across transmission and distribution networks (Robb & Mondliwa, 2018, 27). In the specific context of this study, particularly within the framework of urban-rural energy cooperatives, the success of electricity wheeling relies on collaborative partnerships among various stakeholders, capacity-building initiatives, innovative strategies, and engagement with established value-chain businesses like PowerX, recognized by NERSA as a licensed wheeling business. In addition, entities such as the Mahlako Energy Fund serve as crucial investment providers, while Ener-Gi Africa sets a precedent as a model for providing gender-sensitive green skills development that align with the broader value-chain opportunities scoped in this study.

6.2. Data overview

The chapter leverages secondary data in the analysis of clean/green electricity generation. Data is gathered from various reports, industry analyses, and organizational case studies (see table 19). This includes assessing women's participation in different stages of production, from manufacturing to distribution, and identifying best practices and gaps in current practices. A key focus of this investigation involves unraveling the structures and operational mechanisms inherent in these case studies, along with evaluating related value-chain landscape within similar contexts. The data also plays an important role in exploring additional potential revenue streams for women enterprises within the renewable energy value-chain.

Table 19. Data overview for sub-question 3

Sub-question 3	Secondary data
How can a women-led model be effectively utilized for the assembly, repair, and maintenance of solar-PV induction stoves, contributing to green skills development, job creation, and entrepreneurship under Just Energy Transition (JET) initiatives in both rural and urban contexts?	- An examination of South Africa's wheeling landscape and the inherent red tape ((Murray & Adonis, 2019, 2; Moodliar, Davidson & Buraimoh, 2023, 2) - An examination of potential entry points for cooperatives to engage in the broader renewable energy value-chain with registered and esteemed organizations such as Mahlako Energy Fund, PowerX, Ener-gi Africa (EGA) - An analysis of the Mahlako Energy Fund as a wheeling, black woman owned public-private business model (Mahlako Finacial Services, 2021). - An analysis of EGA's approaches to reducing reliance on imported goods that aligns with the value chain development featured in this study (Department of Trade Industry & Competition, 2023), - An examination of a wheeling company (PowerX) to wheel power over the grid through long-term agreements, (Robb & Mondliwa, 2018, 32).

6.3. South Africa's wheeling landscape

Several factors, including the success of the REIPPP, technological advancements, local government policies, market competition, and global demand, have collectively reduced the cost of renewable energy (Murray & Adonis, 2019, 2). Following on REIPPP's verifiable accomplishments, IPPs can now establish long-term Power Purchase Agreements (PPAs) with various private sector consumers as opposed to solely relying on Eskom. As the number of private generators seeking to connect to the grid increases, the need for private-sector energy off-takers becomes more pronounced. Recent amendments to Schedule 2 of the Electricity Regulation Act mark a transformative phase. Specifically, these revisions entail a significant departure from the past regulatory framework as power generation facilities with a capacity of up to 100MW are no longer subject to the stringent licensing conditions that previously constrained private generators (Moodliar, Davidson & Buraimoh, 2023, 2). This relaxation in licensing requirements, coupled with the escalating tariffs of grid electricity, has naturally fostered a more conducive environment for the burgeoning presence of private generators. As shown in table 20, these amendments signify a paradigm shift, removing barriers to entry for private generators and creating conditions that encourage the emergence of independent power producers who are no longer bound to Eskom as the off-taker.

Table 20. South Africa's wheeling bylaws. Source: (Moodliar, Davidson & Buraimoh, 2023, 7).

2006 — 2022

ACT	POLICY	CODE	RULE
The Electricity Regulation Act [15] The Electricity Regulation Act relates not to wheeling but rather to trading electricity. As defined, "trading" refers to the commercial purchase or sale of energy. Therefore, one may claim that wheeling constitutes trading because it involves buying and selling. Notwithstanding the lack of reference to wheeling, sections 2 (a) and (b) define the act's objectives as follows: *(a)* Achieve the efficient, effective, sustainable, and orderly development and operation of electricity supply infrastructure in South Africa. *(b)* Ensure that the interests and needs of present and future electricity customers and end users are safeguarded and met, having regard to governance and efficiency. Effectiveness and long-term sustainability of the electricity supply industry within the broader context of economic energy regulation in the *(c)* Facilitate investment in the electricity supply industry - (d), (e), (f), (g) also apply. It is evident within the objectives that effectiveness, sustainability and competitiveness must be supported.	**The Electricity Pricing Policy [7]** Unlike the ERA, the electricity pricing policy of South Africa dedicates a paragraph to discuss the concept of wheeling. The principal points are highlighted as per policy position 5 below: 5 a) Fair and non-discriminatory access to and use of networks to all users of the relevant networks. b) The total cost to operate the networks is reflected in the various connection and use of system charges; therefore, no additional charges for wheeling electricity will be levied unless the wheeling action introduces incremental costs. c) Any incremental wheeling costs associated with a specific wheeling transaction and its fair share must be recovered as a connection charge. d) Wheeling of electricity can only be permitted if the action complies with all technical, safety and commercial requirements. e) A methodology for transmission and distribution wheeling, including the treatment of network congestion, must be developed by NERSA. The policy has forward stepped and pronounced on two specific issues of wheeling, including the access rights of wheeling (5a) as well as the pricing methods (5b,5c); however, it also pronounces in (5e) that NERSA must develop a methodology for wheeling.	**The Distribution Grid Codes [16]** The tariff grid code v6.2 states the following: 5.5.1. Embedded generators, including those that wheel, that use the distribution network to export power shall pay the Distribution generator use-of-system charges. 5.5. (2) All customers receiving a network service (including wheeling) shall pay the distribution use of system charges (DUoS), irrespective of any energy trading arrangement, which may or may not be unbundled depending on the tariff structure. 7. (5) All load customers, including those wheeling energy, shall be required to contribute to network-related subsidies. However, what form or quantity the customers shall contribute to subsidies is unclear.	**Third-Party Transportation of Energy [14]** Section 6.11 of the rules says generators' UOS system charges must be fixed and indexed annually to CPI. Unfortunately, not all costs are indexed to CPI; hence, municipalities may be under recovering in these cases where costs exceed CPI. Section 11.3 states, Upstream reinforcements costs shall not be raised from wheeling generators but an early termination guarantee for shared assets. The non-raising of costs can be viewed as municipalities funding infrastructure used by generators. 12.2 Generators connected below 11kV shall not be allowed to wheel energy.

6.4. Solar PV flagship wheeling projects in the South African energy generation landscape

6.4.1. Mahlako Energy Fund

The Mahlako Energy Fund stands out not only for innovative projects but also as a pivotal entity in a highly male-dominated market of energy infrastructure financing. As a woman-led enterprise, Mahlako Energy Fund challenges the traditional norms that have long governed this sector, which has historically seen an underrepresentation of women in leadership roles. This male dominance can be attributed to various factors, including entrenched cultural norms, historical biases, and a lack of representation in STEM fields. This disproportionately affects women's participation in energy and finance roles, leading to a risk-averse culture that may overlook innovative solutions brought forward by women and diverse teams. This environment can stifle the inclusion of diverse perspectives, which are essential for addressing the complex challenges facing the energy sector today (WEGE Policy, 2021 – 2025, 20).

Furthermore, women entrepreneurs in energy financing often face additional hurdles, such as limited access to capital, networking opportunities, and mentorship. These barriers not only hinder their ability to enter the market but also affect the sustainability and growth of women-led enterprises. The predominance of male-led firms can perpetuate a cycle where investment and resources are channeled toward initiatives that may not fully consider the diverse needs of all stakeholders, including women and marginalized communities. In response to these challenges, the Department of Mineral Resources and Energy introduced the Women Empowerment and Gender Equality (WEGE) of 2021 – 2025 to promote gender equity in the energy sector. This policy aims to increase women's participation in leadership roles, enhance access to financing for women-led enterprises, and foster an inclusive environment that supports the professional development of women in the industry. By setting specific targets and encouraging collaboration among stakeholders, the WEGE policy seeks to dismantle barriers and create a more equitable energy landscape.

Mahlako Energy Fund operates a 10MW solar plant in the Northern Cape, which pioneers large-scale energy wheeling to provide clean energy to Amazon Web Services (as off-taker/consumer) via the Eskom grid. It emphasizes collaboration between Mahlako Financial Services (MFS), Amazon Web Services (AWS), and the SOLA Group. Mahlako was part of the first project of the REIPPP program to be refinanced through leveraging a public-private business model with the backing of the Department of Minerals and Energy, along with support from the National Energy Regulator of South Africa (NERSA) and Eskom (MFS, 2021).

In the realm of wheeling and investment screening for renewable energy projects, the economic viability of partnerships between private energy generators and off-takers constitutes the cornerstone for success. This trend in the electricity market is particularly significant in South Africa given that electricity tariffs for grid-supplied energy have consistently increased at rates above inflation, thus adding pressure on general consumers and businesses alike (Moodliar et al., 2023). In such a landscape, cooperative energy models — especially those bridging rural and urban areas — emerge as innovative solutions. Through joint ventures, such cooperatives, are able to pool resources, distribute risks, and leverage the expertise and financial power of more established industry players, thus making them a compelling model for sustainable energy development.

The South African legislative framework, particularly the Electricity Regulation Act of 2006, provides a legal foundation for wheeling agreements, which enable private energy producers to sell electricity directly to end-users across municipal and national grid infrastructures. This legislation ensures that electricity wheeled from private generators, such as solar cooperatives, adheres to regulatory standards and is subject to oversight by the National Energy Regulator of South Africa (NERSA). Within this context, investment screening becomes more than just a financial exercise; it also involves compliance with the stringent regulations governing energy production, distribution, and consumption. For cooperatives and joint ventures, securing sound offtake agreements — long-term contracts in which energy buyers commit to purchasing power at predetermined rates — is critical. These agreements offer predictability and financial stability, which in turn instill confidence among investors and lenders. Thorough screening processes are vital to guarantee that projects are not only financially sound but also compliant with South Africa's renewable energy targets and socio-economic development criteria (Mahlako Fianacial Services, 2021). Such agreements often include stipulations that align with the South African Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), which mandates that projects contribute to local economic development and job creation.

A notable example within this framework is the Redstone Concentrated Solar Power (CSP) project, a flagship renewable energy initiative in South Africa (Mahlako Fianacial Services, 2021). Although not structured as a conventional joint venture, Redstone was developed through a consortium led by Saudi Arabian energy giant ACWA Power, in partnership with key South African institutions such as the Central Energy Fund, Pele Green Energy, and the Public Investment Corporation. The project exemplifies how cross-border collaborations and local partnerships can bring substantial foreign investment into South Africa's energy sector while simultaneously bolstering the country's renewable energy capacity. Redstone is expected to generate over 100 MW of clean energy, which further supports South Africa's commitment to reducing its carbon footprint and improving energy security.

A meticulous screening process by Mahlako Energy offers a clear view of how potential investments are evaluated for their long-term sustainability and financial viability. The process involves evaluating for regulatory compliance, financial models, and social impact assessments, thus ensuring that any investment is well-positioned to succeed under both market and regulatory criteria. This level of diligence not only aligns with South Africa's energy laws but also enhances investor confidence, based on the understanding that projects are robust, resilient, and capable of generating reliable returns over the long term. Projects like Redstone serve as a testament to how sound investment screening, combined with strategic partnerships, can drive forward South Africa's clean energy transition while creating shared value for all stakeholders involvedA notable example within this framework is the Redstone Concentrated Solar Power (CSP) project, a flagship renewable energy initiative in South Africa (Mahlako Financial Services, 2021). Although not structured as a conventional joint venture, Redstone was developed through a consortium led by Saudi Arabian energy giant ACWA Power, in partnership with key South African institutions such as the Central Energy Fund, Pele Green Energy, and the Public Investment Corporation. The project exemplifies how cross-border collaborations and local partnerships can bring substantial foreign investment into South Africa's energy sector while simultaneously bolstering the country's renewable energy capacity. Redstone is expected to generate over 100 MW of clean energy, which further supports South Africa's commitment to reducing its carbon footprint and improving energy security.

Mahlako Energy's meticulous screening process, illustrated in Figure 43, offers a clear view of how potential investments are evaluated for their long-term sustainability and financial viability. The process involves evaluating regulatory compliance, financial models, and social impact assessments, ensuring that any investment is well-positioned to succeed under both market and regulatory conditions. This level of diligence not only aligns with South African energy laws but also enhances investor confidence, knowing that projects are robust, resilient, and capable of generating reliable returns over the long term. Projects like Redstone serve as a testament to how sound investment screening, combined with strategic partnerships, can drive forward South Africa's clean energy transition while creating shared value for all stakeholders involved.

Figure 43. Mahlako's investment screening criteria. Source: (Researcher, 2024 as adapted from Mahlako Financial Services, 2021)

The screening is based on a questionnaires which covers aspects such as economic viability, contractual commitments, and a comprehensive understanding of financial, legal, and operational elements as follows:

- *Have you secured a long-dated off-take agreement?*
- *Do you have a quality order book with [3 to 5] year contracts? (Only applicable for companies)*
- *Are you a publicly listed entity?**
- *Is your entity a fund/vehicle which charges fees or carried interest?**
- *Do you require equity and/or quasi-equity funding?*
- *What is the location of your project/company?**

6.4.2. Ener-G-Africa (EGA)

Ener-G-Africa (EGA) specializes in renewable energy technologies, particularly solar panels which are assembled at its plant in Cape Town. The plant has a production capacity of 15MW of panels annually. EGA's primary focus is on expanding clean energy access to low-income households in sub-Saharan Africa, which closely aligns with its mission of social impact through localized energy solutions. EGA's land requirements are primarily related to the manufacturing facility's size, storage, and amenities for the workforce. The land requirement for this operation primarily includes the footprint of the manufacturing facility itself. The size of the facility depends on the production capacity and layout of the assembly lines. In a different effort, ongoing manufacturing of energy-efficient cookstoves, coupled with planned expansion of the solar plant by the third or fourth quarter of 2024, constitutes the primary interventions. These interventions aim to address energy access and affordability issues in local communities through a women-dominated workforce as evidenced by successful trials and incentives provided through a carbon-financed cookstove program.

Employment opportunities generated by such manufacturing value chains would positively impact both skilled and unskilled individuals in local communities (Department of Trade Industry & Competition, 2023). Facilitated by product sales through various channels, diversification of economic opportunities within local communities is another expected outcome, particularly with local shops, agents, and employees benefiting from commission-based sales incentives. As highlighted by EGA's approach to reducing reliance on imported goods (Department of Trade Industry & Competition, 2023), the commitment to sustainability and local empowerment aligns closely with the value chain opportunities envisaged in this study. Some of EGA's achievements include supplying rocket stoves (devices designed to burn biomass fuel such as wood, dung, or crop residues in a controlled combustion chamber) to over four million households across 12 countries in sub-Saharan Africa and maintaining an all-female workforce in the solar panel production facility, thus setting a commendable precedent for the industry.

6.4.3. PowerX

Implementation of wheeling electricity in South Africa requires approval from the National Energy Regulator of South Africa (NERSA). Wheeling emerges from collaborative efforts between the Department of Minerals and Energy, NERSA, and Eskom which led to expedited deregulation of the country's electricity sector, opening doors for increased participation of private-sector entities. Despite attempts to introduce independent power producers (IPPs) into the generation sector, their contribution remains limited (approximately 5% of total generation in the year 2017) (Robb & Mondliwa, 2018, 27), while municipalities play a significant role in distribution which generates revenue for local authorities licensed to play such a role. Currently, Eskom, is undergoing restructuring into three separate entities which will handle generation, transmission, and distribution while still operating as Eskom subsidiaries thus reinforcing monopolistic position of the utility in electricity market.

Effective competition against Eskom is therefore minimal across the value chain due to ongoing bias in policies and regulations in favour of the utility. One notable exception in this scenario is the private company, PowerX, which obtained a wheeling license from NERSA, enabling it to purchase electricity from independent generators and distribute it to municipalities and other customers. This necessitated the process of electricity wheeling across transmission and distribution networks owned and operated by other parties (Robb & Mondliwa, 2018, 27). In the specific context of this study, particularly within the framework of urban-rural energy cooperatives, the success of electricity wheeling relies on collaborative partnerships among key stakeholders (primarily generators and consumers, Eskom and municipalities and the wheeling facilitator company), capacity-building initiatives, innovative strategies, and engagement with established value-chain businesses like PowerX which are licensed for wheeling by NERSA.

Municipalities such as Nelson Mandela Bay Municipality have authorized PowerX to wheel power over their grid based on long-term agreements which enable the company to directly supply to consumers without direct involvement of the municipal electricity department (Robb & Mondliwa, 2018, 32). Each unit of power generated by Independent Power Producers (IPPs) receives certification from an independent auditing body, the issuing body (IB), facilitating sales to customers or trading in South Africa's voluntary energy market or internationally.

Municipalities derive revenue from a "use of system" fee charged per kilowatt-hour (kWh) of electricity wheeled over their networks. By facilitating wheeling, the municipality incentivizes investment and job creation within its regions while buffering consumers from ongoing escalation in Eskom-generated electricity tariffs (SALGA-GIZ, 2015). The progression of this model faces several challenges, including difficulties in securing financing for new electricity generation projects without long-term Power Purchase Agreements (PPAs), especially for smaller consumers.

In addition, the absence of a comprehensive regulatory framework governing network access and usage fees poses a significant obstacle. While PowerX has the capability to transmit electricity across municipal networks with local approval, scaling this operation to cover longer distances and establishing a fully functional trading market necessitates access to multiple municipal networks and the national transmission grid, along with compensation arrangements for infrastructure utilization (Robb & Mondliwa, 2018, 32).

6.4. A responsive consumer-generation model for value-chain devolopment

Ongoing surge in solar technology has dramatically increased demand for skilled technicians specializing in installations, commissioning, operation and maintenance of renewable energy infrastructure. Solar photovoltaic technology now constitutes about 40-43% of employment opportunities within electric power generation, thus highlighting the urgent need for qualified professionals in this field. According to Azizi & Fuente (2022, 2), there are considerable opportunities for income generation and capacity building, especially for women in urban and rural settings. The model appraised in this study envisions empowerment of women not only as beneficiaries of renewable energy but primarily as active participants and key decision-makers (entrepreneurs) in the energy market.

In addition to opportunities such as land leasing and electricity sales, rural women can leverage the potential of providing critical maintenance services for solar panels. Effective maintenance is essential for ensuring reliable and efficient power generation. With appropriate training, women can acquire the skills needed to perform regular inspections, cleaning, and minor repairs. Such competencies would not only improve the performance and lifespan of solar PV systems but would also enhance energy output while reducing operational costs. By taking on these responsibilities, women can become integral to success and sustainability across diverse value chains in renewable energy market.

Within such a context, the installation of solar PV systems in rural areas also opens up opportunities for agrivoltaics, where the land beneath solar panels could be utilized for agricultural purposes. Agrivoltaics is a promising approach that mitigates the trade-offs between agricultural production and solar energy generation. Research into crops like wheat, maize, potatoes, and rice, along with modeling for cotton and aloe vera, demonstrates that the partial shading provided by solar panels can create a more favorable microclimate for certain crops (Azizi & Fuente, 2022, 2). This shading can reduce water consumption, lower soil evaporation, and boost crop yields in areas with high temperatures and limited natural shade.

Organizations like Ener-G-Africa (EGA) and PowerX would play a crucial role beyond financial support. This would include offering essential training and expertise to help women establish themselves in the renewable energy sector. As depicted in Figure 44, EGA’s focus on women’s involvement in renewable energy manufacturing, includes specialized training in areas such as solar PV production, installation, and maintenance. This training can empower rural women with practical skills, which would enable them to take on significant roles in the solar energy market, including production, assembly, and maintenance.

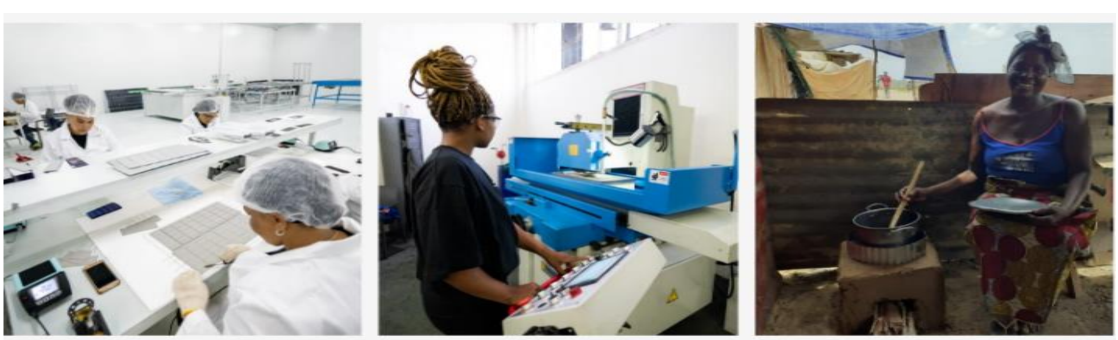

Figure 44. Ener-G-Africa’s support of women-based workforce: Source: (Energ-G-Africa, nd)

Similarly, PowerX, a licensed electricity trader involved in wheeling, supports women's empowerment through business and technical training. This organization can provide women with the knowledge necessary for managing infrastructure and understanding the logistics required for maintaining renewable energy projects. By learning about power purchase agreements (PPAs), tariff structures, and regulatory frameworks, women can effectively navigate the energy market and oversee energy cooperatives.

6.5. Sub-findings on sub-question 3

The sub-findings of this chapter focus on three key aspects of value-chain development. First, the evolving regulatory framework acts as an enabler, contributing to the success of notable wheeling entities like Mahlako Energy Fund and PowerX. Second, the employment opportunities generated by manufacturing value chains, as demonstrated by EGA, are inclusive and not restricted to individuals with specific academic qualifications that may be absent in local communities. Lastly, the potential for joint ventures, funding, or collaborative efforts serves as a crucial economic link between private electricity generators that are not established as yet, and off-takers. Together, these factors highlight the economic potential of wheeling, especially in low-income communities, by fostering job opportunities in technical areas such as system repairs, maintenance, and operational support for solar-PV installations and induction stoves. As the expansion of wheeling increases access to clean energy, there will be a growing need for skilled technicians on the consumer and generation value chains for maintaining and servicing these solar-PV systems. This local technical expertise becomes critical for ensuring the efficiency and reliability of the energy infrastructure. Women-led cooperatives are well-positioned to seize this opportunity, offering specialized technical services, thus enhancing their role in the clean energy sector.

The shift to solar-PV systems and induction stoves requires a workforce capable of managing technical operations—skills not typically found within these communities. As appraised in this chapter, the integration of clean energy systems with agrivoltaic models further diversifies economic opportunities for rural women. By combining solar panel installations with agriculture, women can generate income from both sectors. This dual involvement in energy and agriculture would allow them to contribute to food security while strengthening energy resilience of their community. Their participation in maintaining solar-PV systems would also complement their roles in agricultural productivity, thus empowering them as key contributors to sustainable development. Specialized training initiatives that align with local needs would therefore be essential towards unlocking this potential. As shown in Figure 45, the mutuality of this green entrepreneurship would strengthen the resilience of the wheeling model while enriching the socioeconomic fabric of rural and urban areas alike.

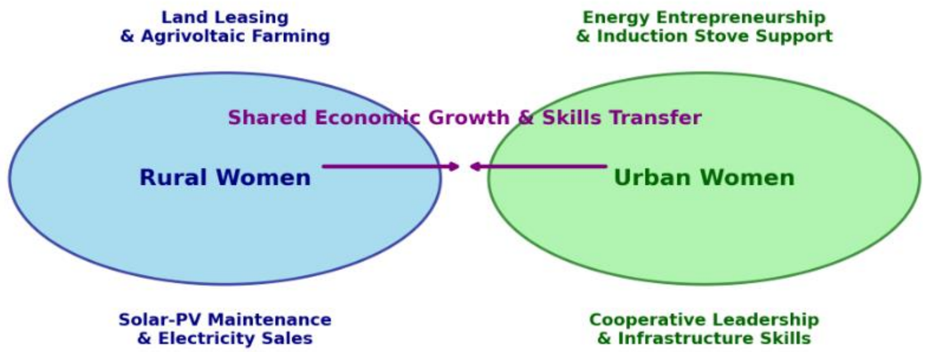

Figure 45: The interconnected pathways between rural and urban opportunities

Power Purchase Agreements (PPAs) emerge as crucial tools for securing funding and building investor confidence, thus ensuring long-term financial viability of renewable energy projects. Mahlako Fund investment-screening process emphasizes the importance of thorough evaluations and strategic partnerships in managing the complexities of wheeling investments, particularly in cooperative models that bridge rural and urban contexts. The launch of EGA's solar panel assembly plant, with a 15MW annual capacity, marks a significant shift toward localized women-led renewable energy value chains, showcasing the potential for renewable energy to transform both urban and rural landscapes by creating new economic pathways. In addition to financial incentives like SARS' Section 12BA accelerated wear and tear allowance (National Treasury 2023), the transformative impact of renewable energy lies in partnerships with organizations at the forefront of innovation.

Collaborating with women-led entities such as Mahlako and EGA facilitates skill transfer, resource pooling, and access to tax relief measures, thus enabling cooperatives to improve their financial returns while driving social and environmental progress. EGA's focus on involving women in the manufacturing and operational roles of the solar-PV industry provides opportunities to break traditional gender barriers, thus expanding economic prospects for women and challenging conventional norms in blue-collar professions. By engaging with forward-thinking organizations, both urban and rural communities can deepen their engagement with solar energy technologies and become active participants in renewable energy projects. These partnerships emphasize the importance of collective responsibility in shaping a sustainable future, particularly in marginalized areas marked by crime, underdevelopment, and stifling of opportunities due to bureaucratic inertia.

In closing, as much as South Africa's wheeling landscape is becoming more progressive the success of integrating electricity wheeling within the *imbokodo*-inspired model is not merely a matter of policy or technical capability; it hinges on the commitment and collaboration of key stakeholders who possess the influence, resources, and expertise to drive meaningful change. In this regard, their willingness to invest and/or collaborate can drive revenue growth through diversified energy transactions, while contributing to their own environmental, social, and governance (ESG) goals.

Chapter 7

Overall findings, conclusions and recommendations

7.1. Introduction

This chapter synthesizes overall findings of the study in response to the main research question. This is primarily based on consolidation of sub-findings on sub-questions 1 to 3 as captured in the final sections of Chapters 4, 5, and 6. The findings are also closely referenced to the working hypothesis as presented in Chapter 1 (see Section 1.5) and conceptual framework of the study (see Chapter 2, Section 2.11). Overall findings are then applied to derive conclusions of the study which are systematically cross-referenced back to existing literature. This is followed by recommendations for future research.

7.2. Overall findings

While the below findings address technical aspects of solar-PV induction stoves, they transcend mere energy mechanics by uncovering deep socio-political entanglements while also offering a roadmap toward a more equitable energy future. At its core, the study does more than merely answer the feasibility of solar-PV induction stoves — it offers an in-depth critique on the very nature of the paradigm of Just Energy Transition itself. In addition, it prompts a confrontation of muted truths: that energy solutions cannot be separated from questions of power-mechanics and technologies, land, and gender. Solar energy, often viewed as a neutral technology, is revealed here as deeply political, to the extent that its potential for transformation is closely intertwined with who controls it and who is excluded from it. The findings push beyond technical fixes, calling for a fundamental rethinking of energy policy that prioritizes the dismantling of entrenched inequalities.

The real challenge, as the study suggests, is not technological adoption but societal transformation. In the end, this study invites a profound re-evaluation of the entire framework for energy access. It challenges the assumption that technology alone can deliver a Just Energy Transition. It has successfully confronted the socio-political dynamics that govern energy and have locked post-apartheid South African communities in a cycle of greenwashed and superficial solutions and narratives.

- **Sub-Question 1: Social acceptability as a key catalyst**

The study's first sub-question, which examines the issue of social acceptability as a key indicator of potential for adoption of induction-stovethe as an energy-efficient clean-cooking technology. This part of the study revealed the deeply entrenched and unsustainable cooking practices within low-income households, particularly in urban areas like Alexandra township. These households continue to rely on paraffin and open flames not merely due to a lack of awareness of cleaner alternatives such as solar-PV induction stoves but because of the broader failures in South Africa's energy infrastructure, policies and socio-economic systems. These embedded practices, passed down through generations, are intertwined with cultural norms and economic realities that are difficult to disrupt, especially when the alternatives are perceived as unreliable or unaffordable.

For instance, paraffin stoves, though hazardous and inefficient, are favored because of their low initial cost and widespread availability. They also allow users to retain traditional cooking methods, such as using three-legged pots for simmering stews or boiling maize meal. Such practices that are deeply ingrained in cultural and culinary identities. The study highlights how these ingrained cooking practices are resistant to change not just because of convenience but also because they reflect a deeper connection to heritage and household traditions. This reality points to a paradox: while cleaner, more efficient technologies exist and are theoretically accessible, the shift away from harmful fuels like paraffin has not materialized at scale due to the instability and unreliability of electricity in low-income communities. Solar-PV induction stoves, On the other hand, while solar-PV induction stoves are promising as an eco-friendly solution, they require a consistent and affordable electricityenergy supply — something that South Africa's under-resourced households in South Africa's townships do not currently have. As a result, these embedded practices persist, creating a vicious cycle of energy poverty, health risks, and environmental degradation.

The findings that go towards answering the first sub-question suggests that the real crisis is not merely a lack of social acceptability for solar-PV induction stoves, but the enduring inequity of energy distribution in post-apartheid South Africa. Energy justice is not just about providing access to modern technologies; it's also about dismantling the structural barriers that keep the most vulnerable populations dependent on outdated, dangerous, and inefficient cooking methods. These disparities are a reflection of a much larger structural failure. While induction stoves and solar-PV systems could potentially revolutionize cooking practices and improve health outcomes, their deployment in low-income communities would be significantlyis currently hampered by the larger systemic inequities in energy access

- **Sub-Question 2: Solar energy entrepreneurship as an equalizer**

The second finding delves into the untapped solar potential in rural regions, yet it uncovers a troubling reality: where socio-political barriers — such as exclusionary land rights controlled by tribal authorities — continue to marginalize women. Solar energy, touted as a democratizing force, risks becoming another arena where power getsis unevenly distributed. While technology and the natural resource base offers the promise of progress, the study raises the provocation of energy as an equalizer where certain segments of the community are systematically excluded from access to land both for user-rights and ownership. The barriers to women's participation in the energy transition thus starts mirroring broader societal inequalities, suggesting that without dismantling these entrenched power dynamics, solar energy risks becoming another site of struggle rather than a pathway to equitable empowerment.

This chapter highlighted the fact that rural-urban women-led cooperatives hold significant potential to leverage wheeling as a business model to overcome the cost barriers associated with adopting solar-PV induction stoves in low-income households. The wheeling of solar-generated electricity from rural generator cooperatives, such as the one hypothesized in Chebeng, to urban consumer cooperatives in Alexandra provides a practical and scalable solution to expand clean cooking technology in underserved areas. In this model, rural cooperatives generate solar power, which is wheeled to urban cooperatives, allowing them to access affordable and stable clean energy without the need for individual solar installations on each household. This structure enables the women-led cooperatives in Alexandra not only to use the stoves themselves but also to receive funding to purchase additional stoves, which they can lease out to other community members. By doing so, they become both consumers and energy entrepreneurs, thus facilitating with creating micro-enterprises that help reduce the upfront cost of clean energy technologies while generating income.

Additionally, women in Alexandra could be trained to provide first-line support for the maintenance and repair of the induction stoves. By offering these services, they would leverage their proximity to users and their knowledge of the technology to build a sustainable service network. This capacity for support enhances the cooperatives' business models, thus creating additional income streams of income through repair services while promoting the long-term adoption and use of induction stoves within the community. This local maintenance capacity reduces reliance on external service providers, thus cutting costs and improving onthe overall sustainabilitydurability of the energy solution.

Supported by tax rebates under South Africa's Section 12B of the Income Tax Act, rural cooperatives can reduce their capital costs for solar-PV infrastructure, making the wheeling and leasing model even more affordable for urban cooperatives. The resulting leasing agreements between rural and urban cooperatives would help lower the cost of energy while ensuring that solar-PV systems remain sustainable through ongoing maintenance and potential upgrades. Such an innovative model would empower and positions women to becomes key agents in the Just Energy Transition (JET), especially through integrating and empowering them into management of energy generation, distribution, and maintenance. By leveraging wheeling agreements, they wouldcan not only break through cost barriers but also play a central role in advancing clean energy access, fostering gender equity, and promoting entrepreneurship in both rural and urban contextss.

- **Sub-Question 3: Value-chain Opportunities.**

The third key finding highlights a crucial element in South Africa's energy landscape: the regulatory oversight provided by the National Energy Regulator of South Africa (NERSA). While NERSA's role is foundational in ensuring compliance and safeguarding the integrity of energy markets, the true potential for transformative change lies in the active and strategic participation of innovative entities like the Mahlako Energy Fund, PowerX, and Ener-G-Africa. These organizations represent a growing movement towards an inclusive and justice-oriented energy transition.

Beyond the technical realm of energy production or the mobilization of investment capital; the finding for this section of the research also touched upon the structural reformation of how energy governance, financing, and community engagement are intertwined. South Africa's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) and initiatives like PowerX's wheeling agreements have demonstrated that public-private collaborations can drive significant investments, as evidenced by the program's cumulative contribution of over 6,000 MW of renewable energy to the national grid. Yet, the deeper question posed by this finding is whether these collaborations go far enough in addressing systemic issues such as the historical marginalization of women and rural communities within the energy sector.

Entities like Mahlako Energy Fund have shown that with a dedicated focus on women-led and black-owned energy businesses, new pathways for equity and empowerment can be forged. For example, Mahlako Energy Fund not only invests in energy infrastructure but also prioritizes gender equity and socio-economic inclusion through its projects. However, such initiatives need to be scaled significantly. Mahlako's investments in projects like the 100 MW Redstone Concentrated Solar Power (CSP) plant demonstrate that major capital-intensive projects can still align with broader social goals. However, a more radical departure from traditional project structures is needed to ensure these benefits trickle down to historically excluded groups.

Furthermore, EGA's work on the ground, producing clean cooking technologies and renewable energy solutions in Malawi and South Africa, points to the broader opportunities for community-driven approaches. Their model, which integrates women into all levels of their operations, from manufacturing to distribution, demonstrates that grassroots-level engagements can be a powerful driver of sustainable energy adoption. But despite these successes, scaling such models across South Africa remains a challenge given entrenched political and economic hierarchies that often favor large corporate players over local communities. The question of radical collaboration thus calls for a reimagining of the role of key stakeholders in the energy transition. Collaboration cannot remain at the superficial level of technical expertise or financing agreements; it must become deeply embedded in a shared commitment to reshaping societal and economic structures. This requires breaking down silos between regulators, financiers, and communities — particularly to ensure women-led initiatives and rural cooperatives so that they become true co-creators in the energy future.

Table 21 presents an overview and synthesis of sub-findings across three sub-questions.

Table 21: Consolidation of overall findings of the study

Sub-Question 1 **What is the potential of adopting induction stoves as a substitute for combustible fuels among low-income households in Alexandra township when considering cultural preferences for traditional cooking methods and limited access to alternative technologies?**	**Sub-Question 2:** **To what extent can rural-urban women-led cooperatives leverage wheeling as a business model to address operational cost barrier associated with the adoption of solar-PV induction stoves among low-income households, given prevailing low levels of commercialization?**	**Sub-Question 3** **How could a women-led operational model be leveraged towards assembly, repair, and maintenance of solar-PV induction stoves, thus contributing to Just Energy Transition (JET) outcomes (green skills development, job creation, and entrepreneurship among others) in both rural and urban contexts?**
- Despite grid connection, marginalized households persistently face energy poverty and resort to traditional cooking practices. Adoption of induction stoves likely to be hindered by high costs, compatibility constraints, limited capacity, and limited access to affordable maintenance services - City Power's tariff system unfairly burdens low-income households, forcing difficult choices between electricity expenses versus essential needs. Recent tariff hikes worsen financial strain, perpetuating illegal connections and deepening socio-economic inequalities. - Alexandra township demonstrated presence of active community structures such as ***stokvels*** which can be formalized into energy consumer cooperatives for promoting community-driven efforts for sustainable energy initiatives such as use of induction stoves. - Wheeling presents a scalable solution to democratize clean energy access, overcoming challenges posed by existing infrastructure deficiencies. - Social acceptance of the induction stove depends on addressing energy supply issues alongside induction stove adoption and positioning wheeling as a remedy for rooftop inadequacy and security challenges for installing roof-top solar-PV	- Indicators like Global Horizontal Irradiance (GHI) and Direct Normal Irradiance (DNI), and substantial annual mean Solar Shortwave Flux (SWFlux) values in Limpopo highlight the region's high solar potential, particularly in the context of wheeling initiatives - Socio-political dimensions of land acquisition for energy projects necessitate adherence to specific prerequisites set by rural tribunals - Challenges stemming from historical legacies and gender disparities within tribal authorities significantly limits land access process for large scale projects especially for women - Various *stokvels* in Chebeng serve diverse needs, with separate groups often formed by women - Strong cooperative support systems from key institutions and stakeholders could serve as an enabler of formalization and transition of Chebeng *stokvels* into established generation cooperatives - Similar land-extensive projects in Limpopo such as the Bolobedu's solar farm represents a significant departure from traditional land uses, signaling a shift towards renewable energy solutions in the province - Uncertainties persist regarding employment strategies and impacts on local communities	- Wheeling unlocks several value chain opportunities, focusing on three key areas: regulatory compliance, green electricity generation, and economic connectivity. It provides avenues for value creation at each stage of the electricity supply chain—from navigating regulatory approvals and leveraging incentives for renewable energy generation, to optimizing transmission and distribution networks. The ability to facilitate direct connections between private generators and off-takers enhances the economic potential across the value chain, allowing for new revenue streams, market diversification, and investment in sustainable energy infrastructure - Once cooperative is established, investment screening procedures, coupled with the establishment of power purchase agreements (PPAs), would be essential for funding and instilling confidence among investors - There are new opportunities for businesses entering renewable energy investments. Strategic collaborations to leverage these opportunities with forward-thinking entities like PowerX offer avenues for skills transfer, resource pooling, and tax relief measures should a joint venture be established - Partnerships with women-led entities in renewable energy, such as Mahlako and gender-sensitive entities in renewable energy, offer opportunities for women to challenge gender norms, expand economic opportunities, and break through prevailing stereotypes in the renewable energy sector

	- Efforts to promote women participation in manufacturing value chains and blue-collar roles within the solar-PV industry are crucial for fostering gender inclusivity and representation within the sector in order to meaningfully pursue overall JET objectives
Overall findings: Given the nexus of gender and energy poverty, particularly in cooking, and considering challenges specific to each context (urban and rural), whose socio-political factors have shaped the hypotehsised model, the coupling of women-led solar-PV generation cooperatives in rural areas with consumer cooperatives in urban settings demonstrates significant merit. Such a coupling would facilitate wheeling of clean electricity for zero-carbon cooking, thus addressing challenges such as energy poverty and security concerns while also empowering women by integrating them into a deeper clean energy value-chain. The study finds that leveraging wheeled solar-PV electricity from rural to urban cooperatives can catalyze green skills development, job creation, and entrepreneurship opportunities for women across the renewable energy value chain in South Africa, thus aligning more systematically with the JET framework towards fostering a low-carbon economy.	**Finding 1:** Ethnographic observations reveal the unsustainable nature of current cooking practices, which rely on inefficient and harmful energy sources. While access to the electricity grid is often seen as a solution, it does not fully address the issues of access and long-term sustainability due to high costs and unreliable supply. Moreover, while social acceptability plays a role in the adoption of clean cooking technologies, it is not the absolute decisive barrier. The broader challenges lie in the technical and economic limitations of current energy infrastructures, making the integration of clean cooking technologies essential for fostering sustainable and resilient energy practices across communities. **Finding 2:** Urban-based participants demonstrate a pronounced focus on addressing the broader energy crisis, often prioritizing immediate solutions to energy access over the health benefits associated with clean cooking. The study finds that proto-cooperative networks are already in place, offering a framework that could be leveraged to mobilize clean energy initiatives. When combined with available funding opportunities from both governmental and private sectors, such cooperatives can facilitate greater access to clean technologies. As such, responsive and innovative models, including wheeling or community-based energy solutions, are necessary to overcome these infrastructural challenges and address the energy crisis effectively. **Finding 3:** The untapped solar potential in Limpopo presents a significant opportunity for advancing renewable energy initiatives. Harnessing this potential, particularly through empowering women, requires strong public-private collaboration and navigating the socio-political influence of tribal authorities among rural communities. South Africa's wheeling landscape offers both advantages and limitations. On the positive side, wheeling enables Independent Power Producers (IPPs) to transmit electricity through Eskom's transmission grid, which spans over 32,000 kilometers, providing access to areas that may otherwise struggle with energy supply. This opens the door for increased participation in the energy market, particularly for renewable energy projects. However, regulatory landscape for wheeling remains fragmented, with inconsistent policies across municipalities. In addition, high upfront costs and complex negotiations make wheeling more accessible to larger entities, while smaller, community-based cooperatives may face significant barriers. Despite these challenges, if effectively managed, wheeling could play a pivotal role in democratizing access to clean energy while supporting women-led solar ventures in rural areas like Limpopo. **Finding 4:** Both urban and rural *stokvels* exhibit significant potential for transitioning into formal cooperatives, thus representing a critical pathway for addressing energy poverty through collective action. In rural contexts, *stokvels* are an untapped reservoir of opportunities, with public and private sector stakeholders well-positioned to facilitate and support their transformation into energy cooperatives. Strategic joint ventures with companies like Mahlako Energy can play a key role in advancing solar-PV projects, enabling cooperatives to access the technical and financial resources necessary to scale their efforts. **Finding 5:** From an *imbokodo* perspective, JET framework embodies a localized and inclusive approach to addressing energy challenges, by wheeling rural-generated renewable energy to urban consumers for clean cooking with induction stoves as a key energy-use. From the perspective of diversifying the revenue streams and optimising the value chain, partnerships with PowerX and Ener-G-Africa (EGA) present valuable opportunities for skills and capacity building, particularly for blue-collar jobs in the manufacturing, installation, and maintenance value chains. PowerX's expertise in energy trading and wheeling can help cooperatives navigate the complexities of energy distribution, while EGA's

proven track record in clean technology manufacturing would offer a model for creating local employment while also enhancing technical capacity

7.4. Updated Conceptual Framework

In light of the findings derived from this investigation and the foundational working hypothesis, Figure 46 aims to provide an enhanced understanding of the intricate interactions and interrelationships among the key themes and concepts integral to our study. These revised insights seek to emphasize the mechanisms through which the desired outcomes are anticipated to materialize, particularly in the context of advancing renewable energy initiatives:

Current Scenario:

- Persistent energy poverty in urban areas where the cooking status quos were under investigation
- Existing CBOs that have the potential to be formalized into cooperatives
- Land leasing potential for wheeling in rural areas
- Significance of tribal authority in rural areas
- High costs and unaffordability of alternative clean cooking technologies and energy services

Processes and Mechanisms for Achieving the Outcomes:

- Adoption of induction stoves for clean cooking
- Establishment of clean energy consumer cooperatives among low-income households in urban areas
- Creation of clean energy generation cooperatives led by women in rural communities with access to land in resource-rich areas
- Development of wheeling operators to connect consumer cooperatives with generator cooperatives

- Formation of collaborative networks to support and resource the model

Desired Outcomes:

- Imbokodo/women-driven entrepreneurship within the renewable energy value chain
- Development of green skills, jobs, and businesses at the grassroots level within communities
- Safer and healthier cooking practices through the use of clean technologies, such as induction stoves and solar-PV electricity
- Contribution to a just energy transition

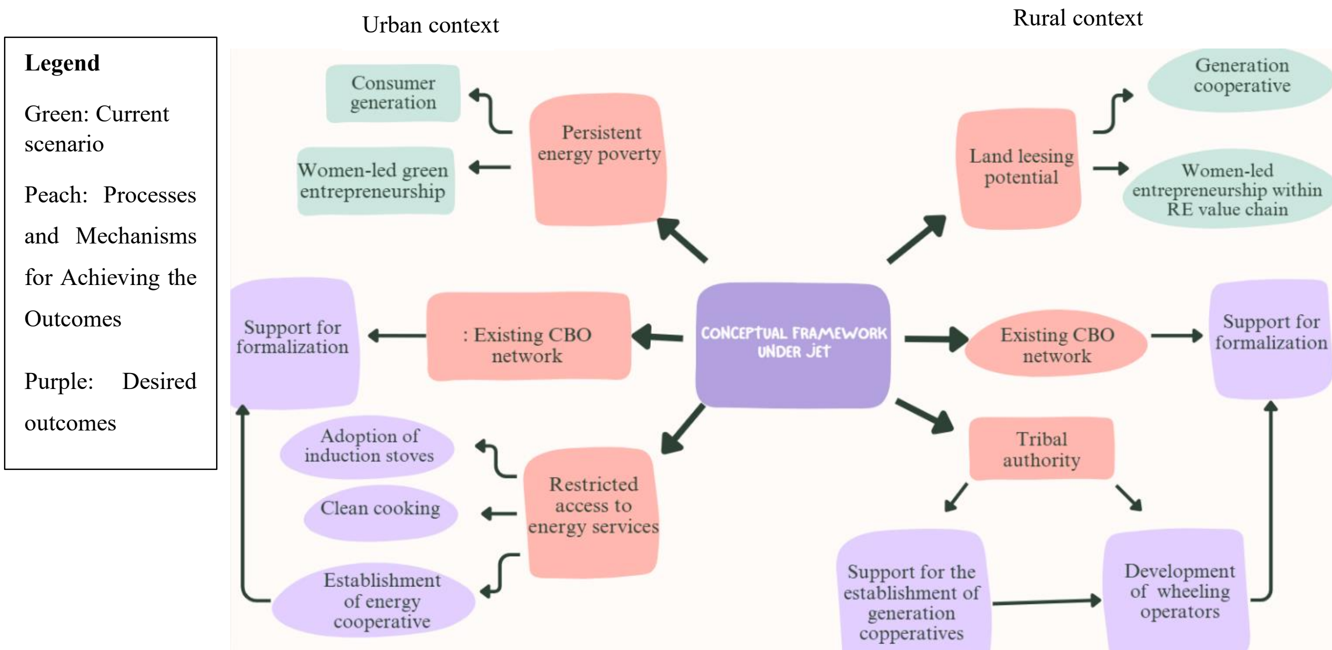

Figure 46. The updated conceptual framework

7.3. Conclusions

Initially focused on the technical and economic feasibility of solar PV-based induction stoves, the study evolved into a deeper inquiry into justice and equity in energy access. The investigation has illuminated that barriers to clean cooking in low-income urban areas are intertwined with cultural practices, socio-political dynamics, and historical injustices. This broader perspective underscores that while high initial costs of solar PV induction stoves pose a significant challenge, they also highlight a deeper issue: the need to dismantle fossil-fuel paradigms that dominate energy choices. This realization sets the stage for understanding how cooperatives could play a pivotal role towards transforming energy access.

In the context of post-apartheid South Africa, cooperatives have emerged as crucial agents of community development. However, the paradox here is that while cooperatives have the potential to empower marginalized women and drive economic growth, their effectiveness hinges on comprehensive training and a nuanced grasp of cooperative values. The transition from prevailing cooking practices among households and communities in areas such as Alexandra Township reveals the complexities involved in overcoming cultural inertia and financial constraints. This understanding leads the study to a consideration of how targeted policies and incentives can bridge the affordability gap and foster acceptance of new technologies.

The challenge of integrating tax incentives into effective support mechanisms becomes evident as we examine South Africa's renewable energy policies. While the 15% tax rebate on solar panels offers some relief, it often falls short for the most economically disadvantaged households. Land leasing agreements for solar projects, typically spanning 20 years, are intended to provide a stable foundation for long-term investments. While these agreements offer the promise of a secure revenue flow, their effectiveness is contingent on several critical factors. Tax rebates, such as those available under South Africa's Section 12B of the Income Tax Act, are designed to alleviate the initial financial burden by significantly fast-track recouping of upfront capital costs of solar infrastructure. This could, in theory, make it easier for women to obtain financing and manage loan repayments over the leasing term.

However, the practical impact of these tax incentives on loan repayment is subject to scrutiny. The overall feasibility depends on the total cost of the solar system, which may still be substantial despite rebates. In addition, success of generating sufficient revenue from energy sales to cover loan repayments and sustain operations is not guaranteed and requires robust financial management and market stability. Revenue potential may fluctuate based on energy demand, pricing, and operational efficiency, thus posing risks to financial stability. Furthermore, the long-term nature of land leasing agreements necessitates sustained performance and effective management to ensure that the benefits of tax rebates and leasing agreements translate into actual financial viability.

Therefore, while tax incentives and long-term land leases offer a promising framework for enhancing financial sustainability, they are not a panacea. The critical challenge lies in navigating the complexities of financial planning, market conditions, and operational management to ensure that these mechanisms support urban women in achieving not only economic viability but also broader energy transition goals. To extend these incentives effectively, there must be a concerted effort to integrate them into broader social support systems. This calls for innovative financial assistance programs and partnerships to make solar technology more accessible, thus addressing the gap between policy interventions and household preferences. This, in turn, highlights the need for behavior change campaigns and efficient supply networks to make alternatives like solar-PV induction stoves practical and accepted.

The potential of *imbokodo*-inspired energy cooperatives emerges as a promising solution to these challenges. By facilitating wheeling of solar-generated electricity, these cooperatives offer multifaceted pathways for women empowerment and economic participation. In rural areas such as Chebeng, a woman-led cooperative would lead the development of solar-PV hubs. In turn, an urban-based woman-led cooperative in Alexandra would lease this infrastructure, integrating rural and urban efforts into a cohesive energy solution. This model exemplifies how decentralization can enhance both rural and urban energy landscapes, highlighting the critical role women can play in driving the Just Energy Transition (JET). Despite systemic barriers—such as patriarchal dominance, limited academic access, and restricted social capital — women in unconventional settings can still emerge as central drivers of this political and economic shift of sustainability through equitable access to clean energy.

Understanding the goals and Corporate Social Responsibility (CSR) initiatives of entities like EGA and PowerX is crucial for leveraging their support. Women-led cooperatives must align their objectives with missions of such entities in order to create compelling business cases for collaboration. Such alignment would facilitate partnerships that can provide essential training and resources, thereby enhancing the cooperatives' capacity to manage solar infrastructure and navigate energy markets. As we consider these partnerships, it becomes clear that integrating existing networks and emphasizing the social impact of collaborations would strengthen the overall approach.

In urban settings like Alexandra, cooperatives would play a transformative role as managers of solar-generated electricity. By wheeling energy from rural areas, urban cooperatives reduce reliance on unstable local grids and advance energy security. As demonstrated in Figure 47, the envisaged working model would not only democratize energy access but also empower women to manage clean electricity distribution and pricing within their communities. Leasing arrangements would further lower barriers to solar energy access, thus promoting inclusivity while also addressing energy poverty. By focusing on mutual benefits across the urban and rural spheres, this model supports the broader goal of energy justice and helps bridge the gap between traditionally marginalized communities.

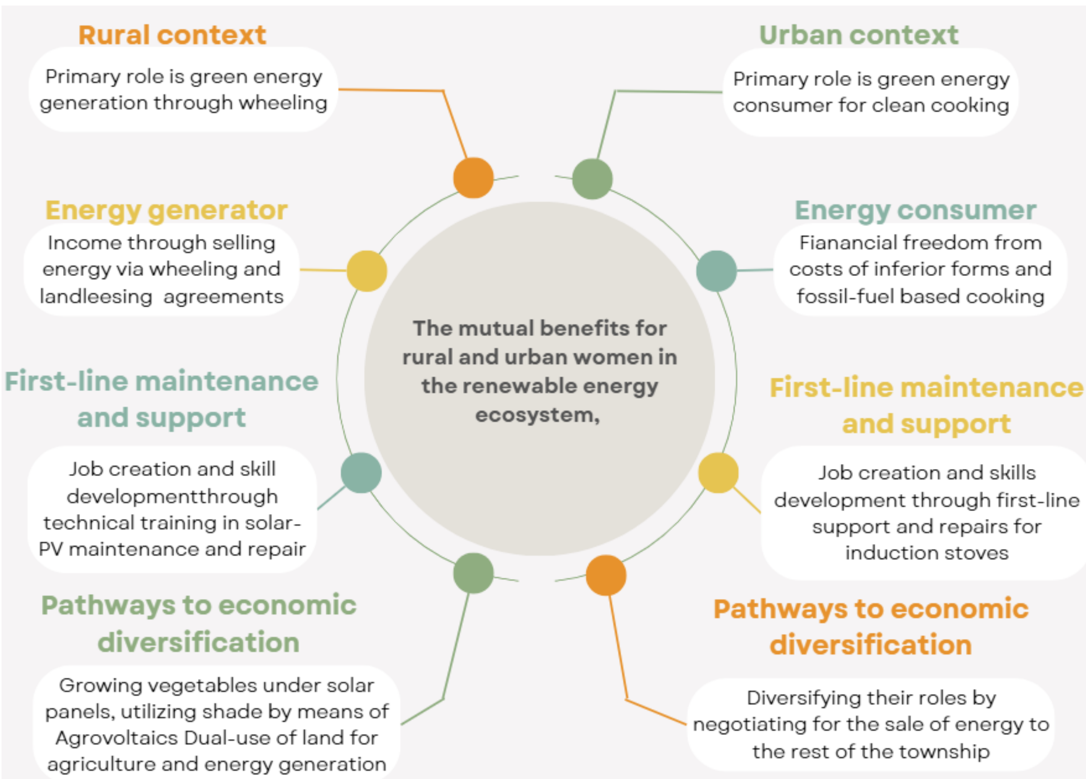

Figure 47. The mutual benefits for urban and rural women.

7.4. Limitations of the study

The limitations of this study include several factors that affect the depth and comprehensiveness of the findings. One significant constraint was the limited timeline for data collection, which were limited to three days for both the urban (Alexandra township) and rural (Chebeng village) contexts due to practical constraints, including conflicting schedules and competing responsibilities for both the researcher and the participants. The available time for conducting in-depth fieldwork was restricted by logistical challenges, as well as participants' existing commitments to work, family, and community obligations, which made it difficult to arrange longer or more flexible engagement periods. These time limitations, coupled with the need to accommodate the availability of various stakeholders, constrained the ability to conduct more prolonged and immersive observations. As a result, the study's findings are based on the insights and interactions that could be gathered within this timeframe. These limitations suggest that follow-up research with a longer engagement and a more robust sampling strategy would be necessary to validate the findings and provide a more comprehensive understanding of the energy-related challenges in these communities.

7.5. Recommendations for further research

There are still structural barriers that hinder access to blue-collar job opportunities in the renewable energy sector, particularly for marginalized communities in South Africa. These barriers can manifest in various ways, including socio-economic factors such as poverty, limited access to education and training, and inadequate infrastructure. Such conditions severely restrict individuals' ability to pursue careers in the rapidly expanding renewable energy field. Systemic issues, including discrimination based on gender, race, or socio-economic status, further exacerbate these challenges, often sidelining women from technical roles within the energy sector.

The roles of maintenance and installation are critical not only for the functionality of renewable energy systems but also for creating sustainable job opportunities for women. Technical positions in maintenance and installation ensure that solar technologies and other renewable energy systems operate efficiently and reliably. By training women in these specialized skills, we can provide them with pathways to stable employment, particularly in communities where such opportunities are scarce.

To advance this study, the next phase of research could focus on cooperative governance models that actively prioritize women's involvement in these technical roles. By exploring how these models can support and facilitate women's entry into maintenance and installation positions, the research would aim at identify strategies that can drive meaningful change within the renewable energy sector.

Reference List

Acero, J., Burdio, J.M., Barragan, L.A., Navarro, D., Alonso, R., Garcia, J.R., Monterde, F., Hernandez, P., Llorente, S. and Garde, I., 2008. The domestic induction heating appliance: An overview of recent research. In *2008 Twenty-Third Annual IEEE Applied Power Electronics Conference and Exposition* (pp. 651-657). IEEE, 24 – 28 February 2008, Austin, TX, USA.

ACWA Power. (n.d.). Redstone Concentrated Solar Power Plant. [Online] Accessed: 29 February 2024. Available here [Redstone Concentrated Solar Project, South Africa (nsenergybusiness.com)]

Adedeji, P.A., 2020. *Hybrid renewable energy-based facility location: a Geographical Information System (GIS) integrated multi-criteria decision-making (MCDM) approach*. University of Johannesburg (South Africa).

Allen, E., Lyons, H. and Stephens, J.C., 2019. Women's leadership in renewable transformation, energy justice and energy democracy: Redistributing power. *Energy Research & Social Science*, *57*, p.101233.

Alstone, P., Niethammer, C., Mendonça, B. and Eftimie, A., 2011. Expanding women's role in Africa's modern off-grid lighting market. [Online] Retrieved on 07 March 2023. Available on: https://openknowledge.worldbank.org/handle/10986/17487

Ateba, B.B., Prinsloo, J.J. and Fourie, E., 2018. The impact of energy fuel choice determinants on sustainable energy consumption of selected South African households. *Journal of Energy in Southern Africa*, *29*(3), pp.51-65.

Ayamolowo, O.J., Manditereza, P.T. and Kusakana, K., 2022. South Africa power reforms: The path to a dominant renewable energy-sourced grid. *Energy Reports*, *8*, pp.1208-1215.

Ayub, H.R., Ambusso, W.J., Manene, F.M. and Nyaanga, D.M., 2021. A review of cooking systems and energy efficiencies. *American Journal of Energy Engineering*, *9*(1), pp.1-7.

Azimoh, C.L., Wallin, F., Klintenberg, P. and Karlsson, B., 2014. An assessment of unforeseen losses resulting from inappropriate use of solar home systems in South Africa. *Applied energy*, *136*, pp. 336-346.

Azizi, S. and Fuentes, V.L., 2022, January. Design and Development of a New Course and Laboratory: Solar PV Installation and Troubleshooting. In *Conference on Industry and Education Collaboration (CIEC)*. [Online]. Accessed 07 September 2024. Available here: https://par.nsf.gov/servlets/purl/10332406

Baker, E., Nock, D., Levin, T., Atarah, S.A., Afful-Dadzie, A., Dodoo-Arhin, D., Ndikumana, L., Shittu, E., Muchapondwa, E. and Sackey, C.V.H., 2021. Who is marginalized in energy justice? Amplifying community leader perspectives of energy transitions in Ghana. *Energy Research & Social Science*, *73*, pp. 1-11

Baker, L., 2017. Commercial-scale renewable energy in South Africa and its progress to date. *IDS Bulletin*, 48 (5-6), pp 1 -185.

Baker, L. and Phillips, J., 2019. Tensions in the transition: The politics of electricity distribution in South Africa. *Environment and Planning C: Politics and Space*, *37*(1), pp.177-196.

Balachandra, P., 2011. Dynamics of rural energy access in India: An assessment. *Energy*, *36*(9), pp.5556-5567.

Balmer, M., 2007. Energy poverty and cooking energy requirements: The forgotten issue in South African energy policy? *Journal of energy in Southern Africa,* 18 (3), 4-9.

Banerjee, M., Prasad, R., Rehman, I.H. and Gill, B., 2016. Induction stoves as an option for clean cooking in rural India. *Energy Policy*, *88*, pp.159-167.

Bisaga, I., Campbell, K., Bellanca, R., Kleijn, M. and To, L.S., 2022. Clean and modern energy for cooking: A path to food security and sustainable development. World Food Programme. [Online]. Accessed 02 January 2024. Available here: Bisaga et al. - 2022 - Clean and modern energy for cooking.pdf

Batchelor, S., 2015. Africa cooking with electricity (ACE). Gamos working paper. Loughborough University, London.

Baylis, S., 2011. Provincial land use legislative reform Limpopo Province: Status report, September 2011. South African Cities Network. [Online]. Accessed 01 February 2024. Available here - Microsoft Word - Limpopo LUMS Laws .docx (sacities.net)

Bing maps, nd. Distance between 28 10th Avenue to 1 Roosevelt, Alexandra Township. Accessed 02 September 2024. Available here: https://www.bing.com/maps?mepi=23%7E%7ETopOfPage%7EMap_Image&ty=18&q=28+10th+Avenue%2C+Alexandra+Extension+62%2C+Johannesburg%2C+2090&ppois=-26.1002894_28.09448_28+10th+Avenue%2C+Alexandra+Extension+62%2C+Johannesburg%2C+2090_%7E&cp=-26.104529%7E28.101924&lvl=15.7&v=2&sV=1&FORM=MIRE

Boserup, E. Tan, S.F. & Toulmin, C., 2013. Woman's role in economic development. Taylor & Francis Publication, London.

Choda, A. and Teladia, M., 2018. Conversations about measurement and evaluation in impact investing. *African Evaluation Journal*, *6*(2), pp.1-11.

City of Johannesburg's Group Finance., 2023. Understanding electricity tariffs: Residential prepaid. [Online]. Accessed 20 March 2024. Available here Electricity Tariff (joburg.org.za)

CSIR, 2017. Statistics of utility-scale solar PV, Wind and CSP in South Africa in 2016. A presentation by Council for Scientific and Industrial Research (CSIR) Energy Centre, in Baker, L., 2017 (ed.). Commercial-scale renewable energy in South Africa and its progress to date. *IDS Bulletin*, 48 (5-6), pp 1 -185.

Debor, S., 2014. *The socio-economic power of renewable energy production cooperatives in Germany: Results of an empirical assessment* (Vol. 187). Wuppertal Institute for Climate, Environment and Energy.

Denzin, N.K. and Lincoln, Y.S. eds., 2011. *The Sage handbook of qualitative research*. Sage, USA

Department of Energy (South Africa)., 2012. A survey of energy-related behavior and perceptions in South Africa: Department of Energy. [Online]. Retrieved 26 March 2023. Available here: resource_76.pdf (cityenergy.org.za)

Department of Economic Development, Cooperatives, Environment and Tourism., 2007. Limpopo Economic Development, Environment and Tourism. [Online]. Accessed 27 October 2023. Available here http://www.ledet.gov.za/

Department of Land Affairs., 1997, 'White paper on South African land policy'. Pretoria: DLA. [Online]. Accessed: 02 April 2024. Available here: http://intranet.ruraldevelopment.gov.za/tenurereform/newpage7.h (www.gov.za)

Department of Mineral Resources and Energy., 2021. Women Empowerement and Gender Equality: Strategy for the Energy Sector. [Online] Accessed 13 October 2024. Available here: http://www.energy.gov.za/files/PPMO/2021-2025-WEGE-Strategy-for-the-Energy-Sector.pdf

Department of Provincial Affairs and Constitutional Development., 1998, The white paper on local government. Pretoria: DPACD. [Online]. Accessed of April 2024. Available here: www.gov.za

Department of Minerals and Energy., 2003. White paper on renewable energy policy. [Online]. Retrieved 01 March 2023. Available on: https://unfccc.int/files/meetings/seminar/application/pdf/sem_sup1_south_africa.pdf

Department of Trade, Industry and Competition., 2023. Ener-G-Africa's R135m investment transforms South Africa's energy landscape. [Online]. Accessed 02 March 2024. Available here Ener-G-Africa's R135m Investment Transforms South Africa's Energy Landscape - The Department of Trade Industry and Competition (thedtic.gov.za)

Department of Trade and Industry. 2010. General notice of 2011: Publication of the integrated strategy on the development and promotion of co-operatives for public comments. Online. Accessed 20 August 2024. Available here: Integrated Strategy on Development and Promotion of Co-operatives: Draft (ilembechamber.co.za)

Dlamini, P., 2023. City Power cutting off electricity supply to non-payers in Alexandra. Sowetan Live. Accessed 21 February 2024. Available here: City Power cutting off electricity supply to non-payers in Alexandra (sowetanlive.co.za)

Duvenhage, D.F., Brent, A.C., Stafford, W.H. and Van Den Heever, D., 2020. Optimising the concentrating solar power potential in South Africa through an improved GIS analysis. *Energies*, *13*(12), p. 1 – 10.

Ener-G-Africa, nd., Sustainability through innovation. Accessed 13 February 2024. [Online]. Available here: Online Version - mid - 2024_EGA-brochure_online-version_001 (ener-g-africa.com)

Eskom., 2022. Factsheet: What you need to know about wheeling of electricity. [Online]. Retrieved 23 March 2023. Available on: https://www.eskom.co.za/distribution/wp-content/uploads/2022/07/20220721-Wheeling-concept_Introduction.final_.pdf

Ehrenreich-Risner, V., 2022. *Bantu Authorities: Apartheid's System of Race and Ethnicity*. Rowman & Littlefield. Online. Access 03 August 2024. Available here: Bantu Authorities: Apartheid's System of Race and Ethnicity - Veronica Ehrenreich-Risner - Google Books

Farmers Weekly, 2020. SA's wind power production to increase substantially by 2030. *Farmers Weekly*, *Volume 2020. Issue 20038.* Caxton Magazines.

Garlet, T.B., Ribeiro, J.L.D., de Souza Savian, F. and Siluk, J.C.M., 2020. Value chain in distributed generation of photovoltaic energy and factors for competitiveness: A systematic review. *Solar Energy*, *211*, pp.396-411.

Green agri., nd. Solar energy in agriculture. Accessed 29 October 2023. Available here: Solar Energy in Agriculture » GreenAgri

Green Cape, 2021. Energy services market intelligence report, Cape Town. [Online]. Retrieved 06 June 2023. Available on: https://www.westerncape.gov.za/110green/files/atoms/files/Energy%20Services%20Market%20Intelligence%20Report%202021.pdf. Last accessed 25 May 2023

Google maps., nd. Distance between Alexandra township and Chebeng. [Online]. Retrieved 11 July 2023, Available here: Alexandra, 2014 to chebeng - Google Maps

Google maps., nd. Chebeng village. [Online]. Accessed 13 October 2024. Available here: https://www.google.com/maps/place/Chebeng,+0756/@-23.8139113,29.249083,14z/data=!4m6!3m5!1s0x1ec722ddf32df383:0x136b1601dff5b464!8m2!3d-23.8135495!4d29.2736432!16s%2Fg%2F1tdj80k7?entry=ttu&g_ep=EgoyMDI0MTAwOS4wIKXMDSoASAFQAw%3D%3D

Google maps., nd. Distance between Chebeng and Bolebedu solar-PV power plant. [Online]. Accessed 13 October 2024. Available here: https://www.google.com/maps/dir/Chebeng,+0756/Bolobedu+Solar+Power+Station,+Nganyeni/@-23.6283419,29.1688577,9z/data=!3m1!4b1!4m13!4m12!1m5!1m1!1s0x1ec722ddf32df383:0x136b1601dff5b464!2m2!1d29.2736432!2d-23.8135495!1m5!1m1!1s0x1ec43dbf27efdf1b:0xf525897de5639266!2m2!1d30.3846434!2d-23.4912277?entry=ttu&g_ep=EgoyMDI0MTAwOS4wIKXMDSoASAFQAw%3D%3D

Google maps., nd. Distance between Chebeng and Dikgale. [Online]. Accessed 13 October 2024. Available here: https://www.google.com/maps/dir/Chebeng,+0756/Ga-Dikgale/@-23.6205389,29.0408998,10z/data=!4m13!4m12!1m5!1m1!1s0x1ec722ddf32df383:0x136b1601dff5b464!2m2!1d29.2736432!2d-23.8135495!1m5!1m1!1s0x1ec798c11f1e6aa5:0xa7dab6f55c55e116!2m2!1d29.0176353!2d-23.3982045?entry=ttu&g_ep=EgoyMDI0MTAwOS4wIKXMDSoASAFQAw%3D%3D

Google maps, nd. Distance between Chebeng and Mankweng. [Online]. Accessed 13 October 2024. Available here: https://www.google.com/maps/dir/Chebeng,+0756/Mankweng/@-23.8786597,29.507425,11z/data=!4m13!4m12!1m5!1m1!1s0x1ec722ddf32df383:0x136b1601dff5b464!2m2!1d29.2736432!2d-

23.8135495!1m5!1m1!1s0x1ec6c8c21b8044f9:0x686c27377f602369!2m2!1d29.7078785!2d-23.8836683?entry=ttu&g_ep=EgoyMDI0MTAwOS4wIKXMDSoASAFQAw%3D%3D

Green Cape., 2022. Large-scale renewable energy market intelligence report. [Online]. Retrieved 12 July 2023. Available here: RE_MIR_29_3_22_FINAL.pdf (westerncape.gov.za)

Haagsma, J.A., Graetz, N., Bolliger, I., Naghavi, M., Higashi, H., Mullany, E.C., Abera, S.F., Abraham, J.P., Adofo, K., Alsharif, U. and Ameh, E.A., 2016. The global burden of injury: incidence, mortality, disability-adjusted life years and time trends from the global burden of disease study 2013. *Injury prevention*, *22*(1), pp.3-18.

Hansmann, H., 2000. *The ownership of enterprise*. Harvard University Press.

Healy, N. and Barry, J., 2017. Politicizing energy justice and energy system transitions: Fossil fuel divestment and a "just transition". *Energy policy*, *108*, pp.451-459.

Heeter, J., Vora, R., Mathur, S., Madrigal, P., Chatterjee, S.K. and Shah, R., 2016. *Wheeling and banking strategies for optimal renewable energy deployment. International experiences* (No. NREL/TP-6A20-65660). National Renewable Energy Lab (NREL), Golden, CO (United States).

Hull, S., Sehume, T., Sibiya, S., Sothafile, L., & Whittal, J. 2016. Land allocation, boundary demarcation and tenure security in tribal areas of South Africa. *South African Journal of Geomatics*. 5(1): 68- 81

International Energy Agency Photovoltaic Power Systems Programme, 2014. Innovative business models and financing mechanisms for PV deployment in emerging regions. [Online]. Retrieved 26 March 2023. Available on: https://energypedia.info/images/9/93/Innovative_Business_Models_and_Financing_Mechanisms_for_PV_Deployment_in_Emerging_Regions.pdf

Jelsma, J. and Clow, S., 2005. Ethical issues relating to qualitative research. *South African Journal of Physiotherapy*, *61*(1), p.3.

Jelti, F., Allouhi, A., Büker, M.S., Saadani, R. and Jamil, A., 2021. Renewable power generation: A supply chain perspective. *Sustainability*, *13*(3), p.1-22.

Jeuland, M.A. and Pattanayak, S.K., 2012. Benefits and costs of improved cookstoves: assessing the implications of variability in health, forest and climate impacts. *PloS one*, *7*(2), pp.1-15

JT Communications., 2024. Founder's vision in the face of crisis – bridging the solar divide through innovative stokvel solutions. Accessed 27 March 2024. Available here: [Founder's Vision in the Face of Crisis - Bridging the Solar Divide Through Innovative Stokvel Solutions - MyBizPress]

Kamaludin, M.F., Xavier, J.A. and Amin, M., 2021. Social entrepreneurship and sustainability: A conceptual framework. *Journal of Social Entrepreneurship*, pp.1-24.

Ketlhoilwe, M.J. and Kanene, K.M., 2018. Access to energy sources in the face of climate change: Challenges faced by women in rural communities. *Jàmbá: Journal of Disaster Risk Studies*, *10*(1), p.1-8.

Kimemia, D., Oladejo, A.O. and Van Niekerk, A., 2022. Energy transitions in the global south and Africa: Policy imperatives, system dynamics and challenges. *Social and Health Sciences*, *20*(1), p.1-6.

Kukula Solar., n.d. Protect Zambian forests with clean cookstoves. [Online]. Retrieved on 20 March 2023. Available on: https://kukulasolar.com/

Łakomiak, A., 2022. Civic energy in an orchard farm–prosumer and energy cooperative—A new approach to electricity generation. *Energies*, *15*(19), p.6918.

Lamhamedi, B.E.H. and de Vries, W.T., 2022. An exploration of the land–renewable) energy nexus. *Land*, *11*(6), p. 1 – 17.

Lee, C.J., Shirley, R., Otieno, M. and Nyambura, H., 2021. Powering jobs: the employment footprint of clean cooking solutions in Kenya. *Energy, Sustainability and Society*, *11*, pp.1-22.

Mahlako Fianacial Services., 2021. Mahlako Energy Fund invests in South Africa's first large-scale operational wheeling project. Online. Accessed 04 June 2023. Available on: https://mahlakofs.co.za/mahlako-news/mahlako-energy-fund-invests-in-south-africas-first-large-scale-operational-wheeling-project/

Mahlako Financial Services., 2022. Mahlako Balancing Growth. Accessed 21/10/2923. Available here Mahlako – Financial Services (mahlakofs.co.za)

Major, F., 2021. Creating the future of life. *IMIESA*, 46

Masuku, B., 2024. Rethinking South Africa's household energy poverty through the lens of off-grid energy transition. *Development Southern Africa*, pp.1-24.

Matthäus, D. and Mehling, M., 2020. De-risking renewable energy investments in developing countries: a multilateral guarantee mechanism. *Joule*, *4*(12), pp.2627-2645.

Mierzwiak, M. and Calka, B., 2017. Multi-criteria analysis for solar farm location suitability. *Reports on Geodesy and Geoinformatics*, *104*(1), pp.20-32.

Mikami, K., 2010. Capital procurement of a consumer cooperative: Role of the membership market. *Economic Systems*, *34*(2), pp.178-197.

Mininni, G.M., 2022. The Barefoot College 'eco-village approach to women's entrepreneurship in energy. *Environmental Innovation and Societal Transitions*, *42*, p. 112-123.

Mkhwebane, E. and Ntuli, N., 2019. Alternatives for small, medium and micro scale enterprises participation in the renewable energy industry-small scale embedded generation review. *Journal of Energy in Southern Africa*, *30*(2), pp.144-151.

Moodliar, L., Davidson, I.E. and Buraimoh, E., 2023. Wheeling of electricity: A friend or foe in the energy transition.

Moodley, N., 2023. Theft of solar panels on increase as criminals seize new opportunity. Daily Maverick. Available here: Theft of solar panels on increase as criminals seize new opportunity (dailymaverick.co.za) Accessed: 10 October 2023

Moore, K.A. and Lobell, D.B., 2024. Opportunities and Barriers for Agrivoltaics on Tribal Lands. *Sustainability*, *16*(13), p.5414. [Online]. Accessed 07 September 2024. Available here: Sustainability | Free Full-Text | Opportunities and Barriers for Agrivoltaics on Tribal Lands (mdpi.com)

Morrison, A., Mainsah, H. and Rygh, K., 2019. Sharp edges, blunt objects, clean slices. Exploring design research methods. *The Design Journal*, *22*(sup1), pp.2267-2273.

Moniruzzaman, M. and Day, R., 2020. Gendered energy poverty and energy justice in rural Bangladesh. *Energy Policy*, *144*, p.111554.

Murray, W.N., 2018. *Energy wheeling viability of distributed renewable energy for industry* (masters dissertation, Cape Peninsula University of Technology).

Murray, W. and Adonis, M., 2019. Efficacy of energy wheeling to endorse renewable energy generation. In *AIUE Proceedings of the 17th Industrial and Commercial Use of Energy (ICUE) Conference*. Accessed 22 October 2023, Available here https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3658901

Muthambi, X., Cloete, C. and Cook, L., nd. Challenges of acquiring tribal land in Giyani, Limpopo Province, South Africa, for commercial development. [Online]. Accessed 26 March 2024. Available here: AFRES PROCEEDINGS 7 9 2019-working-copy (architexturez.net)

National Empowerment Fund., nd. National Empowerment Fund Growing Black Economic Participation: Rural, Township and Community Development Fund. Accessed 20 August 2024. Available here: Rural, Township and Community Development Fund - National Empowerment Fund (nefcorp.co.za)

National Treasury., 2023. Budget speech by Minister Enoch Godonfwana. Retrieved 10 March 2023. Available on: Minister Enoch Godongwana: 2023 Budget Speech | South African Government (www.gov.za)t

News 24., 2023. Here's what you need to know about a new stokvel to help you go solar. Acceseed 20 August 2024. Available here: Here's what you need to know about a new stokvel to help you go solar | Business (news24.com)

Nkoana, E.M., 2018. Community acceptance challenges of renewable energy transition: A tale of two solar parks in Limpopo, South Africa. *Journal of Energy in Southern Africa*, *29*(1), pp.34-40.

Ntsebeza, L., 2004. Democratic decentralisation and traditional authority: Dilemmas of land administration in rural South Africa. *The European Journal of Development Research*, *16*(1), pp.71-89.

Nwachukwu, P.T. and Asuelime, R.A., 2018. Shaping capabilities for gender balanced participation in eco-entrepreneurship for sustainable development in Africa. *Gender and Behaviour*, *16*(2), pp.11308-11323.

Orlu, K.N. and Rambe, P., 2022. The significance of market power in the financial sustainability of emerging agricultural cooperatives in the central Free State of South Africa: A resource-based view. *Southern African Business Review*, *26*, pp.21-pages.

Osterwalder, A., Pigneur, Y., Clark, T., 2010, *Business model generation : a handbook for visionaries, game changers, and challengers.* Hoboken : Wiley.

Parker, D., 2022. Motsepe Foundation, partners invest in projects to uplift farmers, communities. Creamer Media's Engineering News. Accessed 04 November 2023. Available here Motsepe Foundation, partners invest in projects to uplift farmers, communities (engineeringnews.co.za)

Phillips, A., 1999. Bantu education. *The Review: A Journal of Undergraduate Student Research*, *2*(1), pp.22-27. Accessed 03 August 2024. Available here: Bantu Education (sjf.edu)

Pietermaritzburg Economic Justice & Dignity Group (PMBEJD)., 2021. Household affordability index. [Online] Accessed 21 February 2024. Available here: April-2021-Household-Affordability-Index-PMBEJD_29042021.pdf

Pueyo, A. and Maestre, M., 2020. Gender and energy: Opportunities for all. Institute of Development Studie, 51 (1)

Qeqe, B., Kapingura, F. and Mgxekwa, B., 2022. The relationship between electricity prices and household welfare in South Africa. *Energies*, *15*(20), p.7794.

Ramagoshi, R., 2016. Stokvels in the African communities: this is how we do it. Plus 50, 11(4), p.51 – 52

Ramantswana, H., 2019. *Wathint'Umfazi, Wathint'Imbokodo, Uzakufa* [you strike a woman, you strike a rock, you will die]: Dinah and Tamar as rape protestors. *HTS Teologiese Studies/Theological Studies*, *75*(1).

Reisman, J. and Olazabal, V., 2016. *Situating the next generation of impact measurement and evaluation for impact investing*. New York, NY, USA: Rockefeller Foundation.

Rey, P. and Tirole, J., 2007. Financing and access in cooperatives. *International Journal of Industrial Organization*, *25*(5), pp.1061-1088.

Republic of South Africa, 1951. Black Authorities Act No.68 of 1951. Pretoria: Government Printer.

Republic of South Africa, 1995. Development Facilitation Act, Act 65 of 1995. Pretoria: Government Printer.

Republic of South Africa, 2013. Spatial Planning and Land Use Management Act, 16 of 2013 (SPLUMA). Pretoria: Government Printer.

Republic of South Africa, 2003. Traditional Leadership and Government Framework Act No.41 of 2003. Pretoria: Government Printer

Riger, Stephanie. and Sigurvinsdottir, Rannveig., 2016. Thematic analysis. *Handbook of methodological approaches to community-based research: Qualitative, quantitative, and mixed methods*, pp.33-41.

Road on map., nd. The locality Chebeng suburb of Polokwane. [Online] Accessed 13 October 2024. Available here: Where is Chebeng suburb of Polokwane Capricorn, Limpopo South Africa (roadonmap.com)

Robb, G. and Mondliwa, P., 2018. SOCs and Competition: Reflections on South Africa's experiences in telecommunications and energy. [Online]. Accessed 24 March 2024. Available here: SSRN-id3244302.pdf

SABC News., 2024. Paraffin price increase puts pressure on households as winter looms. [Online]. Accessed: 02 January 2024. Available here Breakdown-of-Prices.pdf (energy.gov.za)

Sadowski, B.M., 2017. Consumer cooperatives as an alternative form of governance: The case of the broadband industry. *Economic Systems*, *41*(1), pp.86-97.

Sánchez-Robles, M., Saura, J.R. and Ribeiro-Soriano, D., 2023. Overcoming the challenges of cooperative startups businesses: insights from a bibliometric network analysis. *Review of Managerial Science*, pp.1-32.

Saunders, M., Lewis, P. and Thornhill, A., 2003. Research methods for business students. *Essex: Prentice Hall: Financial Times*, pp 1 -649.

Seitz, T., 2018. The spectrum of impact investing, 2019.Cited in Choda, A. and Teladia, M., 2018. Conversations about measurement and evaluation in impact investing. *African Evaluation Journal*, *6*(2), pp.1-11.

Shapurjee, Y. and Charlton, S., 2013. Transforming South Africa's low-income housing projects through backyard dwellings: Intersections with households and the state in Alexandra, Johannesburg. *Journal of Housing and the Built Environment*, *28*, pp.653-666.

Sibiya, B.I. and Venugopal, C., 2017. Solar powered induction cooking system. *Energy Procedia*, *117*: 145-156.

Singh, J., 2016. Ranking South African provinces on the basis of MERRA 2D surface incident shortwave flux. *Journal of Energy in Southern Africa*, *27*(3), pp.50-57.

Singh, J., Bhattacharya, B. K., Kumar, M., 2012. Solar radiation and evaporation trend over India. *Journal of Earth Science and Engineering*, 2(3): 160-165.

Smit, B., 2002. *Atlas. ti* for qualitative data analysis. *Perspectives in education*, *20*(3), pp.65-75.

Smith, C., 2022. New solar plant in Limpopo to supply Richards Bay Minerals with power by 2024. [Online]. Accessed 18 February 2024. Available here - New solar plant in Limpopo to supply Richards Bay Minerals with power by 2024 | Business (news24.com)

Smith, K.R., 2000. National burden of disease in India from indoor air pollution. *Proceedings of the National Academy of Sciences*, *97*(24):13286-13293.

Sola-admin, 2021. What does the first large scale wheeling project mean for South Africa. [Online] Accessed 10 February 2024. Available here https://solagroup.co.za/sola-launches-south-africas-first-large-scale-wheeling-project-what-this-means-for-south-africa/

SOLA group, 20202. Solar-PV wheeling projects. [Online]. Accessed 02 March 2024. Available here - Solar PV Wheeling Projects - SOLA (solagroup.co.za)

State of New South Wales, Department of Education and Training, 2015. Induction cooking. Available on: http://lrrpublic.cli.det.nsw.edu.au/lrrSecure/Sites/ Web/physics_explorer/physics/lo/induction_09/induction_09_06.htm

Statistics South Africa., 2019. General household survey 2018, statistical release P0318. [Online), Retrieved 28 June 2023. Available on: http://www.statssa.gov.za/publications/P0318/P03182018.pdf

Sustainable Energy Africa (SEA)., 2018. Local government energy efficiency and renewable energy strategy, [Online]. Retrieved 01 March 2023. Available on: https://www.sustainable.org.za/uploads/files/file100.pdf

SEA., 2018. Energy poverty and gender in urban South Africa. [Online]. Accessed 22 June 2023. Available on: file124.pdf (sustainable.org.za)

Sustainable Energy Africa (SEA)., 2019. (Modelling) the financial case for rooftop solar PV in low- and mid-income households in South Africa. Accessed 29 October 2023, available here (modelling) the financial case for rooftop solar pv in low- and mid-income households in south africa (sseg.org.za)

SEA., 2019. (Modelling) The financial case for rooftop solar PV in low- and mid-income households in South Africa. Accessed 12 October 2023. [Online]. Available here: (modelling) the financial case for rooftop solar pv in low- and mid-income households in south africa (sseg.org.za)

Thaba, S., Chingono, T. and Mbohwa, C., 2015. Strengthening cooperatives development in South Africa: a case study of the Limpopo and Gauteng Provinces. In *World Congress on Engineering and Computer Science 2015*.Available here: WCECS2015_pp992-995.pdf (iaeng.org) Accessed: 12th of October 2023

Ulsrud, K., Winther, T., Palit, D. and Rohracher, H., 2015. Village-level solar power in Africa: Accelerating access to electricity services through a socio-technical design in Kenya. *Energy Research & Social Science*, *5*, pp.34-44.

United Nations. (n.d.). Sustainable development goals - Goal 7: Affordable and clean energy. [Online]. Retrieved 26 June 2023. Available on: https://sdgs.un.org/goals/goal7.

United Nations., 2015. Transforming our world: the 2030 Agenda for sustainable development. United Nations. [Online]. Retrieved 26 March 2023. Available on: Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs (un.org)

Urban Landmark, 2013. Land governance in South Africa - working towards improving access to land and property rights: Implementing the Land Governance Assessment Framework. [Online]. Accessed 26 March 2024 Available from: http://www.urbanlandmark.org/downloads/lgaf_booklet.pdf

van der Poel, J., Kota, M. and Felekis, A., 2020. Shedding light on grid independence. Source, 22(2), pp.38-39. Vermaak, C., 2014. Developing an energy-based poverty line for South Africa. *Journal of Economic and Financial Sciences*, *7*(1): 127-144.

Voltalia., 2022. In South Africa, Voltalia builds the Bolobedu solar power plant PDF version. [Online]. Accessed 13 October 2024. Available here: https://www.voltalia.com/news-releases/news-release-details/south-africa-voltalia-builds-bolobedu-solar-power-plant

Weather Forecast., Nd. Polokwane weather forecast. [Online]. Accessed 12 October 2024. Available here: Polokwane Weather Forecast (weather-forecast.com)

Wentzel, M. and Pouris, A., 2007. The development impact of solar cookers: a review of solar cooking impact research in South Africa. *Energy policy*, *35*(3):1909-1919.

Wolf,J., Prüss-Ustün,A., and Vickers,C., 2016. The public health impact of chemicals: Knowns and unknowns. Geneva: WHO International Programme on Chemical Safety. [Online] Retrieved 09 March 2023. Available on: https://apps.who.int/iris/bitstream/handle/10665/206553/WHO_FWC_PHE_EPE_16.01_eng.pdf

WWF Africa., nd, Opportunities in South Africa's solar PV energy value chain. [Online]. Retrieved 30 June 2023. Available on: solar_pv_vale_chain_factsheet.pdf (panda.org)

Zhang, J., Raufer, R. and Liu, L., 2020. Solar home systems for clean cooking: A cost–health benefit analysis of lower-middle-income countries in Southeast Asia. *Sustainability*, *12*(9):1-14.

Appendices

Appendix A: Research tools and instruments used

Site	Instrument/tool	Format presented to the participants
Alexandra township	Interview guide and ethnographic guides Transect walk plan	Appendix A1 Appendix A4
Chebeng village	Interview and ethnographic guide Transect walk plan	Appendix A3 Appendix A2

Appendix A1: Research Instruments- Interview and Ethnographic Guide Questions for Host-Household in Alexandra

Research Title: *An Imbokodo-driven cooperative model for wheeling rural-generated solar-PV electricity to facilitate clean induction-stove cooking among low-income urban households in South Africa*

Research focus: Gender-oriented just energy transition (JET) towards leveraging women's role in cooking as an empowerment opportunity across clean energy value-chain with solar-PV induction stove cooking, women-led energy cooperatives and wheeling as the key elements of the study.

Anticipated Observation-Based Questions

Observation/Questions: Context and Setting: Cooking space, time of cooking, meal-type (breakfast, lunch, dinner, other), who cooks etc	**Observation/Questions:** Context and setting: Roof-space, roof-quality, vandalism and safety concerns	**Observation/Questions:** Context and setting: Communal self-help structures for women, existing cooperative models
• Who typically cooks the main meals in your household? • What is the main meal that consumes most of your time in the cooking and how long would you typically spend making this meal? • In what ways would you describe the cooking experience in your kitchen with the appliances you currently use to prepare a meal? • What is your most trusted energy source, especially on days when there is load-shedding? • What are the push factors that would influence you to change your way and apparatus of cooking? • In what ways does the induction stove differ from the conventional stove already in use, in terms of user-friendliness, aesthetics, and spatial requirements in your kitchen?	• What is your evaluation of the strength of your roof and would you feel safe with a solar panel installed on it? • What is your knowledge on the safety of rooftop solar installations and have there been cases of solar panel theft? • What kind of crime and other external factors that you have witnessed, have owners of roof top solar panel installations been subjected to?	• In what ways have your local stokvels contributed to your empowerment in terms of access to financing? • Are there any existing initiatives or success stories that demonstrate the positive influence of stokvels in women's lives? • Has there been any instances where a new technology/product had been introduced in the stokvel, which you can elaborate on?

Appendix A2: Research Instruments- Interview Guide Questions for Transect Walk in Chebeng village

Research Title: *An Imbokodo-driven cooperative model for wheeling rural-generated solar-PV electricity to facilitate clean induction-stove cooking among low-income urban households in South Africa*

Research focus: Gender-oriented just energy transition (JET) towards leveraging women's role in cooking as an empowerment opportunity across clean energy value-chain with solar-PV induction stove cooking, women-led energy cooperatives and wheeling as the key elements of the study

Anticipated Transect-Walk Observation-Based Questions

Observation/Questions: Context and Setting: existing land-use activities, the requirements for women to get access to land, land-leasing and land-use policies	**Observation/Questions:** Context and setting: similar land use activities for large-scale investments, commonality of large-scale projects, existing renewable energy projects	**Observation/Questions:** Context and setting: existing communal self-help structures, generation cooperative model
• What are the common uses of land in Chebeng? • What is the procedure for getting land in the village and what are the key steps that need to be taken? • What role does your tribal authority play in the governing and provision of land? • Are you able to provide a timeline in cases where land has been identified for a project and the support your tribal community is able to provide to ensure the identified land was secured?	• What would you describe as the primary drivers behind the establishment of a land lessor agreement? • In your opinion, do you think women would be supported enough to drive a large-scale women-focused project where land-leasing for wheeling was their primary offering? • What are your main concerns when hearing of a wheeling entity or partnership arrangement with other women outside of Chebeng	• What have your experiences been with your local stokvel in terms of financing and overall empowerment? • Are there any limitations or restrictions on the membership within your stokvel or stokvels that you know of? • Have there been instances where stokvels have been used to negotiate land-use activities with your tribal authority?

Appendix A3: *Research Instruments- Interview Guide Questions for Ethnographic observation and interview in Chebeng village*

Research Title: *An Imbokodo-driven cooperative model for wheeling rural-generated solar-PV electricity to facilitate clean induction-stove cooking among low-income urban households in South Africa*

Research focus: Gender-oriented just energy transition (JET) towards leveraging women's role in cooking as an empowerment opportunity across clean energy value-chain with solar-PV induction stove cooking, womenled energy cooperatives and wheeling as the key elements of the study

Observation/Questions: Context and Setting: establishment of the tribal authority and the requirements for land	**Observation/Questions:** Context and Setting: frameworks, policies and women's participation in land intensive projects	**Observation/Questions:** Context and Setting: existing land-use activities, barriers and perceptions
• What is the establishment date of the tribal authority? • How does the tribal authority handle the management and allocation of land under its jurisdiction? • What criteria do community members need to meet in order to acquire land for large-scale projects?	• How frequently do women seek land for housing and project-based activities, considering their previous land acquisition patterns? • Is there a specific women-led large-scale project within the community that serves as a point of reference for community development? • What are the specific challenges and opportunities faced by women in the community when acquiring and utilizing land for income-generating projects?	• Do any energy-based projects currently exist or have planned implementation in the near future? • What obstacles or challenges could hinder the development of energy-based or other land-intensive projects? • In your opinion how would the tribal community perceive and respond to the introduction of new energy-based projects in their territory?

Appendix A4: *Research Instruments- Interview Guide Questions for Transect walk in Alexandra Township*

Research Title: *An Imbokodo-driven cooperative model for wheeling rural-generated solar-PV electricity to facilitate clean induction-stove cooking among low-income urban households in South Africa*

Research focus: Gender-oriented just energy transition (JET) towards leveraging women's role in cooking as an empowerment opportunity across clean energy value-chain with solar-PV induction stove cooking, womenled energy cooperatives and wheeling as the key elements of the study.

Anticipated Transect-Walk Observation-Based Questions

Observation/Questions: Context and setting: crosssection of the study area, covering different streets	**Observation/Questions:** Context and setting: infrastructure, housing, density within the township and overall quality of living
• What energy sources do you typically see women relying especially on since loadshedding levels have been escalated? • In your opinion, how has the current energy crisis affected women's cooking patterns?	• In your opinion, what are the major factors hindering or encouraging development in the township? • What types of housing are prevalent in the township?

Appendix B: Ethics approval letter

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

SCHOOL
of ARCHITECTURE
& PLANNING

23 August 2023

Dear Dimpho Teffo (797367)

This letter confirms that your clearance/waiver application has been approved. Your protocol/clearance number is: SOAP076/07/2023

Yours sincerely

Lerato Nkosi