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Exploring the nexus of solar adoption, sustainability, and rural community development through the role of white commercial farmers: The case of Mkushi, Zambia

Hillary Chanda [a,c,*], Eugene Mohareb [a], Michael Peters [a], Chris Harty [b]

[a] University of Reading (School of the Built Environment, Department of Sustainable Energy, Environment and Engineering), United Kingdom
[b] London South Bank University (School of the Built Environment and Architecture Dean), United Kingdom
[c] The Copperbelt University (School of Business, Department of Business Administration/Marketing/HR), Zambia

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ABSTRACT

Persistent rural energy poverty, weak institutional service delivery, and socio-environmental vulnerability continue to constrain equitable development in many rural settings. While decentralised solar technologies offer promising alternatives, their uptake remains uneven and poorly understood, particularly regarding the role of unconventional actors such as white commercial farmers (WCFs). This study addresses a critical research gap by exploring whether, and in what ways, WCFs facilitate solar photovoltaic (PV) adoption, foster environmental sustainability, and contribute to rural community development. Using a multi-sited qualitative case study in Mkushi and surrounding rural districts, the study engaged 16 in-depth semi-structured interviews with WCFs, 1 focus group discussion and 3 interviews with key stakeholders from the energy sector and government policy institutions. Findings reveal that WCFs are not passive economic agents but actively engage in energy transitions and socio-environmental governance. Their contributions span community infrastructure provision, informal solar finance, and conservation-oriented agricultural practices. WCFs also act as intermediaries between local communities and external actors, although their efforts are often constrained by affordability barriers, policy fragmentation, and institutional inertia. The study recommends strengthening cross-sector collaboration to integrate WCFs into national solar strategies, incentivising off-grid systems through land and infrastructure partnerships, and securing solar investments through community-driven security solutions. Furthermore, environmental stewardship programmes should be scaled and linked to energy policy through participatory frameworks. This research provides new insights into the intersecting domains of decentralised energy, agrarian development, and environmental transitions, offering practical and theoretical contributions to more inclusive and context-responsive rural energy policy.

1. Introduction

Access to clean, affordable, and reliable energy remains a persistent development challenge across sub-Saharan Africa (SSA), where over 600 million people lack electricity [1,2]. In Zambia, only 25 % (less than 6 % for rural areas) of the population has access to electricity and clean cooking facilities, despite the country's significant solar potential [1–5]. Current power deficit, which is partly climate induced, stands at 594 MW for Zambia. Production is 1806 MW, of which about 3.23 % is solar, against 2400 MW demand on average. Decentralised solar photovoltaic (PV) technologies - such as mini-grids and standalone systems - are widely recognised as key solutions for rural electrification [6]. Yet, their adoption remains constrained by high costs, limited technical capacity, inadequate infrastructure, and underdeveloped markets [7]. Most initiatives are led by governments, NGOs, or international donors, while the role of other local actors - particularly white commercial farmers - has received limited scholarly attention.

This study explores the underexamined role of white commercial farmers (WCFs) in facilitating solar PV adoption, promoting environmental sustainability, and supporting community development in

* Corresponding author at: Sustainable Energy, Environmental and Engineering Department, Reading University, Whiteknights Campus, RG6 6AH, Reading, Earley Berkshire, United Kingdom of Great Britain and Northern Ireland.
E-mail addresses: h.chanda@pgr.reading.ac.uk (H. Chanda), e.mohareb@reading.ac.uk (E. Mohareb), m.d.peters@reading.ac.uk (M. Peters), hartyc@lsbu.ac.uk (C. Harty).

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Zambia's Mkushi farming block. Located in the Central Province, the Mkushi block spans 176,000 ha and was originally designated in the 1950s by the colonial government for European tobacco farmers, particularly ex-servicemen [8]. Today, Mkushi remains a prominent site for large-scale agriculture, predominantly owned and operated by WCFs [9]. These farmers hold a distinctive position in Zambia's rural socio-economic landscape - not only as agricultural producers, but also as landowners, employers, and providers of critical infrastructure in otherwise underserved areas. Their influence extends beyond formal farming operations to include informal contributions to rural services, local employment, and, in some cases, decentralised energy access.

The relationship between WCFs and their surrounding rural communities is complex yet interdependent. While smallholder farmers and local households often rely on these farms for jobs, services, and infrastructure, the farmers themselves depend on local labour, land access, and community cooperation. This symbiotic dynamic, if strategically harnessed, could serve as a foundation for collaborative investments in solar PV infrastructure and broader sustainability initiatives. However, there is little empirical evidence on how these farmers engage - directly or indirectly - in energy transitions or in supporting rural community sustainable development. The aim of this paper is to investigate whether, and in what ways, WCFs in Mkushi contribute to the adoption of solar PV technologies, sustainability, and community development in surrounding rural areas. The study has three objectives:

- To assess the nature and extent of white commercial farmers' engagement in off-grid solar energy transitions within the Mkushi block, and their potential role in Zambia's decentralised energy strategy.
- To examine the impact of white commercial farmers on rural livelihoods, equity, and social outcomes in nearby communities.
- To explore their contributions to local environmental sustainability and conservation practices.

In Zambia's context of limited state capacity, understanding how commercial farmers operate as informal development agents may offer insights into hybrid governance models that integrate private actors into public energy and sustainability agendas. This research contributes to an emerging literature that foregrounds the social, institutional, and relational dimensions of energy transitions, moving beyond purely technical solutions to consider the actors who shape them [10].

2. Literature review

The literature on solar energy adoption in Sub-Saharan Africa has often focused on state actors, NGOs, and end-user households, but less attention has been given to meso-level actors like commercial farmers who interface directly with both technology suppliers and rural communities. This review therefore synthesizes the role of white commercial farmers (WCFs) across five thematic areas, laying the foundation for understanding their influence on solar diffusion, sustainability, and rural development.

2.1. Informal solar use by white commercial farmers

White commercial farmers are largely absent in scholarly and policy discussions around solar energy transitions in Zambia. However, their position as rural infrastructure providers and economic anchors makes them potentially influential actors in informal energy governance [11]. In contexts where formal energy access is limited, WCFs could act as entry points for off-grid solar PV deployment, especially if they invest in technologies like solar water pumps or cold storage systems [12]. Yet empirical studies focusing on the contributions of WCFs to energy transitions remain sparse. This is despite growing recognition that exogenous actors - such as commercial landholders - can support niche energy innovations and influence national policy regimes [13]. In Zambia, which struggles with rural energy access [1,14], WCFs may bridge the access gap through demonstration effects or partnerships with local communities. Moreover, WCFs often operate beyond the purview of formal electrification efforts, making their energy decisions both autonomous and impactful in rural off-grid areas. Their embeddedness within agro-industrial systems offers a valuable yet underexamined lens for assessing decentralised solar energy transitions.

2.2. Community development in farming zones

The socio-economic effects of commercial farming on surrounding communities are multifaceted. In Mkushi, WCFs have created employment opportunities but have also been associated with casual labour practices and low wages [9]. Mechanization and precision farming have displaced traditional jobs, creating a labour-supply paradox: demand for specialised labour coexists with underemployment of local populations [15]. While outgrower schemes to induce specific crop production by smallholders have shown potential for asset accumulation [9], issues such as gendered income disparities and elite capture persist. Moreover, these dynamics are complicated by land governance challenges; even when investments occur on state land, dissatisfaction often arises due to opaque land acquiring processes and unequal power dynamics [15]. As community development increasingly intersects with energy transitions, the importance of transparent and participatory approaches becomes more salient. If appropriately engaged, WCFs could contribute to community-based solar governance models that address social equity alongside energy access. Such collaboration could reposition farmers not just as economic agents, but also as social intermediaries linking energy providers and local institutions. Additionally, existing community-based structures, such as farmer cooperatives, could be leveraged to scale off-grid solar adoption through shared infrastructure or pooled financing.

2.3. Sustainability in commercial agriculture sector

WCFs also have a potentially transformative role in promoting environmental sustainability. Large farms are significant consumers of water and energy, and their practices can either degrade or conserve ecosystem functioning. Hybrid energy systems integrating solar, wind, and biogas offer promising options for sustainable farm operations [16], yet there is limited documentation on WCF adoption of such technologies. Conservation agriculture models like Pfumvudza - focused on minimum tillage and crop rotation - demonstrate strong environmental benefits [17]. However, these approaches also pose socio-economic concerns, such as labour intensiveness and gendered workloads [18,19]. WCFs, given their access to mechanized technologies, could support adaptation and scaling of such models, reducing the physical burden on labourers and integrating conservation with productivity. Additionally, their capital-intensive operations may enable early adoption of cleaner technologies, which can later be replicated in smallholder systems. Their participation could also generate vital data on the performance of sustainable practices under local conditions, contributing to region-specific innovations.

2.4. Agricultural spillovers and rural livelihoods

Commercial agriculture has shown the potential to catalyse rural development through knowledge and technology transfer. In Nigeria, white Zimbabwean farmers improved local productivity through the dissemination of high-input practices [20], though tensions over land rights and exclusionary dynamics emerged [21]. In Zambia, proximity to large farms has been associated with increased cultivation among smallholders, but not with improved input access [22]. Similar patterns are observed in community integration models, where outgrower schemes create differentiated outcomes depending on implementation design and household structure [8]. These insights suggest that rural development outcomes depend heavily on how commercial agriculture

interfaces with local governance, land rights, and institutional arrangements [23]. WCFs are thus uniquely positioned to foster productive spillovers if institutional bottlenecks are addressed and engagement is guided by inclusive frameworks. Moreover, solar technology diffusion could benefit from these agricultural networks, particularly in enhancing productive use of energy at household and enterprise levels.

2.5. Corporate social responsibility and local engagement

Evidence from Zambia's mining sector illustrates that the success of corporate-led development initiatives hinges on early community engagement, trust-building, and realistic expectations [24]. WCFs, occupying similar positions in rural geographies, must navigate these relational dynamics to avoid enclave outcomes and foster co-development [15]. Mechanisms such as participatory energy planning, co-financing of SHS, or infrastructure-sharing could align WCFs' interests with those of their surrounding communities. The reviewed literature reveals that WCFs in Zambia, and particularly in Mkushi, possess considerable latent potential to advance solar PV adoption, sustainability, and rural development. Their influence stems not only from their economic power and infrastructural reach but also from their embeddedness within local socio-ecological systems. However, their contributions remain understudied, and their engagement largely informal. Addressing these gaps requires empirical research that situates WCFs as strategic actors within Zambia's decentralised energy landscape, while critically evaluating the social and environmental implications of their involvement. This study aims to contribute to this nascent field by exploring the interplay of energy, equity, and development through the lens of commercial agriculture in Mkushi. Integrating CSR with energy access initiatives could shift WCF engagement from *ad hoc* philanthropy to structured rural development models. As energy justice and decentralisation gain traction in SSA policy discourse,

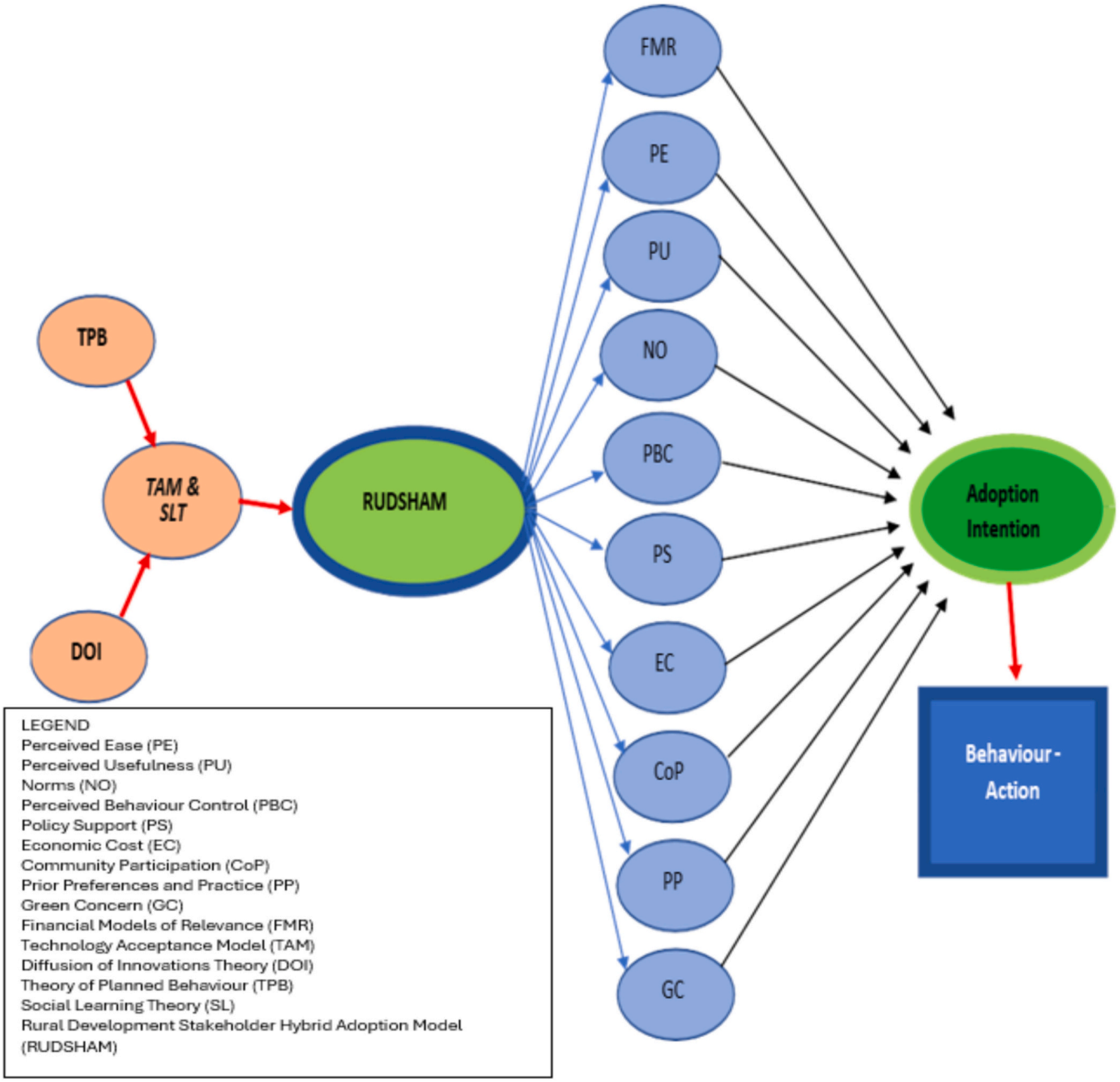

Fig. 1. RUDSHAM hybrid adoption model.

WCFs represent an important but overlooked stakeholder group for inclusive energy transitions.

3. Theoretical framework

To interrogate the role of WCFs in solar PV adoption, community development, and environmental sustainability in Mkushi, Zambia, this study applies the Rural Development Stakeholder Hybrid Adoption Model (RUDSHAM) [1,14,25] (see Fig. 1). RUDSHAM offers an integrated, multi-theoretical framework to explore how rural actors - both formal and informal - navigate intersecting pressures of economic survival, energy access, and environmental conservation. In a context where public services are limited and commercial agriculture dominates, the model is uniquely suited to unpack the uneven dynamics of rural development and energy transitions in Zambia.

RUDSHAM blends behavioural, structural, and ecological perspectives, drawing upon four foundational theories: the Technology Acceptance Model (TAM) [26,27], Diffusion of Innovations (DOI) [28,29], the Theory of Planned Behaviour (TPB) [30], and Social Learning Theory (SLT) [31]. These are integrated with broader policy, economic, and environmental variables to assess how actors such as WCFs influence or impede equitable solar adoption and sustainability. TAM informs how WCFs and surrounding households interpret the usefulness and cost-benefit of solar technologies. In the Mkushi context, WCFs may adopt solar for irrigation or agro-processing, while rural households might prioritise it for essential services such as lighting and charging. The distinction between commercial and domestic motivations highlights the divergent perceptions of utility. Often, short-term financial logics overshadow environmental considerations, particularly where investment risk is high or energy markets are unstable.

DOI helps illuminate the spread of solar innovations within rural systems. As early adopters with economic capital and infrastructural resources, WCFs can play a catalytic role in disseminating new technologies across local networks. Turner (2007) and Rogers (2003) suggest that diffusion occurs not merely through access, but through visibility, influence, and trust [1]. WCF - led installations - when visible to labourers, local suppliers, or outgrower scheme participants - may act as informal demonstration projects, promoting wider uptake through observational learning and imitation.

TPB provides a mechanism to analyse the behavioural intentions behind solar PV adoption. The attitudes of WCFs toward sustainability, perceived social obligations, and perceived behavioural control (*e.g.*, financial liquidity, regulatory clarity) all contribute to the decision to invest in off-grid energy. Similarly, the aspirations and constraints experienced by rural households are shaped by socio-cultural expectations, economic dependency, and perceived legitimacy of solar systems installed on commercial farms.

RUDSHAM's inclusion of SLT further embeds individual energy decisions in collective social contexts. In rural Zambia, energy and technology choices are often influenced by peer practices and community norms [31]. If local residents observe WCFs powering irrigation systems or storing perishable goods with solar cooling, such practices may gain symbolic and practical legitimacy (Chanda a). This visibility effect, however, can also reinforce inequalities if WCFs adopt advanced systems that remain inaccessible to poorer households.

Where RUDSHAM departs from conventional behavioural models is in its explicit ability to analyse governance, market failures, and ecological trade-offs among other things. In Zambia's weakly institutionalised energy landscape, policy ambiguities and lack of affordable financing mechanisms constrain rural electrification. The model enables analysis of how WCFs operate in this vacuum - as either gap-fillers or gatekeepers. Their capacity to finance private solar systems or co-invest in local initiatives may accelerate decentralised energy access, but their priorities may not align with inclusive or sustainable development. Furthermore, the model supports exploration of sustainability trade-offs. In resource-scarce contexts, households may sell charcoal or timber to purchase solar kits, creating a paradox where clean energy uptake coexists with forest degradation. While the Clean Energy - Deforestation Paradox is typically applied to household dynamics, RUDSHAM allows its extension to WCFs who may promote conservation agriculture while indirectly contributing to land pressure through expansionist practices or mechanization.

RUDSHAM's analytical versatility permits the study to evaluate how WCFs' influence manifests across interconnected domains of energy, livelihoods, and the environment. It situates solar PV adoption not simply as a technological choice, but as a socially and ecologically embedded process shaped by visible power asymmetries, institutional fragility, and contested rural development trajectories. For details of how each attribute of the RUDSHAM framework assisted see Appendix B.

4. Research methodology

This study employed a qualitative case study design, grounded in the Rural Development Stakeholder Hybrid Adoption Model (RUDSHAM) [1,14,25], to critically examine the contributions of white commercial farmers to solar PV adoption, environmental sustainability, and community development in Mkushi, Zambia. RUDSHAM's integrative framework facilitated a multi-dimensional exploration of socio-technical transitions in rural energy, with attention to behavioural, institutional, and environmental dynamics.

The RUDSHAM-guided methodology enabled an investigation into how socio-economic positionality, perceived utility, community influence, and governance structures converge to shape energy adoption processes. By drawing from the model's ten theoretical and contextual attributes (see Appendix B), the study identified intersecting influences on solar PV uptake among commercial and smallholder actors. This analytical breadth provided an enriched perspective on how commercial farming operations - particularly those run by white settler-descendant farmers - affect rural electrification and sustainability transitions.

Data was collected over a six-month period from October 2022 to March 2023 in Mkushi district in Central Province of Zambia (see Fig. 2). The site was purposefully selected based on its geographical isolation, presence of large-scale commercial agricultural operations and limited access to the national electricity grid among the surrounding rural community. Prior to the main study, a four-week pilot was conducted with five participants in Luano village (Chingola Rural, Copperbelt Province) to refine the research instruments and protocols. Feedback from this pilot informed minor modifications to the interview guide and focus group procedures, enhancing validity and contextual sensitivity. A local research assistant proficient in English and multiple indigenous languages (Bemba, Tonga, Soli, Lamba, and Nyanja) supported data collection. The principal investigator, with fluency in English and working knowledge of Bemba, Nyanja, and Lamba, provided additional linguistic and cultural mediation during interviews and focus groups. Data collection comprised 16 in-depth semi-structured interviews (see Appendix C) with white commercial farmers, 1 focus group discussion and 3 interviews with key stakeholders from the energy sector and government policy institutions.

All interviews and FGDs were recorded with prior informed consent. Digital files, including audio recordings and consented photographs, were securely stored on the University of Reading's OneDrive cloud platform, with access restricted to the research team. Data were analysed thematically using NVIVO 14 software and colour coding. Interview transcripts were coded based on emergent themes and mapped against the RUDSHAM framework to identify cross-cutting patterns related to solar energy adoption, livelihood outcomes, and ecological stewardship. Quotations were extracted to support key findings and enhance narrative authenticity. The research adhered strictly to ethical protocols and received prior ethics approval from the University of Reading's ethics committee. Participants were fully briefed on the study objectives, data confidentiality, and their right to withdraw at any point.

Fig. 2. Map of Zambia (UN 2022).

Written and oral informed consent was obtained, and data handling procedures complied with international standards for research ethics and data protection.

By integrating the RUDSHAM model into a methodologically rigorous, context-specific qualitative framework, this study offers empirically grounded insights into the socio-political ecology of solar PV adoption in rural Zambia. It provides a foundation for developing policy interventions that recognise the hybrid governance role of white commercial farmers in off-grid energy transitions. However, the focus on only White Commercial farmers for data collection and relatively short time duration emerged as limitations.

5. Findings

5.1. Community engagement & development

The findings in Table 1 indicate that white commercial farmers (WCFs) function as *de facto* providers of public goods, actively engaging in community infrastructure, education, health, and spiritual support. Their efforts are institutionally coordinated through mechanisms like the Mkushi Farmers Association, reflecting a participatory model of rural development grounded in mutual respect and co-contribution. This theme was explored under the Community Participation (CoP) and Policy Support (PS) dimensions of RUDSHAM, enabling a focused assessment of community ownership and stakeholder collaboration.

5.2. Energy access & affordability

Data in Table 2 reveals that while rural demand for solar energy is high, affordability remains a major constraint. White commercial farmers offer informal support by providing land, infrastructure, and wage-deduction schemes for solar purchases. However, their facilitative role is limited by policy inefficiencies, high costs, and an inability to access grid markets. Several also expressed a desire for feed-in tariffs that could help cover the cost of the PV investment. The RUDSHAM attributes of Economic Cost (EC), Perceived Usefulness (PU), and Policy Support (PS) informed our analysis by illuminating key financial and infrastructural barriers to solar adoption.

5.3. Governance, policy & institutional support

The research demonstrates that WCFs often substitute for weak state institutions by funding security, healthcare, and infrastructure (Table 3). Although some collaboration with traditional leaders and NGOs exists, systemic fragmentation and lack of public-private integration hinder their impact. Calls for policy reform, including reduced electricity grid connection charges (*i.e.*, wheeling costs), remain urgent and unresolved. This theme was interpreted through the lens of Policy Support (PS) and Perceived Behaviour Control (PBC), highlighting institutional constraints and governance gaps in line with RUDSHAM dimensions.

5.4. Technology access, theft & security

The study found that persistent theft and inadequate law enforcement are critical barriers to solar scalability (Table 4). Farmers mitigate risk through private security investments, but these measures reinforce socio-economic disparities. The data underscores the need for decentralised, community-based protection models to support equitable access to solar technologies in vulnerable settings. This was examined using Perceived Ease (PE) and Perceived Behaviour Control (PBC) within RUDSHAM, which helped assess concerns over operational security and end-user autonomy.

5.5. Environmental sustainability & climate awareness

The findings in Table 5 revealed that WCFs are increasingly adopting environmental stewardship practices, such as conservation agriculture, reforestation, and sustainable energy alternatives. Their engagement in collaborative conservation bodies reflects a proactive ecological ethic. Nonetheless, external pressures from mining and charcoal commodification threaten long-term sustainability. This section draws from the Green Concern (GC) and Prior Preferences and Practice (PP) components of RUDSHAM to contextualise environmental behaviours and legacy energy practices.

Table 1
Community engagement & development.

#	Participant	Direct quotation
a	Mkushi CF Interview 1	"The relationship with the surrounding community is friendly."
b	Mkushi CF Interview 9	"I have such a good relationship with the surrounding community… they brought the gates back… (laughs)."
c	Mkushi CF Interview 1	"There are lots of projects I know—like primary schools, clinics, etc. Commercial farmers (CFs) are involved in the community."
d	Mkushi CF Interview 1	"Sadly, a senior government official…said Mkushi commercial farmers do nothing for the community… He apologised when he saw the magnitude of our community efforts."
e	Mkushi CF Interview 1	"As Mkushi Farmers Association (MFA), we ensure that our aid reaches the intended rural community recipients…"
f	Mkushi CF Interview 4	"The Mkushi Farmers Association (MFA) gets a levy from each farm depending on farm size, to raise funds to help schools, clinics, churches, individuals, and traditional ceremonies, etc."
g	Mkushi CF Interview 4	"When we do community projects, we ensure that the community also contributes to build a sense of ownership."
h	Mkushi CF Interview 6	"Handouts don't work. I don't give things for free but ensure that the rural community contributes to encourage a sense of ownership."
i	Mkushi CF Interview 2	"Many farmers have built clinics and schools on their farms. I know of a farmer who has a clinic, school, shop, and church at his farm. It's self-contained."
j	Mkushi CF Interview 9	"My neighbour has a school, a clinic, and is building houses…"
k	Mkushi CF Interview 6	"We have a school on our farm, which I built 16 years ago… sadly, they stole the doors to the school a day before it was opened… (laughs)."
l	Mkushi CF Interview 2	"Chengelo International School, an initiative of CFs, has its own community service programme, which has built some classroom blocks in the surrounding community area."
m	Mkushi CF Interview 2	"CFs organised funds to provide a loan for the church to buy a soya expressing machine."
n	Mkushi CF Interview 2	"Currently, with the assistance of CFs, the block has 26 local language churches and 2 English churches… fostered positive moral change…"
o	Mkushi CF Interview 2	"As CFs, we built a house for a missionary… linked up with an NGO called World Servants… The teams come twice or thrice a year."
p	Mkushi CF Interview 10	"We work with Dutch volunteers who have helped with various projects…"
q	Mkushi CF Interview 2	"The CFs have also formed an orphanage and an after-school feeding programme and homework club…"
r	Mkushi CF Interview 6	"In the Mkushi farming block, 25 information centres for rural farmers have been resuscitated by CFs…"
s	Mkushi CF Interview 6	"There are many acts of kindness that CFs do in the community… hospital bills… they keep a low profile."

Table 2
Energy access & affordability.

#	Participant	Direct quotation
a	Mkushi CF Interview 12	"So many solar systems are entering the rural places because people appreciate them."
b	Mkushi CF Interview 8	"Beyond lighting and charging phones, productive solar use is prohibited by cost…"
c	Mkushi CF Interview 2	"Because batteries are prohibitively expensive for rural people, I would recommend that they only use solar during the day when the sun is out… especially for productive purposes."
d	Mkushi CF Interview 3	"I would be willing to deduct money from my employees' salaries if solar companies provided pay-slow models."
e	Mkushi CF Interview 2	"I have encouraged my gardener from the rural community and supported him to use solar for lighting his poultry business, his home, and for charging his phone, etc."
f	Mkushi CF Interview 2	"I suggest that to help the rural people, the government can make community farms for the rural people, and the proceeds used for solar or biogas promotion."
g	Mkushi CF Interview 1	"Government should consider widespread solar grids in remote places and offer incentives to the private sector or partner with national and international organizations…"
h	Mkushi CF Interview 1	"I am willing to offer land for a solar plant and to host and manage it, provided it can also feed into the grid."
i	Mkushi CF Interview 4	"I am willing to host a solar farm, but I need to have the ability to sell power to ZESCO."

Table 3
Governance, policy & institutional support.

#	Participant	Direct quotation
A	Mkushi CF Interview 1	"We rarely report cases to the police because they rarely act."
b	Mkushi CF Interview 1	"Because of thieves, we had to close one of our shops… police could not help much."
c	Mkushi CF Interview 1	"At one point, we had to use our own resources to catch a gang of thieves terrorising us…"
d	Mkushi CF Interview 9	"Sending employees to government hospitals is not helpful…"
e	Mkushi CF Interview 6	"We respect and work with the local chiefs… we had to go and kneel and apologise…"
f	Mkushi CF Interview 2	"North Swaka Trust (NST) has been helpful in conservation and enjoys much support from CFs and other external funders, but it's not government funded."
g	Mkushi CF Interview 1	"At some point, the commercial farmers (CFs) wanted to install a community solar farm, but sadly, ZESCO did not cooperate…"
h	Mkushi CF Interview 4	"It's easy to implement and control sustainability issues within your farm, but quite difficult beyond it - hence, the government needs to come in. Additionally, the wheeling cost should be reduced because currently it's too high."
i	Mkushi CF Interview 1	"What government should consider doing is giving concessions for charcoal farming and ensuring trees are replanted."

5.6. Cultural & behavioural factors

Evidence in Table 6 suggests that socio-cultural norms significantly impede the adoption of sustainable technologies. Beliefs linking bush-burning to rainfall and preferences for traditional cooking methods undermine environmentally sensitive innovations. Farmers encounter behavioural resistance rooted in cosmology and custom, underscoring the necessity for culturally informed environmental communication strategies. The Norms (NO) and Prior Preferences and Practice (PP) elements of RUDSHAM were central in identifying entrenched cultural attitudes and behavioural inertia related to energy use.

5.7. Labour relations & economic inclusion

The data in Table 7 shows that white commercial farmers are major contributors to rural employment and welfare. They provide not only jobs but also social infrastructure such as housing, schools, and healthcare. While casualisation and wage debates persist, many farmers demonstrate a commitment to inclusive labour practices and employee advancement, as well as to the country. Community Participation (CoP) and Economic Cost (EC) from the RUDSHAM model provided structure for examining how labour dynamics intersect with energy access and rural development. This theme aligns with Norms (NO) and Policy Support (PS) within RUDSHAM, which guided exploration of public discourse, reputational dynamics, and their influence on adoption behaviour.

5.8. Public perceptions & media narratives

Study participants reported a disconnect between their lived contributions and public representation. The findings in Table 8 highlight how media and some academic narratives often amplify isolated grievances, overshadowing broader socio-economic impacts. This suggests a need for more balanced, participatory research frameworks that reflect the complexity of rural development actors.

Table 4
Technology access, theft & security.

#	Participant	Direct quotation
a	Mkushi CF Interview 11	"Theft is a big problem."
b	Mkushi CF Interview 2	"Theft of solar panels is rampant."
c	Mkushi CF Interview 12	"Theft is definitely a problem… we had our borehole pump stolen."
d	Mkushi CF Interview 5	"Theft does happen. The movement of panels in and out of the house for fear of thieves eventually weakens the system."
e	Mkushi CF Interview 1	"Two years ago, our two big solar panels…got stolen… The Zambia Police has not helped much."
f	Mkushi CF Interview 6	"Theft is a big problem, and CFs have lost pumps, centre pivot motors, and wires. We have to weld the motors to secure them on the centre pivots."
g	Mkushi CF Interview 4	"Theft is a problem in Mkushi, so I ensure that I have watchmen and shepherds with animals at all times, especially because we use solar for strip grazing."
h	Mkushi CF Interview 9	"Solar panels are very desirable, so we employ a watchman to guard them…"
i	Mkushi CF Interview 1	"Fire and theft are always a problem. We have a watchman for the solar PV, sleeping there every night."
j	Mkushi CF Interview 1	"To secure the panels from thieves, we use straps - but sadly, any shade on the panel affects performance."
k	Mkushi CF Interview 1	"Vandalism is not a problem here, even though people steal."
l	Mkushi CF Interview 2	"The short battery life of normal batteries is a problem unless you use lithium batteries..."
m	Mkushi CF Interview 2	"CFs have installed solar power at a government clinic within the farming block."

6. Discussion

6.1. Community engagement & development

The data (refer to Table 1) reveal that white commercial farmers (WCFs) in Mkushi actively engage in a broad spectrum of community development activities that extend far beyond economic extraction. Their involvement includes education (MCF 5.2l), health infrastructure (MCF 5.2i), spiritual life (MCF 5.2n), and targeted charitable interventions such as orphanages and after-school programmes (MCF 5.2q). Such initiatives suggest that WCFs are functioning as *de facto* providers of public goods, particularly in rural areas where state presence remains limited [8,24]. This aligns with broader patterns in Sub-Saharan Africa, where private actors often substitute for weak institutional capacity in service provision [32].

Community relations appear to be largely positive, with several respondents emphasising mutual respect and reciprocity (MCF 5.1a, MCF 5.1b). The notion of social embeddedness is particularly evident in practices that promote co-contribution, such as requiring community members to participate in projects to enhance ownership and reduce dependency (MCF 5.1g, MCF 5.1h). These findings echo Nyoh's (2021) emphasis on participatory, locally anchored development strategies that foster durable community buy-in for sustainability initiatives, including solar PV. This also builds on Chileshe's [33] argument that inclusive, non-state governance actors are vital to accelerating rural electrification and co-producing social value.

Such multi-stakeholder collaborations highlight how WCFs may serve not only as service providers but also as institutional innovators in weak governance contexts.

The legitimacy of CFs is also reinforced through institutionalised mechanisms like the Mkushi Farmers Association (MCF 5.1e, MCF 5.1f), which operates a levy system to redistribute resources. These practices indicate a quasi-formal governance system, consistent with Chileshe's [33] findings on the importance of inclusive stakeholder frameworks in advancing rural energy transitions.

Moreover, evidence of collaboration with external actors - such as NGOs and foreign volunteers (MCF 5.2o, MCF 5.2p) - illustrates WCFs' role as bridging agents capable of attracting additional development resources. This positions them as influential exogenous actors in rural development, consistent with Le Dong and Mori's (2017) call for

Table 5
Environmental sustainability & climate awareness.

#	Participant	Direct quotation
a	Mkushi CF Interview 1	"We are very conscious of the environment and have groups to remind and sensitise each other. We pass on this knowledge to our farm employees."
b	Mkushi CF Interview 1	"As CFs, we have been spearheading environmentally friendly living… regenerative agriculture… discourages deforestation and charcoal burning."
c	Mkushi CF Interview 1	"Urban areas are the biggest drivers of charcoal demand."
d	Mkushi CF Interview 8	"Domestic charcoal production is sustainable… but commercialisation is the problem."
e	Mkushi CF Interview 1	"Burning down of the bush every year is a big problem… It was a massive fire that took us three days to quench."
f	Mkushi CF Interview 3	"Burning is a big problem from villagers who start fires during hunting of small animals and honey collection..."
g	Mkushi CF Interview 5	"We teach people not to burn the environment because it's a big problem… burning needs to be controlled."
h	Mkushi CF Interview 1	"When flying over Zambia in winter… smoke is everywhere, and visibility is so poor."
i	Mkushi CF Interview 6	"Mopani worm, fire, and honey collectors destroy a lot of trees…"
j	Mkushi CF Interview 2	"We are very concerned about the manganese mining, which is just next to the main road, and the smelter in the area, which harms the environment, pollutes the Lunsemfwa River, and emits smoke."
k	Mkushi CF Interview 2	"To protect the environment and the communities around, the CFs came together to buy a farm… They want to conserve it under NST."
l	Mkushi CF Interview 3	"As CFs, through NST, we are actively ensuring that the conservation of trees and forests around headwaters of rivers and streams is protected..."
m	Mkushi CF Interview 4	"NST provides alternative income by promoting honey farming, value addition, and the growing of cover crops to replace charcoal burning."
n	Mkushi CF Interview 10	"NST uses planes to monitor deforestation…"
o	Mkushi CF Interview 2	"Through Foundations Zambia, CFs are helping the community make charcoal from maize cobs."
p	Mkushi CF Interview 1	"An alternative to firewood would be maize cobs and cow dung..."
q	Mkushi CF Interview 12	"To solve deforestation, we need ways to cook sustainably and cost-effectively."
r	Mkushi CF Interview 6	"We are encouraging conservation farming called Pfumvudza…"
s	Mkushi CF Interview 6	"I planted 120 ha of trees… but don't allow them to cut the trees."

Table 6
Cultural & behavioural factors.

#	Participant	Direct quotation
a	Mkushi CF Interview 1	"Some locals believe that burning the bush contributes to more rain, when the exact opposite is true. It's a dangerous superstition."
b	Mkushi CF Interview 2	"Energy-saving clay stoves have not been embraced because people prefer firewood and charcoal braziers… for warmth and socialising, fellowship and interaction."
c	Mkushi CF Interview 5	"Energy-efficient stoves have been introduced but never stay because they can't cook nshima quick enough… laughs..."
d	Mkushi CF Interview 7	"NST is promoting conservation farming and fuel-efficient stoves… but don't use them."
e	Mkushi CF Interview 12	"The surrounding community is cutting down our trees for honey and mopani worms."
f	Mkushi CF Interview 6	"We allow people to fish… but not use mosquito nets… they police themselves."
g	Mkushi CF Interview 6	"The traditional leaders charge K10… it's a mockery…"
h	Mkushi CF Interview 1	"Never give things for free - people subconsciously don't appreciate them… Handouts destroy self-worth..."

Table 7
Labour relations & economic inclusion.

#	Participant	Direct quotation
a	Mkushi CF Interview 1	"*We, as commercial farmers, create employment for thousands of unskilled workers… Some rise to become supervisors eventually…*"
b	Mkushi CF Interview 3	"*The coming of the white Zimbabwean farmers to the Mkushi farming block… caused a huge increase in employment in the area…*"
c	Mkushi CF Interview 1	"*Most farmers have a good relationship with their staff… Unhappy workers can take the business down.*"
d	Mkushi CF Interview 6	"*Casual workers can't be trusted or developed… gratuities are too high.*"
e	Mkushi CF Interview 1	"*I would like to employ more permanent workers, but it's quite expensive.*"
f	Mkushi CF Interview 4	"*We have 110 permanent employees, and when doing maize seed, we need another 250 employees for three months… We ensure we take good care of both permanent and temporary staff.*"
g	Mkushi CF Interview 4	"*I provide housing and grid electricity for [110 permanent employees] for free…*"
h	Mkushi CF Interview 4	"*On our farm, we run a clinic and two schools with 100 pupils… We try to motivate our staff because rubbish staff gives rubbish output.*"
i	Mkushi CF Interview 6	"*I have a school and employ five teachers… we use the government curriculum.*"
j	Mkushi CF Interview 10	"*I have clinics, schools… and support some government clinics and churches.*"
k	Mkushi CF Interview 2	"*I know of a colleague who supports his farm employees by growing maize, which he uses to make mealie meal [a maize based staple] … He also gives farms to his senior employees to do their own farming.*"
l	Mkushi CF Interview 3	"*I used to loan my employees fertiliser and seed. Fertiliser was repaid when they sold their crop, and for seeds I deducted a little bit from their salaries…*"
m	Mkushi CF Interview 8	"*Foundations for Farming Zambia (F4FZ) has helped small scale farmers by creating opportunities for them to supply CFs with cover crops etc… but they still have a charity mentality and at times even fail to manage.*"
n	Mkushi CF Interview 4	"*I do my very best, so it's quite sad when people condemn CFs and demand that they pay exorbitant salaries. The truth of the matter is that most farmers provide almost everything for their workers.*"
o	Mkushi CF Interview 6	"*I lost everything when I was expelled from Zimbabwe. It was terrible, but also a blessing in disguise, because Zambia and the Mkushi farmers welcomed us and offered fertile land in the Mkushi farming block - even the head of state, Levy Mwanawasa, came and addressed us. I can confess now that I am 100 % Zambian, and I love this country - just like many other commercial farmers who were forced out of Zimbabwe and settled in Zambia.*"

Table 8
Public perceptions & media narratives.

#	Participant	Direct quotation
a	Mkushi CF Interview 1	"*The media has, on many occasions, demonised us—picking disgruntled workers as case studies and taking their word as gospel truth.*"
b	Mkushi CF Interview 1	"*For the media, a story about how farmers abuse workers would sell better than one where farmers are praised…*"
c	Mkushi CF Interview 1	"*It's sad that some researchers… would choose to pick one disgruntled worker's opinion and make conclusions.*"
d	Mkushi CF Interview 9	"*Previously, there was a large community dependent on stealing maize… but with the coming of many tobacco farmers from Zimbabwe who employed thousands, maize theft has reduced. Such things are rarely reported in the media.*"

recognising external actors in shaping socio-technical transitions. Overall, these practices substantiate WCFs' potential role in Zambia's decentralised energy and development strategies.

6.2. Energy access & affordability

White commercial farmers in Mkushi demonstrate a proactive, though largely informal, role in rural solar transitions (refer to Table 2). While the rural appetite for solar PV is reportedly increasing (MCF 5.2a), affordability remains the principal constraint (MCF 5.2b, 5.2c), reflecting broader concerns across Zambia about the exclusion of non-elite households from energy access [7]. The expressed willingness by WCFs to host solar plants (MCF 5.2h, 5.2i) and contribute land or management oversight aligns with Naumann and Rudolph's (2020) call for recognising the role of large-scale agricultural actors in energy transitions. However, commercial viability - particularly the ability to feed power into the national grid (MCF 5.2i) - remains a critical policy bottleneck, mirroring Stritzke's (2018) emphasis on institutional coordination in Zambia's solar deployment strategies.

More notably, WCFs expressed interest in financing mechanisms that enable rural workers to access solar incrementally (MCF 5.2d), and some already provide targeted support to their staff or community members for solar-based livelihoods (MCF 5.2e). These micro-level interventions align with findings by Tinta et al. [35], who note that entrepreneurial rural actors are more likely to adopt SHS when affordability and support systems are in place. Similarly, the suggestion to use proceeds from communal farming to fund biogas and solar access (MCF 5.2f) signals a bottom-up model of decentralised financing, echoing Zulu's [36] vision for community-based solar ecosystems.

At the policy level, calls for broader incentives and partnerships (MCF 5.2g) highlight the necessity of systemic support. This supports Chambalile et al.'s (2024) recommendation that financial and institutional reforms must complement grassroots efforts to unlock the full potential of renewable energy in rural Zambia. Overall, WCFs are emerging as latent intermediaries in Zambia's decentralised energy future. This supports Dong and Mori's (2017) proposition that actors situated outside the formal energy policy apparatus can initiate valuable bottom-up innovations. It also reflects Mwanza et al.'s (2017) emphasis on the catalytic role of agricultural elites in diffusing solar infrastructure through informal, community-driven arrangements.

6.3. Governance, policy & institutional support

White commercial farmers in Mkushi operate within a governance vacuum characterised by limited institutional responsiveness, prompting them to assume quasi-governmental roles in security and service provision (refer to Table 3). As reported, repeated theft and ineffective police response (MCF 5.3a, 5.3b, 5.3c) compel WCFs to self-finance security measures, highlighting the fragility of rural governance infrastructures - an issue well documented in the broader Zambian rural context [15]. Similar frustrations extend to the health sector, where reliance on underperforming public services leads some WCFs to opt to have their own clinics for treating employees (MCF 5.3d). These experiences reinforce calls for more robust public-private collaboration to enhance rural service delivery and decentralised infrastructure support [24]. Despite some tensions with formal institutions, WCFs maintain constructive relationships with traditional authorities (MCF 5.3e), reflecting Nolte's (2016) argument that respectful initial contacts with local power structures are critical for long-term social licence. Additionally, actors like the North Swaka Trust (MCF 5.3f) serve as non-state conservation vehicles supported by WCFs, though their impact remains constrained by the absence of government backing, echoing Batisai and Mudimu's (2021) findings on institutional vacuum in rural development partnerships.

The thwarted attempt by WCFs to install a community solar farm due to ZESCO's non-cooperation (MCF 5.3g) mirrors structural barriers noted in Zambia's energy sector [34], where poor inter-agency coordination hampers decentralised solar initiatives. Policy misalignments - such as high wheeling costs (MCF 5.3h) - discourage private sector participation in rural solar infrastructure, a critical bottleneck also

identified by Chambalile et al. (2024). Farmers' pragmatic calls for regulated charcoal farming and reforestation efforts (MCF 5.3i) reflect a growing awareness of sustainable resource management and the desire for incentive-compatible policy reforms. As Naumann and Rudolph (2020) argue, recognising exogenous actors like WCFs as informal energy and development intermediaries remains key to unlocking inclusive rural energy transitions. This perspective is reinforced by Chu (2013), who asserts that weak institutional contexts require adaptive governance networks anchored in local legitimacy. Hence, WCF engagement should be strategically institutionalised rather than treated as peripheral to Zambia's energy and policy architecture.

6.4. Technology access, theft & security

Widespread theft of solar photovoltaic (PV) components in Mkushi significantly undermines both the viability and scalability of rural energy transitions (refer to Table 4). Respondents describe theft as "rampant" (MCF 5.4b) and "a big problem" (MCF 5.4a, 5.4c, 5.4f), reflecting systemic security vulnerabilities that force WCFs to adopt labour- and capital-intensive protection strategies, such as employing night watchmen (MCF 5.4h, 5.4j) and welding infrastructure to prevent equipment loss (MCF 5.4f). These protective measures increase the operational costs of solar installations and reinforce rural inequalities, given that such security responses are unaffordable for poorer smallholders. The practice of repeatedly moving panels indoors to avoid theft (MCF 5.4d) weakens systems, exacerbating the technical fragility of PV units already constrained by short battery life and performance issues (MCF 5.4l, 5.4j). This reveals the intersection of socio-technical challenges noted by Stritzke and Jain (2021), where infrastructure design must be attuned to the lived realities of theft-prone environments. The failure of formal policing to respond to equipment theft (MCF 5.4e) points to broader institutional incapacities and governance gaps, which scholars like Chambalile et al. (2024) and Le Dong & Mori (2017) argue must be addressed through decentralised policy reform and local stakeholder engagement.

Despite these barriers, WCFs remain active agents in promoting solar adoption. Their contribution to powering a local government clinic (MCF 5.4m) illustrates their role as informal energy intermediaries, aligning with Naumann and Rudolph's (2020) framing of exogenous actors as key to enabling niche innovations in rural sustainability transitions. However, without systemic policy interventions and improved security infrastructure, the proliferation of solar PV risks entrenching energy exclusion for vulnerable groups and deterring broader participation in Zambia's decentralised energy strategy. Thus, addressing theft is not peripheral, but central to achieving equitable energy access in rural contexts. This resonates with Stritzke and Jain (2021), who note that energy systems in Sub-Saharan Africa must be designed for socio-technical resilience in insecure environments. Without addressing these vulnerabilities, rural solar diffusion risks reproducing, rather than resolving, spatial inequalities in energy access.

6.5. Environmental sustainability & climate awareness

The environmental stewardship practiced by WCFs in Mkushi reflects a notable, albeit under-researched, contribution to Zambia's sustainability transitions (refer to Table 5). Farmers demonstrated a collective environmental ethic, often internalised through peer sensitisation groups (MCF 5.5a) and embedded in regenerative agricultural practices that discourage deforestation and charcoal dependence (MCF 5.5b). Their awareness of the socio-ecological dynamics, such as the urban demand driving charcoal commodification (MCF 5.5c) and the adverse impacts of bushfires (MCF 5.5e, 5.5f, 5.5h), aligns with broader critiques of charcoal markets across the Global South [7,37,38].

These farmers do not merely diagnose environmental degradation; they act upon it. Responses include implementing controlled conservation farming systems like Pfumvudza (MCF 5.5r), tree planting initiatives (MCF 5.5s), and education on fire management (MCF 5.5g). This is congruent with evidence that successful adoption of sustainable agricultural practices requires both technical adaptation and social mobilisation [19,39]. Of particular significance is their engagement with a farmer-initiated conservation body (the North Swaka Trust), using innovative tools such as aerial surveillance (MCF 5.5n) and promoting economic alternatives like honey farming and value-added agroforestry products (MCF 5.5m). These strategies are in line with broader arguments that climate-smart solutions must integrate ecological protection with livelihood enhancement [40].

Furthermore, the WCFs' opposition to harmful extractive industries, such as manganese mining (MCF 5.5j), illustrates their emergent role as local environmental monitors, an aspect not commonly associated with agribusiness actors. This also suggests an indirect conflict with the clean energy transition, as manganese is a key component of lithium-ion batteries and renewable energy generation technologies [41–44]. Their push for sustainable energy alternatives - charcoal from maize cobs and cow dung (MCF 5.5o, 5.5p) - is particularly relevant in light of Zambia's energy poverty crisis, offering decentralised, low-cost energy options that complement solar PV interventions.

Overall, while the structural inequalities embedded in Zambia's agrarian landscape must not be ignored [9,45], this study suggests that WCFs are playing a hybrid role as both agricultural modernisers and environmental stewards. Their actions offer practical entry points for climate policy and decentralised energy interventions, especially when state support remains fragmented. These findings affirm the argument by Mavesere and Dzawanda (2023) that sustainable agricultural actors can double as environmental stewards and innovation brokers. By integrating conservation with energy innovation, WCFs demonstrate how climate-smart agriculture and energy transitions can be pursued in tandem.

6.6. Cultural & behavioural factors

The socio-cultural dynamics surrounding energy and sustainability transitions in rural Mkushi reveal a complex interface between community norms, technology adoption, and environmental stewardship (refer to Table 6). White commercial farmers emerge as both informants and enforcers of sustainability ethics, yet their efforts often clash with entrenched rural beliefs and practices. For instance, the persistence of bush-burning myths, where locals believe it brings rain (MCF 5.6a), reflects a deep-rooted cosmological worldview that undermines environmental conservation efforts. This highlights the necessity of participatory communication strategies for behavioural change, as advocated by Nyoh (2021).

Moreover, the rejection of energy-efficient stoves due to their incompatibility with social rituals (MCF 5.6b), inadequate functionality for staple food preparation (MCF 5.6c), and lack of adoption despite promotion efforts (MCF 5.6d) underscores the cultural embeddedness of energy practices. This aligns with Chambalile et al. (2024) and Chanda et al. (2025), who emphasise that energy transitions in Zambia are constrained not only by technical and financial barriers but also by social acceptability.

Environmental degradation through deforestation for mopani worms and honey (MCF 5.6e), as well as inadequate penalties for environmental harm (MCF 5.6g), further reveals governance deficits. In response, some CFs have established informal conservation mechanisms such as community self-policing (MCF 5.6f), reflecting emergent forms of localized governance. These practices, though commendable, require institutional reinforcement through stronger policy frameworks and integration into Zambia's decentralised energy strategy.

Additionally, resistance to donor-driven models is evident in WCFs' critique of free distributions, which they argue erode local agency (MCF 5.6h). This resonates with Chambalile et al. (2024) and Chanda et al. (2025)) warning that externally imposed interventions, devoid of community buy-in, often fail to yield sustainable outcomes.

Ultimately, the findings suggest that WCFs, while not central actors in formal policy domains, function as important intermediaries - bridging technical solutions and community contexts. Their embedded roles in knowledge dissemination, enforcement, and social influence present an opportunity for more inclusive, culturally attuned energy and environmental interventions in Zambia. Such dynamics reinforce Bhatasara et al.'s (2025) assertion that social norms and cosmologies remain key determinants in the adoption of clean energy. Consequently, WCFs' efforts must be augmented with culturally literate programming that addresses the symbolic as well as material dimensions of energy use.

6.7. Labour relations & economic inclusion

White commercial farmers in Mkushi play a discernible and largely positive role in promoting local economic inclusion and community development, particularly through employment creation and social investment (refer to Table 7). In this study, WCFs report employing hundreds of permanent and seasonal workers, offering opportunities for upward mobility, with some workers progressing to supervisory roles (MCF 5.7a, 5.7b). This aligns with findings by Muzekenyi et al. [46], who highlight that small-scale commercial farming is pivotal for rural economic development, contributing to job creation, food security, and income diversification.

The provision of social services - such as housing, schools, clinics, and access to grid electricity (MCF 5.7f–5.7j) - demonstrates a strong commitment to local welfare. These practices echo successful models of inclusive agrarian development where commercial farming areas become hubs of rural infrastructure [8]. Such investments reflect an informal form of corporate social responsibility that complements weak rural public services, as observed in other sectors across Zambia [24]. One WCF's operation of a school with five teachers using the national curriculum (MCF 5.7i) supports rural education access, a key enabler of long-term development [40].

Notably, WCFs also engage in livelihood enhancement for their employees through input credit, land access for farming, and food production schemes (MCF 5.7k, 5.7l). These efforts align with broader calls for out grower-type partnerships and private sector engagement in rural transformation [8,32]. While concerns around casualisation remain (MCF 5.7d), WCFs' expressed desire to offer more permanent employment (MCF 5.7e) suggests awareness of this limitation and a willingness to address it where feasible. The integration of ex-Zimbabwean farmers into the Mkushi community further illustrates resilience and productive inclusion. Their contribution to employment and farming revitalization is positively acknowledged (MCF 5.7o), supporting earlier findings in Nigeria where displaced Zimbabwean farmers enhanced local agricultural productivity [20]. This reflects the potential of exogenous actors to catalyse rural development, as emphasised by Le Dong and Mori (2017).

In sum, WCFs in Mkushi significantly enhance rural livelihoods and community welfare. Their efforts resonate with broader frameworks advocating for private sector participation in inclusive, sustainable rural development [11,47] and offer a constructive model for integrating commercial farming into Zambia's decentralised development agenda. These contributions substantiate Muzekenyi et al.'s [46] view that commercial agriculture can function as a platform for rural transformation when paired with socially embedded practices. Moreover, the layered nature of WCF employment practices suggests a hybrid model of economic inclusion that deserves further empirical investigation.

6.8. Public perceptions & media narratives

The public perception of WCFs in Mkushi emerges as a complex and often contested space, shaped by media narratives and selective representation (refer to Table 8). Several WCFs expressed frustration over negative portrayals in both media and some academic research, arguing that such narratives tend to amplify grievances from isolated individuals while ignoring broader contributions to rural employment and community development (MCF 5.8a, 5.8b, 5.8c). This aligns with insights from Naumann and Rudolph (2020), who note that the role of exogenous actors - such as foreign or white farmers - in sustainability transitions is often oversimplified, leading to skewed assessments that overlook intricate local realities.

The comments from WCFs suggest a perceived disconnect between lived experiences and public discourse, particularly around issues of labour and social integration. For instance, while some studies have critiqued commercial farming for limited socio-economic inclusion [9], WCFs in Mkushi point to tangible impacts such as reduced theft and increased employment following the influx of Zimbabwean farmers (MCF 5.8d). This aligns with Adewumi et al. (2013), who observed that white Zimbabwean farmers settling in Nigeria contributed to local agricultural revitalization and job creation, albeit amid tensions over land and power dynamics.

These tensions highlight the importance of balanced, participatory research approaches recommended by Nyoh (2021), to avoid reinforcing narratives that may hinder collaborative rural energy and development efforts. Recognising the legitimacy of diverse voices - including that of WCFs - is essential for fostering inclusive, just transitions, particularly in contexts like Zambia where decentralised energy and agricultural systems are still maturing [6]. In this regard, reframing WCFs not merely as controversial figures but as underutilised stakeholders in rural sustainability efforts aligns with calls for more integrative and evidence-based development models. This also echoes Mondoloka's (2017) call for more reflexive, participatory methodologies that foreground the lived realities of corporate actors in rural development. Better narrative balance could help depoliticise WCFs' contributions and encourage collaboration between public, private, and community actors in advancing equitable energy transitions.

7. Policy recommendations

Drawing from the empirical evidence presented in Mkushi, this study offers six actionable policy recommendations tailored to Zambia's national development priorities. These recommendations aim to support solar PV adoption, promote community inclusion, and enhance environmental sustainability through strengthened institutional frameworks and stakeholder collaboration.

7.1. Formalise commercial farmer role in electrification

The Ministry of Energy, in collaboration with the Rural Electrification Authority (REA), should formally integrate white commercial farmers (WCFs) into Zambia's off-grid energy policy framework. Given WCFs' capacity to offer land, management oversight, and capital for solar projects, the government should develop a structured public–private partnership model that supports shared solar mini-grids and facilitates grid interconnection through revised licensing and feed-in tariff protocols. This will bolster decentralised electrification in underserved rural regions.

7.2. Launch national solar security initiative

Solar equipment theft significantly threatens solar scalability in rural Zambia. The Ministry of Home Affairs and Internal Security, working in conjunction with local government authorities and farmer associations, should establish a national rural solar security initiative. This should include dedicated rural security patrols and the introduction of affordable solar theft deterrents. The Ministry of Technology and Science should collaborate with non-governmental organizations such as the Netherlands Development Organisation (SNV Zambia) and Practical Action Zambia to pilot and scale up cost-effective PV security technologies.

7.3. Incentivise green farming and conservation

The Ministry of Green Economy and Environment and the Ministry of Agriculture should introduce a joint incentive programme that formalises and supports conservation practices already implemented by WCFs. This programme should provide fiscal incentives and extension support for initiatives such as afforestation, Pfumvudza (conservation agriculture), sustainable charcoal alternatives, and watershed protection. Oversight should be provided by the Zambia Environmental Management Agency (ZEMA), ensuring synergy with climate resilience strategies.

7.4. Community solar financing through cooperatives

To enhance access to solar PV systems among rural populations, the Ministry of Small and Medium Enterprise Development and the Zambia Development Agency should develop cooperative-based financing schemes modelled on informal systems already supported by WCFs. These should include input credit, solar leasing, and revolving loan funds targeting women, youth, and smallholder farmers. Implementation should involve civil society organizations such as the Zambia Social Investment Fund (ZAMSIF) and local community-based organizations.

7.5. Promote inclusive media and research

The Ministry of Information and Media, in partnership with academic institutions and think tanks such as the Zambia Institute for Policy Analysis and Research (ZIPAR), should spearhead a national campaign for inclusive rural development storytelling. This should encourage evidence-based reporting that accurately reflects the roles of all actors, including WCFs, in sustainability transitions. A research ethics framework should also be developed to guide participatory methodologies and discourage reductionist portrayals of rural dynamics.

7.6. Institutionalise multi-stakeholder planning platforms

The Ministry of Local Government and Rural Development should establish district-level multi-stakeholder forums that bring together WCFs, smallholder representatives, traditional leaders, civil society, and development partners. These platforms should support co-creation of community infrastructure, renewable energy projects, and social investments. International development partners such as the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the United Nations Development Programme (UNDP) should be engaged for technical and financial support.

By implementing these recommendations, Zambia can strategically harness the potential of white commercial farmers as key collaborators in decentralised energy, environmental conservation, and rural development, fostering inclusive and sustainable transformation.

8. Conclusion

This study set out to examine whether, and how, white commercial farmers (WCFs) in Mkushi, Zambia contribute to solar photovoltaic adoption, community development, and environmental sustainability in rural contexts. Anchored in the Rural Development Stakeholder Hybrid Adoption Model (RUDSHAM), the research offers important empirical and theoretical insights into a triadic nexus that has hitherto been largely overlooked: the intersection of decentralised solar energy transitions, rural development imperatives, and the often-contested role of WCFs.

8.1. Key findings

Three overarching findings emerge. First, WCFs are actively contributing to community development by providing essential services such as education, health, and employment in contexts where the state's presence is weak. Second, although their involvement in solar energy adoption is primarily informal, WCFs show a strong willingness to facilitate solar transitions by offering land, infrastructure, and financing mechanisms that benefit workers and local communities. Third, their environmental stewardship is evident in climate-smart agriculture, reforestation, and conservation partnerships - indicating their dual role as agricultural modernisers and sustainability actors.

The study also revealed critical systemic barriers, including policy misalignments, institutional fragmentation, and persistent insecurity - particularly theft of solar equipment - which undermine the scalability of rural energy solutions. Nevertheless, WCFs demonstrate agency, adaptability, and embeddedness within local social systems, allowing them to function as informal intermediaries for decentralised development.

8.2. Contribution to knowledge

This research makes several original contributions. Most notably, it is the first scholarly investigation to explore the integrated dynamics of solar adoption, sustainability, and rural development through the lens of white commercial agriculture. Secondly, the application of the RUDSHAM framework presents an innovative analytical tool for understanding and addressing complex social problems at the intersection of stakeholder behaviour, governance gaps, and technological transitions. The study thus extends the conceptual boundaries of energy justice, community development, and environmental policy by recognising exogenous actors as underutilised agents in rural transformation.

8.3. Future research recommendations

Future research should expand the geographical and temporal scope by conducting longitudinal studies across multiple farming regions in Zambia. A nationwide study guided by RUDSHAM would help test the generalisability of findings and refine the model's applicability in diverse rural environments. Furthermore, comparative studies across Sub-Saharan Africa would illuminate regional variances in the roles of foreign and commercial agricultural actors in sustainability transitions.

8.4. Study limitations

The primary limitation of this study lies in its relatively short duration, which restricted the ability to capture seasonal fluctuations and longer-term policy developments. Additionally, while the research was conducted within a specific region in Zambia, this allowed for an in-depth, context-specific understanding that may differ in other locations. Furthermore, data collection focused exclusively on the perspectives of commercial farmers, as the study specifically aimed to explore the role of white commercial farmers as potential entry points for community-level solar adoption and financing. Future research would benefit from incorporating the perspectives of a broader range of stakeholders to provide a more holistic understanding of the dynamics at play. Nonetheless, these limitations do not detract from the robustness or credibility of the findings, which are grounded in rich empirical evidence and informed by triangulated insights.

CRediT authorship contribution statement

Hillary Chanda: Writing – review & editing, Writing – original draft, Validation, Software, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Eugene Mohareb:** Writing – review & editing, Supervision, Software, Resources, Methodology, Funding acquisition, Conceptualization. **Michael Peters:** Writing – review & editing, Supervision, Methodology, Formal analysis, Conceptualization. **Chris Harty:** Writing – review & editing, Methodology, Funding acquisition, Data curation, Conceptualization.

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Declaration of competing interest

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

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Appendix A. Supplementary data

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Data availability

Data will be made available on request.

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