

RESEARCH ARTICLE

Empowering marginalised communities: Leveraging indigenous knowledge for sustainable energy development in South Africa

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Abstract

Amidst South Africa's volatile energy landscape—characterised by political turbulence, economic instability and Eskom's chronic financial and operational challenges—the imperative for transformative reform is both urgent and indispensable. Municipalities are confronted with deteriorating infrastructure, recurrent power disruptions and widespread electricity theft, which collectively exacerbate the national energy crisis. This paper investigates the integration of indigenous knowledge systems within the country's energy sector as a strategic response to these persistent challenges, promoting the empowerment of marginalised communities and advancing environmental sustainability. Anchored in the theoretical frameworks of environmental justice and indigenous rights, the paper advocates for Afrocentric paradigms such as traditional resource governance and community-driven energy solutions. Employing thematic analysis of secondary data, it evaluates the viability and prospective benefits of this paradigm shift. The paper posits that the inclusion of indigenous knowledge in energy practices not only presents tangible solutions to the energy crisis but also cultivates socio-economic empowerment and reinforces environmental stewardship.

KEYWORDS

electricity challenges, indigenous communities/peoples, indigenous knowledge systems, municipalities, South Africa

1 | INTRODUCTION

South Africa's energy sector stands at a critical juncture, grappling with intricate financial, environmental and socio-political challenges. Persistent operational inefficiencies, financial mismanagement and an overreliance on conventional energy sources have deepened the nation's energy crisis, sparking public dissatisfaction, environmental degradation and mounting pressure for sustainable solutions (Vhumbunu, 2021). Although the Integrated Resource Plan (IRP) plays a central role in shaping the country's energy trajectory, critics argue

that it inadequately prioritises green energy alternatives essential for long-term sustainable development (Kumba et al., 2023).

Amid these challenges, interest in indigenous knowledge systems (IKS) is growing as a potential solution to South Africa's energy crisis. Rooted in time-honoured traditions and deep environmental knowledge, these systems offer critical insights into sustainable energy practices (Bruchac, 2014). However, it is crucial to critically assess the relevance of IKS in addressing contemporary energy challenges. Rather than positioning indigenous knowledge as a universal solution, it is vital to recognise that these systems evolved within specific

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historical and environmental contexts (Bruchac, 2014). Their applicability in today's rapidly shifting socio-economic and technological landscape requires careful consideration and adaptation within South Africa's current energy framework.

Effectively operationalising indigenous approaches to energy sustainability demands a nuanced strategy that aligns IKS with the needs of marginalised communities and modern technological developments (Cameron, 2017). Energy authorities and companies must take intentional steps to incorporate IKS into national energy strategies, ensuring these approaches contribute to equitable energy distribution and sustainability. Nonetheless, challenges remain, including the need for technical expertise, potential conflicts with existing infrastructure and the socio-cultural dynamics that may influence their acceptance and effectiveness.

This paper critically examines the potential of IKS as a strategic response to South Africa's energy crisis by focusing on the energy practices of six prominent indigenous communities: the San, Zulu, Tswana, Pedi, Xhosa and Venda. Each community presents unique approaches to energy use and sustainability (Mawere, 2024). By integrating IKS into national energy strategies, South Africa can address pressing environmental issues while promoting socio-economic empowerment for marginalised communities.

The analysis begins by establishing a theoretical framework, drawing on pertinent literature and case studies. It then explores South Africa's energy challenges, particularly at the municipal level, and investigates how IKS can intersect with green energy solutions. Finally, the paper highlights specific examples of indigenous energy practices and offers policy recommendations aimed at forging a more sustainable and equitable energy future for South Africa.

2 | INDIGENOUS KNOWLEDGE AND ENERGY TRANSITION IN SOUTH AFRICA

South African municipalities grapple with severe electricity challenges, necessitating green energy solutions and the empowerment of marginalised indigenous communities. This literature review analyses existing research, focusing on the intersection of energy governance, sustainability and social equity, guided by environmental justice and indigenous rights theories.

2.1 | Theoretical framework: Indigenous knowledge and energy justice

IKS embody the traditional wisdom, practices and beliefs that indigenous communities have accumulated over generations (Berkes, 2018). These systems are invaluable for sustainable development, offering critical insights into resource management, community resilience and environmentally sound practices (Ross, 2019). Rooted in local ecosystems, cultural norms and socio-economic contexts, IKS provide holistic solutions to environmental challenges (Battiste, 2013). Integrating

IKS into energy planning and governance not only respects and preserves cultural heritage but also fosters environmental stewardship and promotes equitable development (Diaz et al., 2020).

To understand the application of IKS in energy governance, the paper draws on theories such as environmental justice and indigenous rights. Environmental justice theory focuses on the fair distribution of environmental benefits and burdens, highlighting the disproportionate impacts of energy infrastructure on marginalised communities (Schlosberg, 2013). This perspective advocates for inclusive decision-making processes that prioritise the interests and rights of indigenous and marginalised groups (Sikor et al., 2021).

Similarly, the indigenous rights theory affirms the inherent rights of indigenous peoples to land sovereignty, cultural preservation and self-determination (Alfred, 2009). In the context of energy governance, this theory supports recognising IKS as legitimate sources of knowledge and emphasises the need for indigenous participation in decision-making. Through incorporating indigenous perspectives, energy planning and service delivery become more inclusive, sustainable and participatory, thereby addressing both environmental and social justice concerns.

2.2 | Challenges with energy transitions in Africa

Energy transitions in Africa face significant challenges rooted in historical legacies, infrastructural deficiencies and socio-political issues. Siakwah et al. (2023) argue that colonial-era reliance on centralised fossil-fuel-based systems has perpetuated a dependency on non-renewable resources, sidelining indigenous energy practices and impeding progress towards sustainable alternatives. The economic drive for fossil fuels has historically overshadowed investments in renewable technologies, leaving many African countries, such as Ghana, grappling with outdated and inefficient energy infrastructures (Nyambura & de Kock, 2021).

Infrastructural deficits further complicate the energy transition. Many African nations, including South Africa and Nigeria, suffer from ageing power plants and unreliable grids that lead to frequent outages and service disruptions (Mandelli et al., 2016). The financial burden of modernising these systems, combined with limited investment in renewable energy, exacerbates the issue. Investments often continue to favour fossil fuel projects due to their immediate economic benefits, leaving renewable energy projects underfunded and underdeveloped (Kamau, 2019). The high cost of implementing and scaling renewable technologies in the face of financial constraints limits progress (Chirambo, 2018).

Governance and socio-political factors also play a crucial role. Marginalised communities, including indigenous peoples, are frequently excluded from energy decision-making processes, leading to decisions that fail to account for their needs and traditional knowledge (Mawere, 2024; Whyte, 2017). Political instability, corruption and inadequate policy frameworks further hinder the effective implementation of energy projects (Dlamini, 2023; Mushemeza, 2022).

Addressing these challenges requires a shift towards inclusive governance and the integration of indigenous perspectives to achieve sustainable and equitable energy transitions (Adams et al., 2017).

2.3 | Energy challenges in South Africa

South Africa's electricity infrastructure is grappling with significant issues, largely due to ageing equipment, inadequate maintenance and insufficient investment in new infrastructure (Pollet et al., 2015). The country's power plants, averaging 30 years in age, have often surpassed their intended lifespan, rendering them prone to malfunctions and power supply limitations (Rahi & Chandel, 2015). This deterioration extends to the distribution and transmission networks, where aged infrastructure results in frequent power outages (Rahi & Chandel, 2015). The insufficient investment in upgrading these systems exacerbates South Africa's electrical issues (Khonjelwayo & Nthakheni, 2021).

Electricity theft further aggravates the crisis. In both urban and rural areas, theft occurs as households and businesses avoid paying for power (Dickson, 2024). Eskom reports that electricity theft constitutes around 10% of total electricity consumption in South Africa (Eskom Report, 2024). As Dickson (2024, p. 1) notes, 'Illegal power connections are syphoning off 37GWh of electricity per day from Eskom, costing the power utility around R15-million daily'. This rampant theft burdens the electrical grid, leading to power outages and frequent load shedding. The need for technicians to disconnect unauthorised connections and restore power affects service delivery and diverts resources from modernising the infrastructure (Dickson, 2024).

South Africa's reliance on fossil fuels, particularly coal, compounds these issues (Akinbami et al., 2021). Coal-fired power plants dominate the country's electricity generation, providing over 90% of its supply (Akinbami et al., 2021). This dependence results in high carbon emissions, worsening climate change. The extensive coal reserves have also deterred investment in renewable energy sources like solar and wind power (Anekwe et al., 2024). These energy challenges disproportionately impact South Africa's marginalised indigenous communities, often residing in rural areas and townships with limited or no electricity access (Frenzel, 2020).

These communities, characterised by lower incomes and higher levels of energy poverty, experience severe consequences from inadequate energy access (Frenzel, 2020). Poblete-Cazenave and Pachauri (2021) define energy poverty as 'a condition where households cannot afford to access or use sufficient energy to meet their basic needs, such as heating, lighting and cooking'. The lack of clean energy access negatively affects health, education and economic growth within these communities (Frenzel, 2020).

In light of the current energy challenges, Ramkissoo (2022) emphasises the importance of adaptive interventions for improving well-being and quality of life. While his work focuses on broader issues, the principles of adaptive management and resilience can be applied to energy governance, particularly in addressing the disparities

faced by marginalised communities. Similarly, Ramkissoo (2023) explores the social impacts of tourism and quality of life, which can be analogously related to the impacts of energy access. Improved energy infrastructure and access can improve overall quality of life, particularly in underserved communities.

Addressing South Africa's energy challenges necessitates a comprehensive approach that includes upgrading infrastructure, addressing electricity theft, reducing reliance on fossil fuels and improving energy access for marginalised communities. Integrating adaptive management strategies and focusing on social impacts can further improve efforts to create a more equitable and sustainable energy system.

2.4 | Indigenous knowledge systems and sustainable energy solutions

IKS in South Africa, deeply rooted in the traditions and practices of local communities, represent a significant repository of wisdom accrued over generations (Kgosimang & Oyedola, 2020). These systems offer profound insights into sustainable development, particularly in energy resource management. Traditional ecological knowledge, for example, has historically informed practices in agriculture, water management and energy use, reflecting a nuanced understanding of local ecosystems and resource cycles (Molefe & Nixon, 2019). This heritage of knowledge is increasingly recognised for its potential to guide and enhance renewable energy projects by aligning them with indigenous practices and fostering greater community acceptance and success.

Empirical evidence underscores the benefits of integrating IKS into renewable energy initiatives. Segooa and Mokheba (2019) demonstrate that embedding IKS into renewable energy projects—especially in rural areas—can significantly boost success rates. This is largely due to the alignment with local customs and the increased involvement of community members. For example, the integration of traditional biogas production methods with modern technology in rural South Africa exemplifies a successful fusion of IKS and contemporary methods, improving both the sustainability and efficiency of energy systems while simultaneously empowering local communities (Khonjelwayo & Nthakheni, 2021).

Furthermore, IKS offers critical insights into natural resource management, vital for ensuring energy security and sustainability. Indigenous communities, as stewards of their environments, possess extensive knowledge on resource conservation and management strategies (Molefe & Nixon, 2019). This knowledge can inform modern energy practices, optimising resource use and mitigating environmental impacts. For example, traditional methods such as controlled burning for vegetation management can be integrated with modern forest management methods to enhance carbon sequestration and reduce wildfire risks (Molefe & Nixon, 2019).

However, it is essential to approach the application of IKS with a critical lens. Samkange et al. (2021) warn against idealising IKS as a catch-all solution for contemporary energy issues. While IKS can

complement scientific approaches and offer valuable insights, its application must be adapted to modern technological and environmental contexts. Indigenous practices, developed for specific historical and ecological conditions, may not always be directly applicable or effective in contemporary settings. For example, traditional water collection methods, while effective in certain contexts, may fall short in meeting the demands of modern urban water supply systems (Akinbami et al., 2021). Therefore, integrating IKS into modern energy solutions requires a balanced approach that acknowledges the limitations and potential adaptations needed to address current technological and environmental challenges.

2.5 | Green energy solutions and indigenous knowledge systems

The integration of IKS with contemporary green energy solutions emerges as a pivotal strategy for addressing South Africa's persistent electricity challenges. Despite the historical dominance of fossil fuels in South Africa's energy sector, recent efforts reveal a growing recognition of the value inherent in traditional knowledge. Eskom, the country's principal electricity provider, has begun to explore the potential of integrating traditional practices with modern renewable energy projects. Notably, Eskom's research into biomass energy has incorporated indigenous techniques such as rotational wood harvesting, aligning with contemporary sustainable forestry practices. This fusion not only augments energy production but also underscores a commitment to sustainable forest management, illustrating a nuanced appreciation of indigenous practices that could be further expanded to meet broader energy needs (Eskom Report, 2024).

Beyond Eskom, government initiatives have actively sought to blend IKS with green energy solutions. The National Department of Science and Innovation's Renewable Energy Technology Demonstration Programme represents a significant effort in this direction, facilitating partnerships with local communities to weave traditional knowledge into the development of solar and wind energy projects. These community-based solar initiatives exemplify how indigenous insights into solar orientation and thermal management have been adapted to enhance the efficiency of modern solar technologies in rural settings. Such integrations not only optimise energy performance but also foster local acceptance and engagement, illustrating the practical benefits of incorporating traditional practices into contemporary energy frameworks (Department of Science and Innovation, 2023).

Further advances are visible in the realm of agroforestry and small-scale hydropower, where projects such as those supported by the Green Fund have successfully integrated traditional water management practices with modern hydropower systems. This integration has led to improved water efficiency and energy output, demonstrating how adapting indigenous practices to contemporary contexts can achieve significant advancements in sustainable energy production. These projects provide a model for harmonising IKS with modern technology, contributing to broader sustainability goals while

empowering local communities through increased involvement and capacity building (Green Fund, 2021).

Despite these positive strides, much remains to be done in fully integrating IKS into South Africa's energy sector. The marginalisation of indigenous practices, stemming from colonial and apartheid-era policies, has led to an overreliance on unsustainable fossil fuel-based energy systems. To address both historical injustices and current energy demands, a more profound incorporation of IKS is necessary. This entails not merely adapting traditional knowledge to modern contexts but also ensuring that local communities are empowered and meaningfully involved in energy decision-making processes. Such integration promises to rectify past inequities while contributing to sustainable development and resilient energy systems that benefit all segments of society.

The literature supports the view that IKS can play a crucial role in developing sustainable and contextually relevant energy solutions. Ramkissoon (2022) highlights how adaptive interventions during the COVID-19 pandemic have underscored the importance of integrating local knowledge into response strategies, a concept that parallels the need for incorporating IKS in energy solutions. Similarly, Ramkissoon (2023) discusses how perceived social impacts and quality of life improvements can be improved by incorporating local knowledge, which aligns with the benefits of integrating IKS into energy governance.

Additionally, Samkange et al. (2021) argue that the principles of innovative and sustainable approaches seen in food production and consumption can be extended to energy solutions, reinforcing the potential of IKS to drive development success. This view is complemented by Samkange et al. (2023), which explores how gender and power dynamics in entrepreneurship can impact the integration of IKS, offering critical insights for effective energy planning and policy-making. These perspectives collectively advocate for the inclusion of IKS as a complementary approach to scientific knowledge, underscoring its importance in achieving sustainable and contextually appropriate energy solutions.

2.6 | Empowerment of marginalised indigenous peoples

Empowering marginalised indigenous communities is pivotal for advancing sustainable energy governance in South Africa. Historically, these communities have been systematically excluded from energy decision-making processes, a pattern that has perpetuated inequality and obstructed the integration of sustainable energy technologies (Nunkoo & Ramkissoon, 2012). This exclusion not only undermines the potential benefits of energy development for these communities but also stymies the broader adoption of sustainable practices. To rectify this, a comprehensive approach to community engagement, capacity building and skills transfer is required.

Community engagement and participation are foundational to effective energy governance. Indigenous knowledge and practices are

invaluable in shaping energy policies that are culturally, socially and economically attuned to local contexts (Adams et al., 2017). Incorporating these perspectives ensures that energy projects are more sustainable and equitable. However, significant barriers remain, including inadequate recognition of Indigenous land rights and limited access to essential resources and information (Thiam, 2019). Overcoming these challenges is crucial for enabling genuine participation and fostering inclusive governance structures.

Capacity building and skills transfer are equally critical in empowering indigenous communities to engage with and benefit from sustainable energy technologies. Evidence shows that targeted programmes focused on knowledge exchange and skills development can significantly enhance the technical capabilities and economic prospects of indigenous peoples (Kaschula & West, 2016; Williams et al., 2019). For these efforts to have a lasting impact, they must be supported by continuous mentorship and aligned with broader policy frameworks (Ruppert-Winkel et al., 2017; Samkange et al., 2023). Such an integrated approach not only facilitates the inclusion of indigenous communities in the renewable energy sector but also amplifies their role in contributing to sustainable development.

The work of Ramkissoon (2022) further highlights the importance of adapting governance strategies to local contexts, emphasising that inclusive approaches improve the quality of life for all stakeholders. Ramkissoon's (2023) exploration of adaptive interventions underscores the necessity of integrating local knowledge into response strategies—an idea that is equally applicable to energy governance. Likewise, Ramkissoon's (2023) findings reinforce the need for decision-making processes that respect and incorporate indigenous perspectives.

Samkange et al. (2021) advocate for innovative and sustainable approaches that extend beyond traditional sectors, emphasising the relevance of indigenous knowledge in driving developmental success. This perspective is echoed by Samkange et al. (2023), who examine the interplay of gender, power dynamics and entrepreneurship, offering insights into how these factors influence the integration of indigenous knowledge into energy governance. Together, these works argue for a more inclusive, equitable approach to energy management, recognising and utilising the full spectrum of knowledge and experience that indigenous communities offer.

3 | METHODOLOGY

The paper uses a secondary data research method to examine the role of IKS in addressing South Africa's electricity challenges. The research involves a detailed review of various sources, selected for their relevance and credibility. Specifically, the paper focuses on South African energy policy documents, reports from Eskom (the national electricity supplier) and relevant academic literature. The methodology provides a comprehensive understanding of how IKS can be integrated into contemporary energy solutions. Data collection is guided by targeted keywords such as 'indigenous knowledge systems', 'sustainable energy' and 'South African electricity crisis'. This approach facilitates

the identification of pertinent materials, including textbooks, peer-reviewed academic papers and government publications (Akinbami et al., 2021; Mujuzi, 2020).

The study examines IKS related to energy practices of six prominent South African indigenous communities, aiming to assess how these traditional methods can address modern electricity challenges. To ensure the reliability and accuracy of the findings, the researchers cross-reference multiple sources and emphasise the use of peer-reviewed and authoritative documents (Kgosimang & Oyedola, 2020; Segooa & Mokhema, 2019). Despite these efforts, a limitation of the paper is its reliance on secondary data, which may not reflect the most recent developments or first-hand insights. This methodological constraint highlights the need for additional primary research to capture up-to-date information and direct experiences within the field.

4 | INDIGENOUS KNOWLEDGE SYSTEMS IN SOUTH AFRICA

This section explores IKS in South Africa, focusing on their potential contributions to contemporary energy solutions. The discussion is organised thematically around key energy types—solar, biomass, wind and hydropower—highlighting specific indigenous practices and their applicability to modern contexts.

4.1 | Solar energy

The IKS of the San people, often referred to as Bushmen, reflect a deep understanding of their natural environment. They skilfully employed passive solar energy methods, constructing dome-shaped shelters from natural materials such as branches, grass and animal hides. These shelters were strategically positioned to capture maximum sunlight in winter for warmth and provide ample shade in summer for cooling (Barnard, 1992; Silberbauer, 1981). By using reflective surfaces such as animal hides and stones to enhance natural lighting during the day, the San demonstrated a form of climate-responsive architecture long before modern sustainability efforts. Their approach to harnessing solar energy for heating, cooling and lighting has influenced contemporary architectural practices, including the work of institutions like the Sustainability Institute in Stellenbosch (Swilling & Annecke, 2012).

Integrating these passive solar methods into South Africa's national energy strategy offers a pathway to reducing electricity demand while promoting sustainable development. Features such as thick-walled structures for thermal mass, well-placed windows for natural light and shaded overhangs could decrease reliance on artificial climate control systems and reduce carbon emissions (Baker, 2010). By empowering marginalised communities to use their IKS for eco-friendly construction, this approach could also stimulate local economies. However, challenges exist, including the need for training in modern adaptations of IKS and ensuring these methods are

compatible with urban infrastructure and scalable for widespread use (Department of Environmental Affairs, 2016). This highlights the need for a balanced, culturally respectful approach to sustainable development without over-romanticising traditional practices.

4.2 | Biomass energy

The IKS of the Zulu people in KwaZulu-Natal highlight a sustainable approach to energy use, particularly through biomass. Practices like 'hot-rock cooking', where heated stones were used to cook food, conserved wood and reduced fuel consumption, minimising environmental impacts and improving air quality (Bryant, 1949; Mthembu, 2009). Additionally, rotational wood harvesting, which allowed forests to regenerate by selectively cutting trees, ensured a sustainable supply of biomass and reflected a deep understanding of long-term resource management (Binns et al., 2001). These traditional methods underscore a harmonious relationship with the environment, aimed at minimising resource depletion. Applying such IKS to South Africa's electricity challenges offers a sustainable alternative for energy generation, particularly in rural and marginalised areas.

Rotational wood harvesting can promote forest conservation, while biomass stoves inspired by hot-rock cooking can improve energy efficiency and reduce reliance on conventional electricity sources (Hiemstra-van der Horst & Hovorka, 2009). This approach can economically empower marginalised communities by creating local industries around sustainable biomass energy production. However, challenges include the need for technological adaptation, training and ensuring that these practices are scalable and compatible with modern energy demands. Additionally, policies must be in place to respect indigenous knowledge, preventing exploitation and misrepresentation (Department of Energy, 2019). Balancing tradition with innovation is crucial to avoid romanticising IKS while ensuring sustainable, inclusive solutions.

4.3 | Wind and water power

The IKS of the Xhosa people in the Eastern Cape highlight their historical use of wind and water power for energy needs. The Xhosa constructed water wheels and windmills to harness the kinetic energy of streams and wind, powering mechanical systems like maize grinders and water pumps (Peires, 1982). These renewable energy methods provided consistent energy for agricultural and daily activities, especially in regions with reliable water flow or strong winds (Hammond-Tooke, 1974). Their practices illustrate an early mastery of sustainable energy, rooted in local environmental conditions. Integrating these traditional methods into modern energy solutions can help address South Africa's electricity challenges, particularly in rural areas.

Small-scale water wheels and modernised windmills or wind turbines can provide off-grid, renewable energy to communities, reducing reliance on non-renewable sources. Projects similar to Nepal's micro-hydropower plants, which combine traditional water wheel

designs with modern technology, can serve as models for developing local energy solutions (Bajgain & Shakya, 2005). However, while this approach can economically empower marginalised communities by fostering local energy industries, challenges remain. These include ensuring the availability of water and wind resources, adapting traditional methods to modern needs and providing the necessary technical support to maintain the systems (Eberhard & Naude, 2016). A careful balance between innovation and respect for indigenous knowledge is crucial to avoid idealising these systems while promoting practical and sustainable energy solutions.

4.4 | Solar and thermal energy

The IKS of the Tswana people in northwestern South Africa reflect their resourceful use of solar and thermal energy for food preservation. By employing solar drying racks and stone-lined pits, they effectively harnessed the sun's heat to dry and store grains and other food items, reducing spoilage and extending the shelf life of their harvests (Schapera, 1938). These sustainable methods offer valuable lessons for modern agricultural practices, especially in reducing dependence on electricity-driven food preservation systems and promoting energy-efficient, climate-adapted food storage solutions. Incorporating these indigenous methods into contemporary agricultural practices can significantly contribute to solving South Africa's electricity challenges while improving rural food security.

Solar-powered dehydrators and thermal storage units, modelled after Tswana's passive solar drying methods, can reduce post-harvest losses and reliance on electric dryers, particularly in off-grid areas (Abdul-Rahman et al., 2019). This approach could empower marginalised communities economically by supporting local food preservation industries, improving resilience to climate change. However, challenges such as the need for modern adaptation, scalability and adequate training must be addressed to ensure these methods are effective and compatible with contemporary needs, avoiding romanticisation of traditional practices (Diosady & Simonne, 2011; Smith et al., 2015).

4.5 | Biomass and efficient cooking methods

The IKS of the Pedi people in Limpopo reflect their innovative use of biomass energy, particularly through the development of energy-efficient clay stoves. These stoves were designed to maximise heat retention while minimising fuel consumption, offering a sustainable solution for cooking in environments with limited access to electricity (Stayt, 1931). This traditional knowledge provides a valuable foundation for modern biomass stove technology, showcasing how indigenous practices can contribute to sustainable energy use and reduce the need for conventional fuels. By adapting and modernising these clay stoves with enhanced materials and engineering, South Africa can address its electricity challenges, especially in rural areas where electricity access is scarce.

More efficient biomass stoves can lower household energy costs, reduce greenhouse gas emissions and promote energy independence in marginalised communities, contributing to national sustainability goals (Lambe et al., 2017; Ventura et al., 2018). However, scaling these technologies requires a careful, context-specific approach. The success of this strategy depends on understanding diverse socio-economic and environmental conditions, ensuring the methods are adapted to modern needs and avoiding the romanticisation of traditional practices. Integrating IKS with modern innovations will be key to creating sustainable and equitable energy solutions that benefit all communities.

4.6 | Hydropower and agroforestry

The IKS of the Venda people in South Africa showcase their historical use of small-scale hydropower and agroforestry for sustainable resource management. Through these practices, the Venda generated local energy and improved environmental health by integrating hydropower with agroforestry, which improved biomass production, improved soil fertility and conserved biodiversity (Mander et al., 2007; Van Warmelo, 1940). These methods reflect a deep understanding of how to balance energy needs with environmental stewardship, providing valuable lessons for sustainable energy strategies today. Adapting these traditional practices to modern contexts offers potential solutions to South Africa's electricity challenges, particularly in rural areas.

Small-scale hydropower systems, combined with agroforestry, can provide off-grid energy while promoting ecological sustainability and economic empowerment for marginalised communities. By leveraging these methods, communities can reduce reliance on non-renewable energy sources, increase local energy production and enhance food security through improved land management (Lund et al., 2018). However, scaling these practices requires careful planning and technological adaptation. The success of such initiatives depends on addressing modern technical and logistical challenges and ensuring that these traditional methods are integrated in ways that are practical and contextually appropriate for contemporary energy needs. A balanced approach that combines IKS with modern innovations is essential to developing sustainable and equitable energy solutions for all of South Africa.

5 | RECOMMENDATIONS

To address South Africa's enduring electricity crisis and empower marginalised communities, it is imperative that Eskom and other energy-producing enterprises embark on a comprehensive integration of IKS into their energy generation strategies. The incorporation of IKS necessitates a multidimensional approach that goes beyond mere symbolic gestures, fostering a deep, respectful synergy between traditional practices and modern technological advancements. Eskom, as the primary energy provider, should spearhead initiatives to embed IKS within its renewable energy projects. This includes engaging with

indigenous communities to co-develop solutions that leverage traditional wisdom in sustainable resource management and energy efficiency.

Moreover, energy-producing enterprises should prioritise collaborative frameworks that ensure meaningful participation of marginalised communities in energy project planning and implementation. Establishing community advisory boards composed of indigenous representatives can facilitate the integration of IKS and improve the relevance and effectiveness of energy solutions. These boards would provide valuable insights into traditional practices and local environmental knowledge, ensuring that energy projects are culturally appropriate and tailored to the specific needs of the communities they aim to serve. Such participatory approaches not only foster trust and cooperation but also empower communities by providing them with a stake in the energy transition process.

In addition to the direct integration of IKS, there should be a concerted effort to build capacity within indigenous communities to engage with and benefit from modern energy technologies. This includes providing training and resources to enable these communities to contribute to and manage energy projects, thereby ensuring that the benefits of energy development are equitably distributed. Initiatives such as community-based renewable energy training programmes and technical support for maintaining and operating energy systems can bridge the gap between traditional knowledge and contemporary energy solutions. As a result of equipping communities with the skills and resources needed to participate in and benefit from energy projects, South Africa can promote both socio-economic development and environmental sustainability.

Finally, aligning these efforts with the United Nations Sustainable Development Goals (SDGs) is essential for ensuring a holistic approach to energy justice and sustainability. The integration of IKS into energy generation directly supports SDG 7 (Affordable and Clean Energy) by improving energy access and sustainability. Additionally, it advances SDG 10 (Reduced Inequalities) by addressing historical injustices and fostering inclusive growth. Implementing these recommendations not only addresses immediate energy challenges but also contributes to long-term sustainability and equity, positioning South Africa as a leader in integrating traditional knowledge with modern energy solutions.

6 | CONCLUSION

The analysis of the findings underscores the essential role of IKS in addressing South Africa's electricity crisis, yet their ability to fully empower marginalised communities and ensure sustainable development is nuanced and context-sensitive. Traditional practices, such as the solar drying racks of the Tswana people and the energy-efficient clay stoves of the Pedi, demonstrate considerable potential for enhancing energy efficiency and reducing reliance on conventional energy sources. These culturally resonant and ecologically sound solutions align with sustainable development goals; however, the analysis also reveals that adopting IKS alone does not address the broader

structural issues of energy justice, including systemic inequalities in energy access and socio-economic disparities.

To fully harness the potential of IKS in fostering sustainable development, it is crucial to complement traditional knowledge with systemic reforms that tackle these underlying challenges. Effective integration of IKS must be paired with strategies that ensure marginalised communities actively participate in decision-making processes and gain equitable access to resources. This comprehensive strategy should balance technological innovation with social and economic equity. Thus, while IKS play a vital role in developing resilient and sustainable energy solutions, their impact on empowering marginalised communities and achieving equitable development necessitates a multifaceted approach that addresses both technological and structural dimensions of energy justice.

This paper illuminates the pivotal role of integrating IKS into South Africa's energy landscape. Amid the ongoing electricity crisis, blending traditional practices with modern technologies offers a strategic solution for improving sustainability and addressing historical inequalities. Indigenous knowledge, refined through centuries of ecological adaptation and resource management, can significantly improve energy efficiency and access. Although initiatives like Eskom's rotational wood harvesting and community-driven solar projects show promise, a more systemic and inclusive approach is essential. Engaging indigenous communities more deeply and ensuring their active participation in energy governance are critical steps towards achieving equitable and sustainable energy solutions.

Aligning these efforts with the Sustainable Development Goals (SDGs) emphasises their global significance. Advancing SDG 7 (Affordable and Clean Energy) and SDG 10 (Reduced Inequalities), the integration of IKS not only addresses South Africa's energy crisis but also promotes the redress of historical injustices, social equity and environmental sustainability. This paper not only offers a model for South Africa but also sets a precedent for other nations facing similar challenges, demonstrating that culturally inclusive and environmentally sound energy practices can drive both national progress and international sustainability.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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