

TOWARDS AN INTEGRATED ENERGY-RESILIENCE MEDIATION MODEL (ERMM): CONCEPTUALIZING ALTERNATIVE ENERGY ADOPTION AND BUSINESS RESILIENCE AMONG WOMEN-OWNED MICRO ENTERPRISES

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ABSTRACT

Women-owned micro enterprises in developing economies operate at the nexus of three compounding vulnerabilities: chronic energy insecurity, systemic financial exclusion, and heightened exposure to economic and environmental disruptions. Despite growing policy attention to productive energy use and gender-equitable energy transitions, the mechanisms through which alternative energy adoption translates into business resilience for women entrepreneurs remain theoretically underexplored. This conceptual paper addresses this gap by synthesizing recent literature to propose an integrated model termed “Energy-Resilience Mediation Model (ERMM).” Drawing on the Unified Theory of Acceptance and Use of Technology (UTAUT), the Resource-Based View (RBV), Dynamic Capabilities theory, and the Capability Approach, the paper identifies four interconnected dimensions: (i) gendered barriers to energy adoption, encompassing financial, institutional, technological, and time-capital constraints; (ii) the antecedents of alternative energy adoption, comprising performance expectancy, effort expectancy, social influence, and facilitating conditions; (iii) enabling mechanisms spanning gender-responsive financing, structured capacity-building, and institutional and policy support; and (iv) multi-dimensional business resilience outcomes operationalized through operational stability, recovery capacity, adaptability, and long-term sustainability. The model posits that the relationship between energy adoption and resilience is mediated by enterprise absorptive capacity, technology–enterprise alignment, and the gendered institutional environment. A structured research agenda and policy implications are provided to guide future empirical studies.

Keywords: Alternative Energy, Business Resilience, Dynamic Capabilities, Micro Enterprises UTAUT, Women.

1. Introduction

Energy access is increasingly recognized as a fundamental enabler of inclusive economic growth. Yet access alone is insufficient. For women-owned micro enterprises in developing economies, the question is not merely whether energy is available but whether it can be effectively adopted, affordably maintained, and strategically deployed to generate productive outcomes that build sustained business resilience. The intersection of clean energy adoption, women's enterprise growth, and business resilience, constitutes an emerging and strategically important research frontier.

Nigeria represents a particularly critical case, with an estimated 85–90 million people lacking access to electricity (International Energy Agency [IEA], 2023; World Bank, 2023) and frequent national grid collapses further exacerbating the country's energy insecurity. Nigeria experienced eight national grid collapses in 2024, highlighting the fragility of the country's electricity infrastructure and the persistent unreliability of grid power for households and businesses (Reuters, 2024; NERC, 2024). Women-owned micro enterprises are disproportionately affected by Nigeria's energy crisis because they face greater barriers to accessing affordable, reliable, and productive energy technologies than their male-owned counterparts (Pueyo et al., 2020; Ferroukhi et al., 2019; Harrison et al., 2024). Analysis of energy access patterns in African micro, small, and medium enterprises found that women-owned enterprises recorded the highest

per-unit energy costs, the lowest energy diversification, and the weakest awareness of thermal energy demand, reflecting structural inequalities that extend far beyond simple infrastructure deficits (Pueyo et al., 2020).

These disadvantages are consequential. Women entrepreneurs in Northern Nigeria allocate an estimated 27% of enterprise income to energy costs, resources diverted from investment, diversification, and shock absorption (ACM, 2025). The compounding effect of energy insecurity and financial exclusion fundamentally undermines business resilience, reducing the capacity to withstand, adapt to, and recover from economic and environmental disruptions.

Despite growing scholarly attention to productive energy use and gender-equitable transitions, two significant gaps persist. First, the literature has predominantly examined energy access and enterprise resilience as parallel rather than mutually constitutive domains. Second, while resilience is increasingly invoked in energy-development discourse, the specific pathways through which alternative energy adoption contributes to enterprise resilience among women entrepreneurs remain theoretically underdeveloped (Shastri & Rai, 2025; Okoli et al., 2025). This paper addresses both gaps. This conceptual paper addresses three principal questions: (i) What are the key barriers and enablers shaping alternative energy adoption in women-owned micro enterprises? (ii) Through what mechanisms does alternative energy adoption contribute to multi-dimensional business

resilience? (iii) How do gendered institutional factors mediate the relationship between energy adoption and resilience outcomes?

The conceptual contribution of this paper is threefold. Theoretically, it integrates previously fragmented frameworks (UTAUT, RBV, Dynamic Capabilities, and the Capability Approach) into a single unified architecture that explains both adoption behaviour and resilience outcomes. Empirically, it provides the theoretical scaffolding needed for rigorous quantitative and mixed-methods inquiry in under-studied contexts such as Kano State, Northern Nigeria. Practically, the proposed model offers policymakers, development agencies, and financial institutions a structured basis for designing integrated energy-finance-capacity interventions that address the compound vulnerabilities facing women entrepreneurs.

2. Literature review

2.1 Women-Owned Micro Enterprises and Energy Insecurity

Women-owned micro enterprises account for nearly half of SMEs in emerging markets, estimated at 8–10 million businesses globally, yet face persistent energy disadvantages (UN Women & UNEP, 2022). In sub-Saharan Africa, more than 600 million people lack electricity access and over 900 million rely on traditional biomass for cooking, constraints that disproportionately burden women entrepreneurs who bear the simultaneous responsibilities of domestic fuel management and enterprise operation (IEA, 2023). In Nigeria specifically, energy poverty is particularly pronounced. An estimated 14 million fossil-fuel generators are in use nationwide, with associated annual CO₂ emissions exceeding the combined emissions of Togo, Rwanda, and Gabon (ACM, 2025; Gawusu et al., 2026).

Gender disaggregated analysis reveals that this energy crisis is not randomly distributed. Pueyo et al. (2020), in a multi-country analysis across West Africa, found that female-owned enterprises face more pronounced energy constraints than gender-diverse or male-owned enterprises, including lower energy diversification, higher per-unit energy costs, greater reliance on biomass, and systematic underreporting of thermal energy demand. This artificial separation between household and enterprise energy needs has historically excluded women entrepreneurs from infrastructure planning, technology subsidies, and tariff design (Clancy & Dutta, 2005; Ferroukhi et al., 2019).

Recent longitudinal evidence from the 2025 Solar Sister Entrepreneur Survey of 400 women entrepreneurs across Kenya, Tanzania, and Nigeria demonstrates the transformative potential of clean energy adoption. Nearly two-thirds of surveyed entrepreneurs invested in at least one additional business using solar products. Entrepreneur households were significantly less likely to live below the national poverty line, and school enrolment among entrepreneurs' children increased from 83% to 95% following

energy adoption (Solar Sister, 2026). These findings illustrate how energy adoption generates multiplier effects that extend well beyond the enterprise itself.

2.2 Alternative Energy Adoption: Barriers and Enablers

Despite its transformative potential, alternative energy adoption among women-owned micro enterprises remains constrained by multiple intersecting barriers. Harrison et al. (2024), in a systematic review of women in off-grid energy, identify five categories of adoption constraint: financial (collateral requirements, credit-scoring mismatches, high upfront capital), technological (domestic-use bias in device design, thermal energy gaps), informational (low energy literacy, limited awareness of productive applications), social (male gatekeeping of technology decisions, restricted mobility), and institutional (gender-blind policy frameworks, weak regulation of off-grid markets). These barriers are mutually reinforcing: financial exclusion limits access to enabling infrastructure; limited training reinforces effort expectancy concerns; social norms restrict access to the networks through which adoption information diffuses.

On the enabling side, a growing body of evidence points to the effectiveness of blended finance mechanisms in overcoming adoption barriers. The Yemen Emergency Electricity Access Project, which partnered with local microfinance institutions to de-risk off-grid solar sales, enabled approximately 15% of beneficiaries to open their first-ever bank accounts (World Bank, 2026). In Nigeria, the ECOWAS Regional Off-Grid Electricity Access Project (ROGEAP) partners with Solar Sister to build women-led clean energy distribution networks across off-grid communities (Solar Sister, 2026). The PowerHer774 programme, operating across all 774 local government areas in Nigeria, provides consumer credit specifically to women entrepreneurs for solar home system acquisition (THISDAYLIVE, 2025). These initiatives illustrate the viability of integrated energy-finance approaches.

Capacity-building represents a third critical enabling mechanism. The ILO (2025), drawing on lessons from Zambia's clean energy enterprise development programmes, identifies the following as essential components of effective capacity-building for women energy entrepreneurs: technical product knowledge, operation and maintenance skills, economic benefit quantification, sales and marketing, basic accounting, and leadership development. Training must be delivered in accessible formats, using visual aids, local languages, and scheduling that accommodates care responsibilities and reinforced through peer-to-peer networks that sustain motivation and knowledge transfer.

2.3 Business Resilience: Concept, Dimensions, and Measurement

Business resilience is a multidimensional construct with roots in organisational theory, supply chain management, and development studies. Vogus and Sutcliffe (2007) define organisational resilience as the capacity to absorb strain and

preserve function in the face of disturbances. Duchek (2020) advances a capability-based framework distinguishing three stages of resilience: anticipation (sensing and preparing for disruption), coping (responding effectively), and adaptation (learning and transforming). Williams et al. (2017) further identify four empirically grounded resilience dimensions: operational stability, recovery capacity, adaptability, and long-term sustainability. These dimensions that provide the dependent variable structure for this study.

In the micro enterprise context, Okoli et al. (2025) conducted an empirical study of micro and small enterprises in Nigeria, identifying four key resilience indicators: personal networks, resource slack, creative problem-solving, and adaptive capacity. Adaptive capacity emerged as the strongest contributor, reinforcing the theoretical primacy of flexibility and learning as drivers of micro-enterprise survival. Critically, this research demonstrates that conventional resilience measures developed for large organisations are poorly suited to resource-constrained micro enterprise contexts, where survival often depends on social capital and improvisation rather than formal risk management systems.

For women-owned micro enterprises specifically, the ISO 22316:2017 organisational resilience standard identifies absorptive capacity (maintaining function), recovery capacity (restoring operations), adaptive capacity (adjusting strategy), and transformative capacity (pursuing growth) as the four key resilience capabilities. Recent European Investment Bank (2025) tools for measuring women's economic and financial resilience operationalise these dimensions through gender-

disaggregated indicators that capture structural barriers and enablers specific to women-led businesses.

2.4 Productive Energy Use and Resilience Outcomes

The concept of productive energy use, energy applications that generate income, employment, or value addition has gained significant traction in recent development discourse. Shastri and Rai (2025) advance an 'impact-resilience' framework, demonstrating that Decentralised Renewable Energy Assisted Machines (DREAMs) activate cascading livelihood impacts: reducing drudgery, creating time savings, enabling skill development, generating employment, and enhancing social capital. These non-financial dimensions are particularly important for women entrepreneurs, who often face constraints that limit the translation of income gains into broader resilience.

Evidence from Northern Nigeria corroborates these theoretical claims. A study of hybrid solar-wind systems for women entrepreneurs in the region found that while only 2.2% of participants used wind energy and 19.3% some form of solar energy, those who adopted renewable technologies reported significantly reduced energy expenditure, improved operational continuity, and greater capacity to maintain business activity during grid failures (ACM, 2025). The case of a rice processing entrepreneur in Kano State whose adoption of solar-powered milling reduced grinding time, eliminated fuel costs, and enabled her to process up to 100 bags per cycle illustrates the transformative potential of productive energy use when aligned with enterprise needs (World Bank, 2026).

Table 1: Synthesis of Gendered Barriers and Enabling Mechanisms

Dimension	Key Barriers	Key Enablers
Financial	Collateral demands; credit-scoring mismatches; microfinance scale limitations; bank lending rates of 20-40% (UNDP, 2026)	Blended capital; gender-lens investing; lease-to-own; cooperative pooling; results-based financing (Gender & Energy Compact, 2024)
Social & Institutional	Sectoral segregation; male guarantor requirements; restricted mobility; masculine entrepreneurship norms (Shankar et al., 2022)	Gender-responsive policies; intermediary networks; role model promotion; Vietnam-style regulatory reform (UN Women, 2024)
Technological	Technology-enterprise misalignment; domestic-use bias in clean cooking design; limited thermal energy solutions (Pueyo et al., 2020)	Participatory demand-driven design; productive use technologies; solar-wind hybrids for northern contexts (ACM, 2025)
Capacity & Information	Limited energy literacy; time poverty due to care burdens; inadequate technical training (ILO, 2025)	Structured training programmes; local-language materials; peer-to-peer networks; Solar Sister model (Solar Sister, 2026)

3. Theoretical Foundation

The conceptual model developed in this paper is grounded in four complementary theoretical traditions, each illuminating

a distinct dimension of the energy-adoption-resilience relationship. Table 2 summarizes the key frameworks, their core arguments, and their relevance to the study.

Table 2: Theoretical Frameworks Underpinning the Conceptual Model

Theory / Framework	Core Argument	Relevance to Study	Key Scholars
Resource-Based View (RBV)	Competitive advantage from valuable, rare, inimitable resources	Clean energy as a strategic resource enabling resilience	Barney (1991); Wernerfelt (1984)
Dynamic Capabilities	Firms sense, seize, and reconfigure capabilities in turbulent environments	Energy adoption as a dynamic capability enabling adaptation	Teece et al. (1997); Eisenhardt & Martin (2000)
UTAUT / UTAUT2	Performance expectancy, effort expectancy, social influence, facilitating conditions drive adoption	Explains clean energy adoption decisions among women entrepreneurs	Venkatesh et al. (2003, 2012)
Capability Approach	Human development as expansion of substantive freedoms and capabilities	Financial empowerment expands women's capability to adopt energy technologies	Sen (1999); Nussbaum (2011)

3.1 The Unified Theory of Acceptance and Use of Technology (UTAUT)

The UTAUT, originally formulated by Venkatesh et al. (2003) and extended in the UTAUT2 consumer context (Venkatesh et al., 2012), remains the most widely validated technology acceptance framework. It identifies four core constructs (performance expectancy, effort expectancy, social influence, facilitating conditions) as primary determinants of technology adoption intentions and behaviours. Within the context of alternative energy adoption, performance expectancy captures women entrepreneurs' beliefs that adopting alternative energy will yield tangible business improvements: reduced fuel costs, extended operating hours, and enhanced productivity. Effort expectancy captures perceived ease of use and maintenance, which is particularly salient for women with limited formal technical training. Social influence acknowledges the significant role of peer networks, community leaders, and business associations in shaping adoption norms. Facilitating conditions encompass the availability of financing, infrastructure, technical support, and training.

Apfel and Herbes (2021) applied an extended UTAUT2 model to renewable energy adoption among SMEs in Senegal, finding that performance expectancy and facilitating conditions were the strongest predictors of adoption, while social influence exhibited context-dependent effects due to informal sector dynamics. Their finding that effort expectancy was underestimated due to limited knowledge of renewable systems which has direct implications for Northern Nigeria, where low energy literacy is compounded by patriarchal norms that restrict women's access to technical training.

3.2 Resource-Based View (RBV) and Dynamic Capabilities

The Resource-Based View, pioneered by Wernerfelt (1984) and elaborated by Barney (1991), posits that firms achieve and sustain competitive advantage through the acquisition and strategic deployment of resources that are valuable, rare, inimitable, and non-substitutable (VRIN). In the context of women-owned micro enterprises, alternative energy technologies constitute a VRIN resource: they reduce operational costs, extend productive hours, and improve product quality in ways that competitors relying on expensive fossil-fuel generators cannot easily replicate. Financial empowerment functions as a complementary resource that enables entrepreneurs to acquire, maintain, and leverage energy assets.

Dynamic Capabilities theory (Teece et al., 1997; Eisenhardt & Martin, 2000) extends the RBV by emphasising the meta-capability of firms to sense opportunities, seize resources, and reconfigure organisational competencies in response to environmental turbulence. For micro enterprises in energy-insecure environments, the capacity to shift from grid dependence to solar adoption, to adjust operating schedules, and to diversify into new energy-enabled activities exemplifies dynamic capability in practice. Shastri and Rai (2025) demonstrate that decentralised renewable energy adoption in rural livelihoods activates cascading impacts across financial, human, social, and operational dimensions—consistent with the dynamic capabilities framing of resilience as a learnable and deployable organisational capacity.

3.3 The Capability Approach

Sen's (1999) Capability Approach conceptualises development as the expansion of substantive freedoms, the

real opportunities available to individuals to lead lives they have reason to value. Within this framework, financial empowerment expands women entrepreneurs' capability set: their freedom to access capital, invest in productive technologies, and make autonomous business decisions. Energy access operates similarly, transforming the material conditions under which women operate and expanding the range of productive activities available to them. Nussbaum (2011) extends this approach through a list of central human capabilities, including bodily health, affiliation, and control over one's environment, each of which is conditioned by energy access and financial inclusion.

The Capability Approach is particularly well suited to the gendered context of this study because it draws explicit attention to conversion factors, the personal, social, and environmental conditions that determine how effectively resources translate into capabilities. In Northern Nigeria, conversion factors such as patriarchal social norms, collateral requirements, and limited technical training impede women entrepreneurs' ability to convert energy access into productive capability, even when the energy resource is physically available.

3.4 Sustainable Livelihoods Framework

The Sustainable Livelihoods Framework (SLF), developed by Chambers and Conway (1992) and institutionalised by the UK Department for International Development (1999), provides a multi-capital perspective on livelihood resilience. It identifies five forms of capital—human, natural, financial, physical, and social—that households and enterprises mobilise in pursuit of livelihood outcomes. The SLF's emphasis on vulnerability context, comprising shocks, trends, and seasonality, is directly applicable to the Northern Nigerian energy context, where grid collapses represent recurrent shocks and rising fossil-fuel prices constitute an adverse structural trend.

Alternative energy adoption influences multiple capitals simultaneously: it enhances physical capital (energy infrastructure), reduces financial capital drain (lower fuel costs), improves human capital (time savings, reduced health burdens from generator fumes), and can expand social capital (through Solar Sister-style networks of women energy entrepreneurs). This multi-capital perspective justifies a multi-dimensional operationalisation of business resilience that encompasses operational, financial, adaptive, and transformative dimensions.

4. Energy-Resilience Mediation Model (ERMM)

4.1 Model Architecture

Drawing on the theoretical foundations and empirical evidences, this paper proposes the Energy-Resilience Mediation Model (ERMM). The model comprises four

interconnected layers that operationalise the mechanisms through which alternative energy adoption contributes to business resilience in women-owned micro enterprises. The ERMM departs from prior models in three important ways: (i) it explicitly integrates gendered barriers as structural preconditions rather than contextual footnotes; (ii) it identifies three mediating conditions that determine whether adoption translates into resilience; and (iii) it operationalises resilience through four empirically validated dimensions rather than a single composite construct.

4.1.1 Layer 1: Gendered Structural Context

The model begins with the recognition that women entrepreneurs do not operate in a gender-neutral environment. The gendered structural context encompasses financial exclusion (collateral demands, credit-scoring mismatches, high interest rates), social and institutional norms (sectoral segregation, male guarantor requirements, restricted mobility, masculine entrepreneurship bias), technological misalignment (domestic-use bias in clean cooking design, limited thermal energy solutions for commercial food processing), and time poverty arising from disproportionate care responsibilities (ILO, 2025; Shankar et al., 2022; Pueyo et al., 2020). These structural constraints constitute the vulnerability context within which adoption decisions are made and resilience capacities developed.

4.1.2 Layer 2: Antecedents of Alternative Energy Adoption (UTAUT)

The model adopts the four UTAUT constructs as the proximate antecedents of alternative energy adoption. Performance expectancy captures women entrepreneurs' beliefs about the business benefits of alternative energy - cost reduction, productivity gains, quality improvement, and operational continuity. Effort expectancy captures perceived ease of use and maintenance, which is moderated by prior technical training and access to after-sales support. Social influence captures the role of peers, community networks, Solar Sister-style distribution networks, and opinion leaders in shaping adoption norms. Facilitating conditions capture the enabling environment: access to affordable financing, technical infrastructure, training programmes, and government or NGO support.

The ERMM proposes that these four antecedents are not independent but are mutually conditioned by the gendered structural context. For example, performance expectancy beliefs are shaped by the availability of role models who have successfully adopted clean energy; social influence is mediated by women's access to social networks, which is itself constrained by mobility norms. This interaction between structural context and UTAUT antecedents is a distinctive

feature of the ERMM, distinguishing it from standard UTAUT applications.

4.1.3 Layer 3: Mediating Conditions

The ERMM proposes that the relationship between alternative energy adoption and business resilience is not direct but is mediated by three critical conditions. First, enterprise absorptive capacity, the enterprise's capacity to effectively integrate new energy technologies, manage energy systems, and leverage energy services for productive activities determines whether adoption generates resilience dividends or merely adds operational complexity. Enterprises with higher absorptive capacity, built through technical training, business skills development, and peer learning, are better positioned to realize the full productive potential of clean energy technologies.

Second, technology-enterprise alignment captures the degree to which the adopted energy technology matches the specific operational needs, scale, and resource constraints of the enterprise. Solar PV systems aligned with food processing needs (powering refrigeration, lighting, and small machinery) generate stronger resilience outcomes than generic household systems deployed in commercial contexts. Participatory, demand-driven technology deployment, as demonstrated by Solar Sister's model, produces better alignment than supply-led rollouts.

Third, the gendered institutional environment (comprising policy frameworks, financial systems, social norms, and governance structures) moderates both the adoption decision and the resilience outcomes. Gender-responsive policies, such as the Vietnamese circular recognising women-owned SMEs

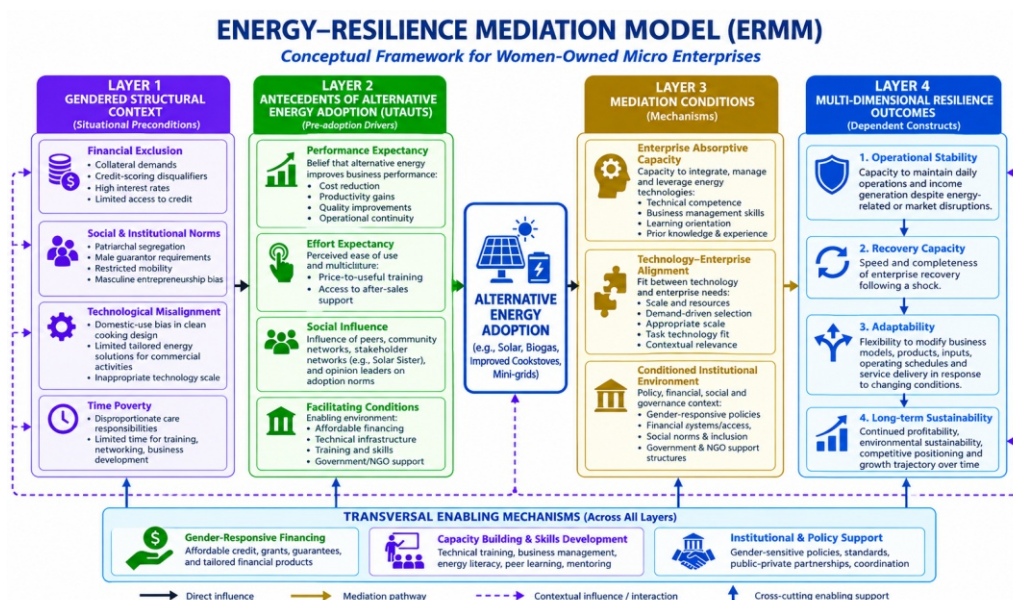
that mandated priority budget allocation (UN Women, 2024), and gender-lens financing instruments can transform the institutional environment from a source of constraint into an enabling foundation for resilience.

4.1.4 Layer 4: Multi-Dimensional Resilience Outcomes

The ERMM operationalises business resilience across four dimensions that integrate established organisational resilience theory (Williams et al., 2017; Duchek, 2020; ISO 22316:2017) with recent empirical evidence from micro enterprise contexts (Okoli et al., 2025). Operational stability encompasses the enterprise's capacity to maintain daily functions and revenue generation despite energy-related or market disruptions. Recovery capacity captures the speed and completeness of enterprise recovery following a shock. Adaptability reflects the enterprise's flexibility to modify its business model, product range, operating schedule, and service delivery in response to changing energy prices, supply conditions, or market demands. Long-term sustainability encompasses continued profitability, environmental sustainability, competitive positioning, and growth trajectory over time.

These four dimensions are not independent. Operational stability creates the platform from which recovery capacity can be mobilised; recovery capacity, when effectively exercised, builds adaptive learning; and sustained adaptability undergirds long-term sustainability. The ERMM thus treats resilience as a dynamic and evolving organisational capability rather than a static attribute.

4.2 Conceptual Model of the ERMM



The Energy-Resilience Mediation Model is conceptually structured as follows. The Gendered Structural Context (Layer 1) constitutes the environmental precondition within which adoption decisions occur. The UTAUT Antecedents (Layer 2: performance expectancy, effort expectancy, social influence, facilitating conditions) drive Alternative Energy Adoption. The three Mediating Conditions (Layer 3: enterprise absorptive capacity, technology-enterprise alignment, gendered institutional environment) determine the degree to which adoption translates into resilience gains. Finally, the four Resilience Outcome Dimensions (Layer 4: operational stability, recovery capacity, adaptability, long-term sustainability) constitute the dependent construct. Enabling Mechanisms (gender-responsive financing, capacity-building programmes, and institutional support) operate transversally across all layers, modifying both adoption antecedents and the mediating conditions.

4.3 Theoretical Contributions of the Energy-Resilience Mediation Model (ERMM)

The Energy-Resilience Mediation Model (ERMM) advances theoretical understanding at the intersection of alternative energy adoption, women's entrepreneurship, and business resilience. While prior research examined technology acceptance, enterprise resilience, and gendered entrepreneurship as distinct streams of inquiry, these literatures have proceeded largely in parallel, with limited conceptual integration (Brush et al., 2019; Linnenluecke, 2017; Venkatesh et al., 2003). The ERMM provides an integrative architecture that explains not merely 'whether' women-owned micro-enterprises adopt alternative energy, but 'how' and 'under what conditions' such adoption translates into meaningful resilience outcomes. This integration yields four specific theoretical contributions.

First, the ERMM extends technology acceptance theory beyond the adoption threshold. The Unified Theory of Acceptance and Use of Technology (UTAUT) and its extensions have been remarkably successful in predicting behavioural intention and initial system use (Venkatesh et al., 2003; Venkatesh et al., 2012). However, these models treat adoption as the terminal dependent variable. This framing is insufficient for understanding enterprise resilience, which requires not momentary adoption but 'sustained, reliable utilization' of technology over time. The ERMM reframes UTAUT constructs (performance expectancy, effort expectancy, social influence, and facilitating conditions) as antecedents not of adoption per se, but of 'reliable energy utilization', which in turn mediates resilience outcomes. In doing so, the model corrects an implicit assumption in the technology acceptance literature that adoption is the endpoint

of interest. For women-owned micro-enterprises in energy-constrained environments, adoption is merely the beginning; the real question is whether the technology continues to serve the enterprise through breakdowns, seasonal variations, and evolving business needs.

Second, the ERMM addresses a critical blind spot in the Resource-Based View (RBV) and Dynamic Capabilities Theory. The RBV explains competitive advantage through valuable, rare, inimitable, and non-substitutable resources (Barney, 1991), while dynamic capabilities theory explains how firms reconfigure resources to adapt to changing environments (Teece et al., 1997). These frameworks have been enormously influential, yet they assume that resource acquisition and deployment occur in a relatively frictionless institutional environment. For women-owned micro-enterprises in developing economies, this assumption is untenable. Gendered institutional constraints such as restricted property rights, limited mobility, household decision-making hierarchies, and time poverty shape which resources women can access, how they can deploy them, and whether they can sustain resource investments over time (Brush et al., 2019; Kabeer, 2012). The ERMM incorporates these constraints not as peripheral control variables but as 'foundational moderators' that condition the entire energy-to-resilience pathway. By doing so, the model answers calls to contextualize strategic management theory for informal, gendered, and resource-constrained enterprise settings (Welter, 2011).

Third, the ERMM identifies the mediating mechanisms that translate energy adoption into resilience. Prior studies have generally assumed a direct relationship between energy access and business performance (Khandker et al., 2014; Sovacool, 2012). This assumption treats energy as a homogeneous input that, once supplied, automatically produces benefits. The ERMM challenges this linear logic by specifying three mediating pathways: 'enterprise absorptive capacity' (the ability to learn, adapt, and integrate new energy technologies into existing operations), 'technology-enterprise alignment' (the degree of fit between the energy system and the enterprise's specific productive requirements), and 'the gendered institutional environment' (the set of formal and informal rules that shape women's economic agency). These mediators explain why two enterprises with identical energy technologies may experience divergent resilience outcomes: one integrates the technology effectively, aligns it with productive needs, and operates within supportive institutional conditions; the other does not. The ERMM thus moves beyond technological determinism toward a more nuanced, mechanism-based account of energy's

developmental effects.

Fourth, the ERMM operationalizes business resilience as a multidimensional construct, responding to conceptual fragmentation in the resilience literature. Resilience researchers have defined organizational resilience as absorptive, adaptive, and transformative capacity (Linnenluecke, 2017; Ortiz-de-Mandojana & Bansal, 2016), yet empirical studies often collapse these dimensions into a single composite measure. This aggregation obscures the possibility that alternative energy may enhance some resilience dimensions while leaving others unchanged. A solar-powered enterprise may achieve operational stability (daily operations continue despite grid outages) without achieving adaptability (the enterprise cannot shift to new products or schedules). The ERMM explicitly theorizes four distinct resilience dimensions (operational stability, recovery capacity, adaptability, and long-term sustainability) and proposes that UTAUT constructs may differentially influence each dimension. This disaggregation provides a more precise theoretical basis for empirical measurement and enables a more nuanced understanding of how energy technologies affect enterprise dynamics over time.

Collectively, these four contributions position the ERMM as a novel integrative framework that bridges technology acceptance theory, strategic management, organizational resilience, and gender-responsive development scholarship. By specifying the mechanisms that mediate the energy–resilience relationship, the model provides a theoretically grounded foundation for future empirical testing. By incorporating gendered institutional constraints as moderators, the framework offers a more realistic account of the conditions under which clean energy translates into genuine economic empowerment for women micro-entrepreneurs. By disaggregating resilience into four dimensions, the model enables more precise empirical investigation and more targeted policy and practice interventions.

5. Policy Implication

5.1 Mainstreaming Productive Users in Energy Policy

The most fundamental policy intervention of the ERMM is the need to reframe women entrepreneurs from passive household energy consumers to productive economic agents and innovation diffusers. Existing national energy policies in Nigeria and across sub-Saharan Africa predominantly centre household electrification as the primary access metric, with productive users, particularly women-owned micro enterprises treated as secondary beneficiaries rather than primary policy targets (UNEP, 2022). This framing

systematically underinvests in the commercial clean cooking, productive machinery, and solar-powered food processing technologies that would most directly build enterprise resilience.

The ERMM implies that productive use targets should be written into national Renewable Energy Master Plans, disaggregated by gender and enterprise type. Development programmes such as the World Bank's Distributed Access through Renewable Energy Scale-up (DARES) programme in Kano State should include enterprise-specific design components, linking solar mini-grid deployment to the needs of women food processors and service enterprises (World Bank, 2026). The ECOWAS ROGEAP–Solar Sister partnership provides a scalable model for integrating women's enterprise development into regional energy access programmes.

5.2 Transforming the Financing Architecture

The ERMM's integration premium hypothesis implies that energy and financial interventions should be co-designed rather than sequenced. Gender-responsive financing mechanisms including lease-to-own arrangements, results-based financing, cooperative pooling, and blended capital structures should be explicitly embedded within energy access programmes rather than treated as separate financial sector concerns. Nigeria's Collateral Registry Act (2017) and recent Central Bank of Nigeria directives on financial inclusion provide regulatory foundations that could be leveraged to develop gender-sensitive energy-finance products. In the short term, donor-backed credit guarantees, as employed in Ghana and Kenya, could unlock private sector participation in women's clean energy financing (UNDP, 2026).

5.3 Embedding Capacity-Building as Foundational, Not Optional

The mediating role of enterprise absorptive capacity in the ERMM implies that capacity-building cannot be treated as an optional add-on to energy access programmes. Technical training, business skills development, peer mentorship, and after-sales support are foundational conditions for translating energy adoption into resilience. The ILO (2025) recommends a structured curriculum covering technical product knowledge, operational management, maintenance and troubleshooting, economic benefit quantification, and marketing delivered in local languages with scheduling adapted to women's care responsibilities.

Policy should formalise the role of trusted intermediaries (reference entrepreneurs) such as Solar Sister agents as a principal delivery channel for technical assistance and social learning. In Nigeria, the PowerHer774 programme's network

of women clean energy advocates across 774 local government areas provides an existing infrastructure that could be leveraged for structured capacity-building delivery (THISDAYLIVE, 2025). The formalisation of co-ownership and revenue-sharing frameworks would further enable anchor-business-community energy models in food

processing clusters.

6. Suggestion for Further Studies

The ERMM identifies five priority areas for future empirical investigation. Table 3 presents a structured research agenda mapping research gaps, proposed questions, and recommended methodological approaches.

Table 3: Proposed Research Agenda for Empirical Investigation

Research Gap	Proposed Research Question	Recommended Method
Mediating role of enterprise absorptive capacity	To what extent does absorptive capacity mediate the relationship between clean energy adoption and business resilience in women-owned MSEs?	PLS-SEM; longitudinal panel data
Gender-disaggregated resilience indicators	What resilience indicators most accurately capture the lived experience of women micro-entrepreneurs in energy-insecure environments?	Feminist participatory action research; grounded theory
Integration premium of energy-finance co-interventions	Does integrated energy-finance intervention produce greater resilience gains than energy-only or finance-only programmes?	Quasi-experimental; difference-in-differences
Context specificity in Northern Nigeria	How do socio-cultural norms in Kano State moderate the relationship between clean energy adoption and business resilience?	Mixed methods; multi-site comparative
Technology alignment and productive use	Which productive use energy technologies yield the strongest resilience outcomes for women in food processing?	Case study; value chain analysis

Methodologically, the field would benefit from greater use of Partial Least Squares Structural Equation Modeling (PLS-SEM) for examining the multi-level mediated relationships proposed in the ERMM, given its suitability for exploratory, prediction-oriented research with non-normal data distributions (Hair et al., 2021). Longitudinal panel designs would enable examination of how resilience capacities evolve over time following energy adoption, capturing the dynamic nature of the relationship. Feminist participatory action research approaches would complement quantitative methods by surfacing women entrepreneurs' own framings of resilience and energy-related challenges, guarding against the imposition of externally derived analytical categories.

Gender-disaggregated analysis is particularly important. Following the SAGER guidelines, future research should distinguish between sex-disaggregated data (biological category) and gender-disaggregated analysis (socially constructed roles and power relations), recognising that the latter is essential for revealing how institutional biases and social norms shape energy outcomes differently across gender

categories (UN Women & UNEP, 2022). Comparative studies across Northern and Southern Nigerian contexts, and across West African countries, would enable identification of context-specific mediating conditions and test the generalisability of the ERMM.

7. Limitations of the Study

This paper has several limitations. As a conceptual paper, it does not provide primary empirical validation of the proposed ERMM. The model's propositions are grounded in a synthesis of existing literature rather than original data, and the proposed relationships remain to be tested through rigorous empirical inquiry. The literature synthesis draws primarily on research from West Africa and Nigeria, limiting the generalisability of the model to other regional contexts without contextual adaptation. Some of the cited studies, particularly those examining large-scale energy access programmes, report aggregate data that may not adequately capture the diversity of experience within the category of 'women-owned micro enterprises', a category that encompasses significant variation in educational level,

enterprise age, sector, and financial status. Future empirical work should attend carefully to this heterogeneity.

8. Conclusion

This conceptual paper has developed the Energy-Resilience Mediation Model (ERMM), an integrated framework for understanding the mechanisms through which alternative energy adoption contributes to business resilience in women-owned micro enterprises. Drawing on a synthesis of literature and four complementary theoretical propositions (UTAUT, Resource-Based View, Dynamic Capabilities, and the Capability Approach), the model identifies gendered barriers, UTAUT adoption antecedents, mediating conditions, and multi-dimensional resilience outcomes as its constituent elements.

Three principal contributions emerge. First, the ERMM provides an integrated theoretical architecture that simultaneously explains alternative energy adoption and its resilience consequences in a women-owned micro enterprise context. Second, it identifies the multiplicative rather than additive resilience gains generated by co-designed energy-finance interventions, providing both theoretical grounding and a hypothesis for empirical investigation. Third, it advances a gender-disaggregated analytical lens that reframes women entrepreneurs from passive energy consumers to productive economic agents, innovation diffusers, and central actors in inclusive energy transitions.

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