Hierarchical, Decentralized, or Hybrid? A Systematic Review of Control Architectures for Distributed Energy Resources

Nenubari Marvin Komi[1], Azeez Adamolekun[2]
[1] Near East University, Lefkosia,
Cyprus
nenubarikomi@gmail.com
[2] Heinekens N. V. -Nigerian Breweries Plc,
Nigeria
adamolekunazeez19322@gmail.com
Corresponding Author: nenubarikomi@gmail.com
DOI: 10.56201/ijemt.v8.no5.2022.pg141.195

Abstract
This paper presents a structured review of the scholarship on control architectures for distributed energy resources, read through a socio-technical lens that treats engineering performance and social outcomes as a single, interdependent concern rather than as separate questions to be addressed in sequence. The review organizes a fragmented body of work that spans engineering, economics, development studies, and energy justice, and it draws these traditions together around a common question, namely how technical capability and social legitimacy jointly determine whether interventions endure in resource-dependent and underserved regions. Particular attention is given to control topology as an implicit governance model that must align with ownership and trust structures, which the review identifies as a recurring but inadequately measured determinant of outcomes. The contribution is conceptual and synthetic: this paper clarifies the state of knowledge, exposes the gap between the recognized importance of social factors and the field's limited progress in measuring them, and sets out a conceptual agenda for integrated evaluation oriented toward inclusive and economically sustainable energy transition

Keywords: *renewable energy; socio-technical systems; conceptual framework; just transition; energy equity; sustainable development; inclusive infrastructure*

1. Introduction

Access to reliable, affordable, and clean energy underpins education, health, livelihoods, and full participation in economic life, yet dependable electricity remains out of reach for a large share of the population in low-income and resource-dependent regions (Ahmed et al., 2020). The scholarship bearing on control architectures for distributed energy resources has grown rapidly, but it has done so across several traditions that have developed in relative isolation from one another, with engineering work emphasizing performance, economic work emphasizing cost, and social-science work emphasizing acceptance, equity, and governance. This review takes as its task the drawing together of these strands, on the premise that the outcomes of interventions in control architectures for distributed energy resources are determined by all of them at once and cannot be understood from within any single tradition (Agbabiaka et al., 2019; Ahmad et al., 2020). The

overall logic relating these elements is summarized in Figure 1 (Basnet et al., 2021; Isiekwu et al., 2021).

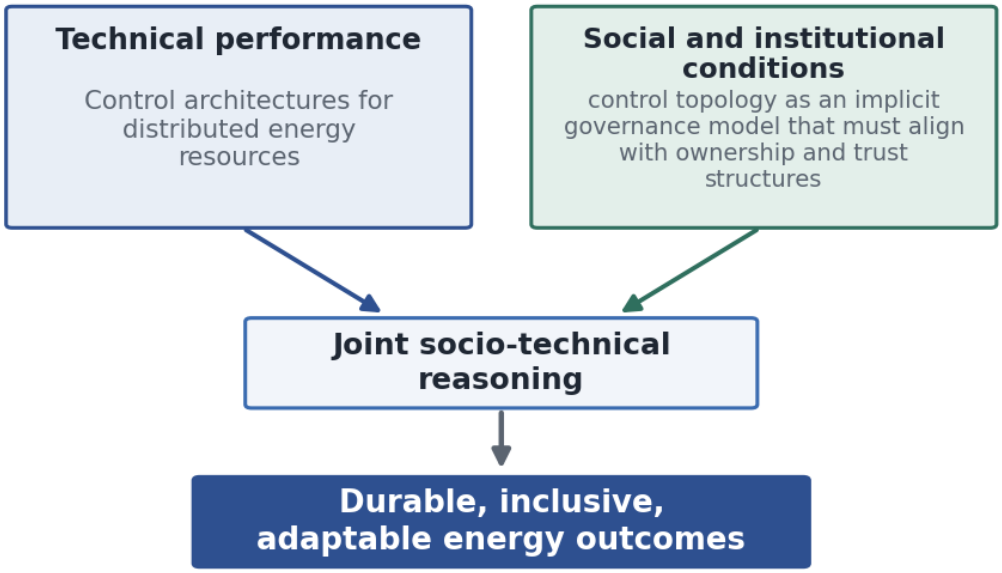

Figure 1. Technical performance and social conditions as jointly determining durable, inclusive outcomes.

This review is organized around a socio-technical understanding of energy systems, in which technical artifacts and social arrangements are treated as mutually constitutive rather than as separate domains joined only at the point of deployment (Arumosoye & Obriki, 2018). From this vantage, a control scheme, a financing structure, or an algorithm is simultaneously a technical object and a social arrangement that distributes capability, cost, and risk (Ambali et al., 2021). The review applies this lens to control architectures for distributed energy resources in order to clarify what is known, to expose where the prior literature has been thinnest, and to identify the conceptual moves needed to integrate technical and social analysis. The aim is synthesis and reframing rather than the reporting of new measurements, and the contribution lies in the organization and interpretation it offers (Lilian et al., 2020).

A recurring theme in the literature on control architectures for distributed energy resources is that interventions which appear similar in technical terms can produce markedly different outcomes across settings, a divergence that reflects the influence of social, institutional, and contextual factors that conventional technical evaluation leaves unmeasured (Arumosoye & Obriki, 2022). This review treats that divergence as the central puzzle to be explained, and it surveys how different bodies of work have approached it, from techno-economic analyses that emphasize cost to justice-oriented scholarship that emphasizes distribution and procedure. By placing these approaches alongside one another, the review seeks to show that each captures part of a larger picture and that an integrated account is both possible and necessary for understanding durability in resource-dependent regions (Arumosoye & Obriki, 2019; Arumosoye & Obriki, 2021; Anene & Clement, 2022). (Dada et al., 2021b).

The diversity of the contexts in which control architectures for distributed energy resources is deployed, spanning climate, institutional maturity, and economic circumstance, means that lessons drawn in one setting do not transfer automatically to another, and the review attends throughout to

this problem of generalization (Collath, 2021). Much of the literature is grounded in particular cases, and while such studies are valuable, their findings are difficult to combine into cumulative knowledge without a framework for distinguishing what is general from what is context-specific. The review treats this difficulty as one of the central obstacles to progress in the field, and its synthesis is organized so as to separate the regularities that recur across settings from the particulars that vary (Bednar et al., 2017; Bhattacharyya et al., 2021; Lilian et al., 2020).

A further concern of the review is the geography of scholarly attention, which does not match the geography of need, since research effort has concentrated in well-resourced settings while the regions where energy poverty is most acute remain comparatively understudied (Dagodzo & Patrick, 2020). The review is positioned deliberately against this imbalance, drawing its questions and its framing from the conditions of the underserved and resource-dependent regions that are its concern. In doing so it seeks to ensure that the synthesis it offers is relevant to the settings that need it most, rather than reproducing a body of knowledge calibrated to contexts whose conditions differ fundamentally from those in which control architectures for distributed energy resources must actually perform (Dagodzo, 2018a; Dagodzo, 2018b).

The review is also attentive to the way the indicators used to judge success shape the interventions that get designed, since what is measured tends to be what is optimized (Dagodzo & Patrick, 2022). The predominance of technical and unit-cost metrics in the literature has, on this reasoning, steered a generation of interventions toward those dimensions while leaving the conditions governing durability comparatively neglected. The review treats this as a consequential observation rather than a methodological aside, arguing that broadening the set of measured outcomes is a precondition for broadening what design seeks to achieve, and it returns to this theme in setting out the conceptual directions it proposes for control architectures for distributed energy resources (Dagodzo & Patrick, 2021a; Dagodzo & Patrick, 2021b).

The review treats control architectures for distributed energy resources as a field whose central difficulty is integration rather than discovery, since the constituent insights largely exist but remain dispersed across traditions that do not communicate (Ewim et al., 2021). The task it sets itself is therefore to assemble these insights into a coherent account, identifying where they reinforce one another and where they conflict, so that the field can move from a collection of partial perspectives toward a shared understanding of how technical capability and social legitimacy jointly govern outcomes (Dagodzo et al., 2022). This orientation shapes the selection and organization of the literature the review goes on to examine. The review carries this concern through its synthesis of the technical and social scholarship that follows (Anene & Clement, 2022).

The review is concerned less with adjudicating between technical and social explanations than with showing why both are necessary and how they fit together (Ijiga et al., 2022). It argues that explanations confined to either dimension are incomplete, and that the durability of interventions can be understood only by attending to the interaction of the two (Guerrero et al., 2013). This integrative ambition shapes the organization of the review, which is structured to bring technical and social scholarship into sustained dialogue rather than to treat them in separate compartments. This consideration informs the themes the review treats as central and the gaps it regards as most consequential. Acknowledging this, at the outset frames the integrative reading the review develops in subsequent sections (Lilian et al., 2020).

The review takes the divergence of outcomes across similar interventions as the puzzle that motivates its synthesis, treating that divergence as evidence that unmeasured social and institutional factors are at work (Jessel et al., 2019). By surveying how different literatures have approached this puzzle, it builds toward an account in which the divergence is explained rather

than merely noted, and it uses that account to identify the conceptual tools the field would need to anticipate, rather than merely observe, the conditions under which interventions succeed or fail (International Energy Agency, n.d.). This premise distinguishes the review from surveys that treat technical and social scholarship in isolation. This concern guides the way the review weighs and combines the studies it surveys.

The review situates control architectures for distributed energy resources within the larger project of inclusive energy transition, arguing that the questions it raises are not peripheral but central to whether that transition succeeds (Mbonu et al., 2020a). The regions where the field operates are those where the transition is most consequential and most fraught, and the review treats the durability and inclusiveness of interventions there as bearing directly on the prospects for a transition that is both rapid and fair, which is the wider purpose its synthesis is ultimately meant to serve (Liu et al., 2014). The review keeps this consideration in view as it moves from technical to socio-technical scholarship. This orientation explains the emphasis the review places on integration over enumeration.

It bears emphasis at the outset that this review is concerned with control architectures for distributed energy resources as it operates in resource-dependent and underserved regions specifically, rather than in the well-resourced settings where much of the literature has been produced (Mbonu et al., 2022a). This focus shapes which questions the review treats as central and which findings it regards as most relevant, since conditions that can be assumed in better-resourced contexts cannot be assumed in the settings of concern here. The review is explicit about this orientation because it bears directly on the external validity of the literature it surveys, and it reads that literature throughout with attention to whether its conclusions are likely to hold where they matter most (Mbonu et al., 2021a; Mbonu et al., 2021b).

The review proceeds on the understanding that a synthesis is valuable precisely when a field has accumulated substantial but fragmented knowledge, which is the situation it finds in control architectures for distributed energy resources (Mbonu et al., 2021c). Rather than adding new findings, the review's contribution lies in organizing existing ones into a coherent account that reveals patterns, tensions, and gaps not visible from within any single study or tradition. This understanding of the purpose of review shapes this paper throughout, orienting it toward interpretation and integration rather than enumeration, and it explains why the review is structured around themes and arguments rather than around a catalogue of the works it considers (Mbonu et al., 2019a; Mbonu et al., 2020b).

A premise of the review is that the apparent disagreements in the literature on control architectures for distributed energy resources often reflect differences in the conditions studied rather than genuine contradictions, so that findings which appear to conflict can frequently be reconciled once their contexts are taken into account (Middlemiss, 2022). The review treats the reconciliation of such apparent conflicts as part of its task, since doing so reveals the conditions under which particular findings hold and thereby contributes to the transferable understanding the field requires. This premise informs the review's interpretive stance, which seeks to make sense of the literature as a whole rather than to adjudicate isolated disputes within it (Mbonu et al., 2022b; Mbonu et al., 2019b). This review attends throughout to the gendered dimension of control architectures for distributed energy resources, since the literature increasingly documents that energy poverty and energy access affect women and men differently, and that interventions can either narrow or widen these disparities (Nnaji et al., 2019). The review treats gender not as a separate topic but as a dimension cutting across the conditions it examines, on the premise that an account of inclusive transition that overlooks gender would be incomplete. By foregrounding this dimension where the

literature addresses it, the review aims to ensure that its synthesis reflects the distributional realities within communities and not only the aggregate outcomes that obscure them (Muhtadi et al., 2021; Mutambatsere, 2022; Anene & Clement, 2022).

The review is attentive to the environmental context of control architectures for distributed energy resources, since the regions it concerns frequently combine demanding operating conditions with heightened exposure to climate change, making environmental resilience integral to the durability it examines (Obogo et al., 2020a). The review reads the literature with attention to how interventions perform under these conditions and to whether their durability accounts for environmental stress (Nnaji et al., 2020). This attention reflects the review's broader argument that durability cannot be assessed apart from the conditions of deployment, of which the environmental conditions are among the most demanding in the settings the review addresses. This consideration shapes which findings the review treats as most relevant to durability.

A concern running through the review is the lifecycle perspective on cost and affordability, since the literature documents that interventions affordable to build can prove unaffordable to operate and maintain, undermining the durability they were meant to secure (Obogo et al., 2021a). The review treats affordability as a condition extending over the full life of a system rather than as a matter settled at installation, and it reads the literature with attention to whether it accounts for ongoing costs. This lifecycle concern reflects the review's emphasis on durability, and it identifies the neglect of operating and maintenance costs as a recurring limitation in the literature on control architectures for distributed energy resources (Obogo et al., 2020b; Obogo et al., 2020c).

The review also attends to the measurement problem that has limited the integration of social factors into the analysis of control architectures for distributed energy resources, since the difficulty of quantifying conditions such as control topology as an implicit governance model that must align with ownership and trust structures has often been treated as grounds for their exclusion (Obogo et al., 2019a). The review surveys how the literature has handled this difficulty, and it treats the development of means to characterize social conditions systematically as a central need (Obogo et al., 2021b). This concern with measurement reflects the review's broader argument that the field's difficulty with social factors is methodological rather than evidence of their unimportance, and it anticipates the conceptual directions the review proposes. The review carries this premise into the critical assessment it develops later.

It is useful to state what a review of this kind can and cannot achieve, since its contribution lies in synthesis and interpretation rather than in the generation of new data (Odejobi & Ahmed, 2018). By drawing together a literature on control architectures for distributed energy resources that has developed across several traditions, the review aims to reveal patterns, tensions, and gaps that are not visible from within any single study, and to advance a reading of what the literature collectively implies. Its value is to be judged by the coherence and usefulness of the account it constructs, and the review is explicit that the integration it offers involves interpretive judgment, which it sets out transparently so that readers can assess the synthesis on its merits (Obogo et al., 2019b; Obogo et al., 2021c). The review proceeds from the observation that the literature on control architectures for distributed energy resources contains a recurring disjunction between the criteria emphasized in research and the criteria that determine outcomes in deployment (Okonkwo et al., 2020). Studies tend to foreground technical performance and cost, while field experience points to durability and inclusion as the decisive considerations, and the review treats this disjunction as a central object of analysis. By tracing how it arises and what it implies, the review builds toward an argument that the field's prevailing criteria are too narrow, and that an integrated account attentive to the social

determinants of durability is needed to close the gap between what is studied and what matters (OECD, n.d.; Ogunwole et al., 2021).

2. Scope and Review Approach

The review's framing of control topology as an implicit governance model draws on a strand of infrastructure scholarship that has documented how technical design choices embed institutional assumptions about authority, accountability, and the distribution of decision-making power among system participants (Jasanoff, 2004; Winner, 1980). The choice between centralized and decentralized control architectures for distributed energy resources is not only a technical question about communication bandwidth and computational load but a social and political question about who controls what, who benefits from control, and who bears the costs of control failures. By foregrounding this governance dimension, the review positions control architecture as a subject of socio-technical inquiry alongside the purely technical literature that has dominated prior treatments of the field. A significant methodological consideration in the review concerns the selection and synthesis of literature that spans computer science, electrical engineering, operations research, and social studies of technology, since these traditions use different vocabularies and evaluate contributions by different criteria (Tranfield et al., 2003). The review addresses this challenge by defining its inclusion criteria in terms of the substantive questions the framework addresses, namely how control architectures govern the behavior of distributed energy resources, rather than in terms of the disciplinary origin of the work. This cross-disciplinary scope is essential to the review's claim that technical and social dimensions of control architecture are inseparable, and it provides a basis for synthesis across literatures that have rarely been read together.

The temporal scope of the review reflects the period during which distributed energy resource integration emerged as a priority concern for grid operators and regulators, beginning with the initial deployment of large numbers of solar and wind generators and extending through the period when battery storage, electric vehicles, and responsive loads began to constitute significant shares of distributed capacity (IEA, 2021). This period witnessed both substantial technical advances in control methodology and equally significant changes in the regulatory and market environments that shape how control architectures are designed and deployed. The review attends to both dimensions, treating the co-evolution of technical capabilities and institutional arrangements as a defining feature of the period it examines rather than as parallel developments to be separately summarized. A further dimension of the review's scope concerns the geographic diversity of the control architecture literature, since the mix of distributed resources, grid conditions, regulatory frameworks, and social contexts differs substantially across national and regional contexts (IRENA, 2022). Technical solutions developed in the context of highly interconnected European grids may not transfer directly to the isolated or weakly connected grid regions of sub-Saharan Africa, Southeast Asia, or Pacific island communities, where the technical requirements and social conditions of distributed resource control are different. The review attends to this geographic diversity, identifying where findings are likely to generalize and where they require contextual adaptation, and it draws lessons that are relevant to the diverse settings in which distributed energy resource control is being deployed. The review also positions itself against the tendency to treat control architecture as a purely present-tense technical question, noting that architecture choices made today commit grid systems to particular institutional arrangements and technical dependencies that may be difficult to revise (Winner, 1980; Jasanoff, 2004). The path-dependence of infrastructure means that the governance implications of current control architecture choices will shape the options available to future grid operators and regulators in ways that cannot always

be fully anticipated at the time of decision. By making this long-term institutional dimension explicit, the review adds a temporal depth to the analysis of control architecture that purely technical reviews lack, and it argues that the governance implications of architecture choices should be assessed prospectively rather than managed retrospectively.

The scope of this review encompasses the scholarship bearing on control architectures for distributed energy resources across the engineering, economic, development, and energy-justice literatures, selected and organized so as to bring these traditions into dialogue rather than to catalogue them separately (Okonkwo et al., 2018b). The review approach is interpretive and synthetic: rather than enumerating studies, it identifies the themes that recur across them, the assumptions that underpin them, and the gaps that separate them, with the aim of constructing an integrated account. This approach is suited to a field whose central difficulty is precisely the separation of its constituent literatures, and it reflects the review's purpose, which is to clarify and reframe rather than to measure (Okonkwo et al., 2021a; Okonkwo et al., 2018a).

In organizing the literature, the review distinguishes between work that addresses the technical dimensions of control architectures for distributed energy resources and work that addresses its social and institutional dimensions, while treating this distinction as a convenience to be transcended rather than a fundamental division (Oladoye et al., 2022). The two bodies of work are read against one another throughout, on the premise that their separation is the source of the field's central limitation. The review pays particular attention to studies that attempt to bridge the divide, since these point toward the integrated approach it advocates, and it treats the relative scarcity and the limitations of such studies as evidence of the gap it seeks to characterize (Okonkwo et al., 2021b; Okwu et al., 2021). The review approach also attends explicitly to the conditions under which findings were obtained, distinguishing results drawn from controlled or simulated settings from those grounded in field experience, since this distinction bears directly on the external validity of the conclusions (Patrick et al., 2021). By foregrounding the realism of the conditions behind each strand of work, the review is able to assess not only what the literature claims but how far those claims are likely to hold in the resource-constrained settings that are its concern. This attention to conditions is a deliberate feature of the approach, reflecting the review's broader argument that the value of a finding cannot be assessed apart from the context in which it was produced within control architectures for distributed energy resources (Oyeleye et al., 2022; Patrick et al., 2020). An additional aspect of the review approach concerns its synthetic rather than enumerative character, since the aim is not to provide an exhaustive catalogue of studies but to construct an integrated interpretation of what the literature, taken together, reveals about control architectures for distributed energy resources (Sunday & Omoegun, 2018). This approach involves identifying the assumptions, themes, and gaps that characterize the field, and reading individual contributions in light of the larger picture they collectively compose. It is suited to the review's purpose, which is to clarify and reframe a fragmented body of work, and it reflects the judgment that the field's central need is not more catalogues of what has been done but a coherent account of what it all amounts to and where it must go next (Shittu et al., 2019; Smith, 2017).

A further aspect of the review approach concerns the breadth of literatures it brings into dialogue, since understanding control architectures for distributed energy resources as a socio-technical concern requires drawing on engineering, economics, development studies, and energy justice, among others (Wustenhagen et al., 2007). The review treats this breadth as necessary rather than incidental, on the premise that the determinants of durability span all of these fields and cannot be apprehended from within any one. Bringing such varied literatures into a single synthesis is demanding, but the review argues that it is precisely the integration of these perspectives that the

field most needs, and that the value of the review lies in the connections it draws across them (Sunday & Omoegun, 2019; World Resources Institute, n.d.).

The review approach is also explicitly interpretive, in that it does not merely report what the literature contains but advances a reading of what it collectively reveals about control architectures for distributed energy resources (Ahmad et al., 2020). This interpretive stance is appropriate to the review's purpose, which is to reframe a fragmented field rather than to catalogue it, and it is reflected in the organization of the synthesis around themes and gaps rather than around individual studies. The review is transparent that this involves judgment, and it sets out the reasoning behind its interpretation so that readers can assess it, in keeping with the standards of rigor appropriate to a conceptual contribution (Yeboah & Ike, 2020; Agbabiaka et al., 2019).

The review approach is interpretive and synthetic rather than enumerative, aiming to construct a coherent account of what the literature collectively reveals about control architectures for distributed energy resources rather than to catalogue individual studies (Ambali et al., 2021). This approach is suited to a field whose central need is integration, and it involves identifying the themes, assumptions, and gaps that characterize the literature as a whole (Ahmed et al., 2020). The review is transparent that this involves judgment, and it sets out its reasoning so that readers can assess the interpretation it advances, in keeping with the standards appropriate to a conceptual contribution. This aspect of the approach reflects the review's purpose of integration rather than enumeration. The scope deliberately spans several literatures, including engineering, economics, development studies, and energy justice, on the premise that the determinants of durability in control architectures for distributed energy resources cut across all of them and cannot be apprehended from within any one (Arumosoye & Obriki, 2019). Bringing such varied bodies of work into a single synthesis is demanding, but the review treats this breadth as necessary rather than incidental, arguing that the integration of these perspectives is precisely what the field most needs and what gives the review its value (Arumosoye & Obriki, 2018). The review adopts this aspect of its approach in service of the integrated account it seeks to construct. This element of the approach shapes which findings the review treats as relevant to durability.

The review approach attends explicitly to the conditions under which findings were obtained, distinguishing results from controlled or simulated settings from those grounded in field experience, since this distinction bears on the external validity of conclusions (Bednar et al., 2017). By foregrounding the realism of the conditions behind each strand of work, the review assesses not only what the literature claims but how far those claims are likely to hold in the resource-constrained settings that are its concern, reflecting its broader argument that a finding's value cannot be judged apart from its context in control architectures for distributed energy resources. In view of this, the review organizes its synthesis around themes and arguments rather than individual studies (Arumosoye & Obriki, 2021; Arumosoye & Obriki, 2022).

A further aspect of the review approach concerns its treatment of disciplinary boundaries, which it crosses deliberately on the premise that the determinants of durability in control architectures for distributed energy resources do not respect the divisions between engineering, economics, and social science (Collath, 2021). The review reads across these boundaries throughout, treating their separation as a feature of the field's organization to be overcome rather than a natural division of the subject (Bhattacharyya et al., 2021). This cross-disciplinary scope is demanding, requiring engagement with literatures that employ different vocabularies and methods, but the review treats it as essential to the integrated account it seeks to construct. This aspect of the approach reflects the review's conviction that a synthesis should serve the improvement of practice.

The review approach also involves explicit attention to the assumptions underlying the works it surveys, since the review's central argument concerns the consequences of assumptions that idealize the conditions of deployment (Dagodzo, 2018b). By foregrounding these assumptions, the review is able to assess not only what the literature claims but the conditions under which its claims hold, which bears directly on their relevance to the resource-dependent settings of concern (Dagodzo, 2018a). This attention to assumptions is a deliberate feature of the approach, reflecting the review's broader argument that the value of a finding cannot be assessed apart from the conditions it presupposes. This aspect of the approach reflects the review's purpose of integration over enumeration. A related aspect of the review approach concerns its orientation toward the construction of an argument rather than the compilation of a survey, since the review advances a thesis about the interdependence of technical and social factors in control architectures for distributed energy resources and organizes its treatment of the literature in support of that thesis (Dagodzo & Patrick, 2021b). This argumentative orientation distinguishes the review from a neutral catalogue, and the review is transparent about it, setting out its thesis and the reasoning behind it so that readers can assess the interpretation it offers. The approach reflects the review's purpose, which is to reframe a field rather than merely to describe it (Dagodzo & Patrick, 2020; Dagodzo & Patrick, 2021a).

The review approach attends, finally, to the relationship between the literature and the practical concerns of the settings in which control architectures for distributed energy resources operates, reading scholarship with attention to its bearing on the durability and inclusiveness of real interventions (Ewim et al., 2021). This practical orientation shapes which themes the review treats as central and which gaps it regards as most consequential, anchoring the synthesis in the outcomes that matter for the populations served. The approach reflects the review's conviction that a synthesis of the literature should ultimately serve the improvement of practice, and it orients the review toward the conditions that bear on real-world outcomes (Dagodzo & Patrick, 2022; Dagodzo et al., 2022). A further aspect of the review approach concerns its attention to lifecycle considerations, since the review reads the literature with attention to whether it accounts for the costs and conditions of operation over the full life of a system rather than only at installation (International Energy Agency, n.d.). This attention reflects the review's emphasis on durability, and it shapes its assessment of which findings are relevant to the sustained performance the review treats as central. The approach thus distinguishes studies that consider the working life of interventions from those confined to their deployment, on the reasoning that durability is determined over time rather than at the moment of commissioning in control architectures for distributed energy resources (Guerrero et al., 2013; Ijiga et al., 2022).

The review approach also attends to the distributional dimensions of the literature, reading studies with attention to whether they address how benefits and burdens fall within as well as between communities, including along lines of gender (Liu et al., 2014). This attention reflects the review's treatment of distribution as encompassing intra-community differences, and it shapes its assessment of whether the literature addresses the disparities that determine genuine inclusion (Jessel et al., 2019). The approach thus foregrounds distributional considerations that aggregate analyses obscure, in keeping with the review's broader concern with the inclusiveness of interventions in control architectures for distributed energy resources. The review adopts this in service of the integrated account it seeks to construct.

A further aspect of the review approach concerns its attention to environmental conditions, since the review reads the literature with attention to whether it accounts for the demanding and changing conditions under which systems in the regions of concern must operate (Mbonu et al., 2021b). This

attention reflects the review's argument that durability cannot be assessed apart from the conditions of deployment, and it shapes its assessment of the reliability of findings about whether interventions endure. The approach thus distinguishes studies attentive to environmental resilience from those that assume favorable conditions, in keeping with the review's emphasis on durability under realistic conditions in control architectures for distributed energy resources (Mbonu et al., 2020a; Mbonu et al., 2021a).

A concluding note on the review approach is that it has been guided throughout by the conviction that the value of a synthesis lies in the connections it draws across a fragmented literature, rather than in the comprehensiveness of its coverage of any single strand (Mbonu et al., 2020b). The review has accordingly prioritized the integration of perspectives over the exhaustive treatment of any one, on the premise that the central need of control architectures for distributed energy resources is the bringing together of knowledge that has developed in isolation. This note clarifies the basis on which the review has selected and organized the literature, and it situates the synthesis that follows as an exercise in integration rather than enumeration (Mbonu et al., 2022a; Mbonu et al., 2019a). A complementary aspect of the review approach concerns the principles by which it has selected and weighed the literature, since a synthesis of this kind must decide which work to foreground and how to assess competing findings (Mbonu et al., 2019b). The review has prioritized work that bears on the durability and inclusiveness of interventions in resource-dependent settings, and it has weighed findings according to the realism of the conditions under which they were obtained, on the reasoning that relevance to the settings of concern is the appropriate criterion. The review is transparent about these principles so that its synthesis can be assessed, and they reflect its broader purpose of constructing an account useful to practice in control architectures for distributed energy resources (Mbonu et al., 2021c; Mbonu et al., 2022b).

The review approach also involves a deliberate orientation toward the construction of an argument rather than the neutral compilation of a survey, since the review advances a thesis about the interdependence of technical and social factors and organizes its treatment of the literature in support of that thesis (Mutambatsere, 2022). This argumentative orientation is appropriate to the review's purpose of reframing a fragmented field, and the review sets out its thesis and reasoning explicitly so that readers can evaluate them. For control architectures for distributed energy resources, the approach reflects the conviction that the field's central need is not another catalogue of what has been done but a coherent account of what it amounts to and where it must go (Middlemiss, 2022; Muhtadi et al., 2021).

3. Thematic Synthesis: Technical Dimensions

The technical synthesis identifies a set of fundamental trade-offs in control architecture design that have been recognized across the literature, including the trade-off between optimality and robustness, the trade-off between communication efficiency and control performance, and the trade-off between algorithmic complexity and practical implementability in resource-constrained field environments (Guerrero et al., 2013; Bidram & Davoudi, 2012). These trade-offs do not have universal resolutions; the optimal balance depends on the specific mix of resources, the grid conditions, and the operational requirements of the context. The synthesis's contribution is to organize the literature's findings in terms of these trade-offs, identifying where particular architectural choices have been shown to shift the balance and under what conditions each position along the trade-off frontier is most appropriate. A major finding of the technical synthesis concerns the convergence of hierarchical and decentralized approaches in the literature, as researchers have increasingly recognized that neither pure centralized control nor pure decentralized control is

optimal across the full range of operating conditions, and that practical architectures require mechanisms for coordinating decentralized local decisions with centralized information and objectives (Olivares et al., 2014; Molzahn et al., 2017). Hierarchical control architectures, which organize control functions across multiple layers with different timescales and information requirements, have emerged as a framework for capturing the benefits of both approaches, and a substantial part of the technical literature reviewed here concerns the design of the inter-layer communication and coordination mechanisms that hierarchical architectures require. The synthesis identifies the design principles that have emerged from this work, and it assesses their robustness across the diverse conditions in which distributed energy resource control is deployed.

The synthesis also finds a growing body of work on the cybersecurity implications of control architecture choices, since architectures that rely on communication infrastructure are exposed to cyber attacks that can undermine control performance or cause physical damage to the energy system (IEA, 2021). The degree of communication dependence of an architecture, the structure of the communication network it uses, and the vulnerabilities of the control algorithms to adversarial inputs are all architecture-level design considerations with significant security implications. The synthesis identifies cybersecurity as a dimension of control architecture evaluation that has grown rapidly in importance and argues that future architecture design must treat security as a first-order constraint rather than an afterthought, particularly as the attack surface of distributed control systems expands with the proliferation of internet-connected devices.

A further finding of the technical synthesis concerns the scalability challenges that distributed energy resource control faces as the number of participating devices grows and the diversity of their capabilities and constraints expands (Bidram & Davoudi, 2012; Guerrero et al., 2013). Architectures designed for grids with hundreds of distributed resources may not scale effectively to grids with millions, and the computational, communication, and algorithmic challenges of controlling at scale have motivated a distinct research agenda on scalable distributed optimization and multi-agent coordination. The synthesis reviews this literature, identifying the most promising approaches to scalable control and the conditions under which they achieve their claimed performance benefits, while also noting the gap between the performance demonstrated in simulations and the performance achieved in heterogeneous, real-world deployments (Lilian et al., 2020). The synthesis also considers the technical literature on demand response and flexible load control as a dimension of distributed energy resource architecture, since the participation of responsive loads in grid balancing services changes both the optimization problem and the governance implications of control architecture design (Molzahn et al., 2017; IRENA, 2022). When loads are controllable assets that participate in control alongside generation and storage, the question of who controls what becomes more complex and the governance implications of architecture choices more significant. The synthesis identifies the technical requirements for effective demand response integration, the architectures that have been shown to accommodate it most effectively, and the interface between demand response control and the broader distributed energy resource management challenge that the review addresses.

Synthesizing the technical literature on control architectures for distributed energy resources reveals a field that has made substantial progress in capability while remaining comparatively silent on the conditions under which that capability is realized in deployment (Obogo et al., 2020a). Across the studies reviewed, performance is most often reported under assumptions of reliable infrastructure, adequate maintenance, and stable operation, and the reported frontiers are correspondingly optimistic relative to field experience in resource-constrained settings. This pattern is not a criticism of individual studies, which are typically rigorous within their own terms,

but an observation about the literature as a whole, namely that its dominant framing tends to abstract away precisely the conditions that determine whether technical promise translates into durable service (Nnaji et al., 2019; Nnaji et al., 2020).

A second theme in the technical synthesis is the recurring tension between optimization for peak performance and design for robustness under adverse conditions, a tension that the literature acknowledges but rarely resolves in favor of the latter (Obogo et al., 2021a). Studies oriented toward maximal efficiency tend to assume the supporting conditions that resource-dependent regions cannot guarantee, while the smaller body of work oriented toward robustness accepts lower nominal performance in exchange for resilience. Reading these strands together suggests that the appropriate balance is context-dependent and that the field would benefit from framing the choice explicitly as a design decision with social as well as technical consequences, rather than treating peak performance as the default objective (Obogo et al., 2020b; Obogo et al., 2020c).

A third theme is the growing technical sophistication of monitoring, control, and analytics, which has made it increasingly feasible to observe and manage systems in detail, yet which also raises the capability and connectivity required to operate them (Obogo et al., 2019b). The technical literature documents impressive gains in what such tools can do, but it less often examines whether the conditions for using them, including skilled staff, reliable connectivity, and sustained budgets, are present in the settings that would benefit most. This synthesis therefore reads the advances alongside their preconditions, arguing that within control architectures for distributed energy resources the value of a technical capability cannot be assessed apart from the conditions required to sustain it (Obogo et al., 2021b; Obogo et al., 2019a; Basnet et al., 2021).

A further theme in the technical synthesis concerns the assumptions about supporting infrastructure that pervade the literature, including reliable communication, stable power quality, and continuous availability of skilled maintenance, none of which can be taken for granted in the settings that are the concern of this review (OECD, n.d.). Where studies make these assumptions explicit, their conclusions can be appropriately qualified, but where the assumptions remain implicit, the reported performance may mislead. The synthesis therefore reads the technical literature with particular attention to its assumptions, treating the realism of those assumptions as a key determinant of how far a finding is likely to hold in the resource-constrained contexts in which control architectures for distributed energy resources must actually operate (Obogo et al., 2021c; Odejobi & Ahmed, 2018).

A connected consideration in the technical synthesis is the degree to which reported advances have been validated under conditions resembling those of resource-dependent regions, as opposed to controlled or well-resourced settings (Okonkwo et al., 2021a). The synthesis finds that validation under realistic conditions is comparatively scarce, which limits confidence that reported performance will be realized in the field. This observation reinforces the review's broader argument that the value of a technical capability cannot be assessed apart from the conditions required to realize it, and it identifies the scarcity of field validation in representative settings as a significant limitation of the current technical literature (Ogunwole et al., 2021; Okonkwo et al., 2020). Reading the technical literature as a whole, the synthesis observes a tendency to treat the supporting conditions for performance as external to the engineering problem, with the result that those conditions are neither analyzed nor designed for within the technical work itself (Okonkwo et al., 2021b). This tendency, the synthesis argues, is precisely what leaves the technical literature unable to explain the gap between laboratory promise and field outcome, since the explanation lies in conditions the literature sets aside. The synthesis therefore calls for a technical literature that internalizes the conditions of deployment rather than abstracting them away, which is the direction

the conceptual integration it advocates would encourage (Okonkwo et al., 2018a; Okonkwo et al., 2018b). The technical synthesis emphasizes that capability and dependability are distinct achievements, and that the literature has advanced the former more than the latter in the settings the review addresses (Oladoye et al., 2022). Dependable performance under adverse, variable, and under-supported conditions remains harder to secure than peak performance under favorable ones, and the synthesis treats this asymmetry as a key feature of the technical literature (Okwu et al., 2021). Within this context, it argues that the field's progress should be assessed by dependability in realistic conditions rather than by capability demonstrated under ideal ones. This theme reinforces the synthesis's broader argument about the dependence of performance on the conditions of deployment. The technical synthesis observes that the literature's treatment of operating conditions is frequently idealized, with the consequence that reported performance reflects what is achievable under assumptions that resource-dependent settings cannot satisfy (Patrick et al., 2020). By foregrounding the realism of these assumptions, the synthesis is able to assess how far technical findings are likely to hold in the field, and it consistently finds that the gap between assumed and actual conditions is large enough to qualify many reported results (Oyeleye et al., 2022). This observation anchors the review's broader argument about the dependence of performance on context. The synthesis treats this as evidence that technical capability cannot be assessed apart from its operating context. The technical synthesis notes that advances in capability have often raised the resources required to deploy and operate systems, creating a tension between sophistication and accessibility (Shittu et al., 2019). The literature documents impressive gains in what systems can do alongside relatively little attention to whether the conditions for using them are present where they are needed (Patrick et al., 2021). For problems of this kind, the synthesis treats this tension as central, arguing that a technical advance whose preconditions cannot be met in the target setting offers little to the populations the field is meant to serve. This observation connects the technical literature to the social conditions examined in the following section.

A theme that the technical synthesis brings to the fore is the trade-off between performance and robustness, since designs optimized for maximal output under favorable conditions often prove fragile under the adverse and variable conditions of resource-dependent settings (Sunday & Omoegun, 2019). The literature documents both ends of this spectrum, but it less often frames the choice between them explicitly as a design decision with social consequences. The synthesis argues that within control architectures for distributed energy resources this choice should be made deliberately rather than by default, since the appropriate balance depends on conditions that vary across settings and that bear directly on whether a system endures in service (Smith, 2017; Sunday & Omoegun, 2018). The technical synthesis also draws attention to the increasing role of software, data, and connectivity in the systems that constitute control architectures for distributed energy resources, a development that expands capability while introducing new dependencies (Wustenhagen et al., 2007). The literature documents impressive gains in what data-driven and connected systems can achieve, alongside relatively little examination of whether the conditions for using them, including reliable connectivity and the capacity to manage them, are present in the target settings (World Resources Institute, n.d.). The synthesis treats this as a significant theme, since it bears on whether advances in digital capability translate into durable benefit where infrastructure and capacity are limited. Acknowledging this, in the technical literature motivates the integrated approach the review ultimately advocates (Basnet et al., 2021).

A further theme concerns the maturity and reliability of the core technologies underlying control architectures for distributed energy resources, which the synthesis finds to be well established in many respects while noting that their performance in the field depends heavily on conditions the

literature often assumes (Ahmad et al., 2020). The technologies themselves are, for the most part, capable; what is less settled is how they behave under the maintenance, environmental, and operational conditions of resource-dependent settings. The synthesis treats this gap between demonstrated capability and field behavior as central, since it locates the explanation of many disappointing outcomes not in the technology but in the conditions surrounding its use (Yeboah & Ike, 2020; Agbabiaka et al., 2019).

The technical synthesis observes that the literature has devoted considerable effort to optimization and comparatively less to the questions of integration and system-level behavior that determine outcomes in practice (Ambali et al., 2021). Studies frequently optimize individual components or functions while giving less attention to how these interact within a complete system operating under realistic conditions (Ahmed et al., 2020). In such settings, the synthesis argues that this emphasis has produced detailed knowledge of parts alongside a thinner understanding of wholes, and that system-level behavior under the conditions of deployment warrants greater attention than the optimization-focused literature has given it. This theme illustrates the gap between demonstrated capability and durable field performance in resource-dependent settings (Lilian et al., 2020).

A final theme in the technical synthesis concerns the assumptions about the human and institutional environment that are embedded, often implicitly, in technical designs, including assumptions about who will operate, maintain, and manage a system (Arumosoye & Obriki, 2019). The literature tends to treat these as given rather than as conditions to be examined, with the result that designs may presuppose an environment that the target setting does not provide (Arumosoye & Obriki, 2018). The synthesis argues that within control architectures for distributed energy resources these embedded assumptions deserve explicit scrutiny, since the mismatch between assumed and actual environments is among the more common and consequential sources of failure the literature documents. This theme reinforces the synthesis's argument about the dependence of performance on its context.

A further theme in the technical synthesis concerns the relationship between technical design and lifecycle cost, since the literature documents that design choices bear heavily on the costs of operation, maintenance, and replacement that determine affordability over time (Bednar et al., 2017). Studies that consider only installation cost, the synthesis argues, misjudge the economic sustainability of the systems they evaluate. Applied to this domain, the synthesis treats lifecycle cost as a technical as well as an economic consideration, since the design of a system shapes the burden of sustaining it, and it identifies the neglect of lifecycle considerations as a limitation of much of the technical literature (Arumosoye & Obriki, 2021; Arumosoye & Obriki, 2022).

The technical synthesis also examines how designs accommodate the environmental conditions of resource-dependent regions, finding that the literature varies widely in the attention it gives to climatic stress, dust, humidity, and temperature extremes (Collath, 2021). Designs developed for temperate, well-supported settings frequently underperform under these conditions, and the synthesis treats environmental resilience as a technical dimension that the literature addresses unevenly (Bhattacharyya et al., 2021). On this account, this theme reinforces the synthesis's broader argument that technical performance cannot be assessed apart from the conditions of deployment, of which the environmental conditions are among the most demanding and least uniformly considered. The synthesis treats this as evidence that capability cannot be judged apart from deployment conditions.

Another theme concerns the extent to which technical designs are matched to the capacity available to operate and maintain them, since the synthesis finds that the literature often presupposes a level

of technical capability that resource-dependent settings cannot provide (Dagodzo & Patrick, 2020). Designs requiring expertise or resources beyond what is locally available tend to degrade regardless of their quality, and the synthesis treats the matching of design to capacity as a technical consideration the literature frequently neglects. For control architectures for distributed energy resources, this theme connects the technical and social dimensions directly, since the sustainability of a technical design depends on the human and institutional capacity to sustain it (Dagodzo, 2018a; Dagodzo, 2018b).

A concluding observation from the technical synthesis is that the literature, taken as a whole, describes a set of capabilities whose realization in the field depends on conditions it largely leaves unexamined, so that the gap between what the technologies can do and what they reliably achieve in resource-dependent settings remains incompletely understood (Dagodzo & Patrick, 2022). The synthesis treats the closing of this gap as a priority for control architectures for distributed energy resources, since it is in that gap that the difference between technical promise and durable service is determined, and it argues that doing so requires the integration of technical analysis with attention to the conditions of deployment that the technical literature has tended to set aside (Dagodzo & Patrick, 2021a; Dagodzo & Patrick, 2021b).

A further dimension of the technical synthesis concerns how the literature treats the relationship between laboratory or simulation results and field performance, since the two frequently diverge in ways that the literature acknowledges but does not always resolve (Guerrero et al., 2013). Results obtained under controlled conditions establish what is achievable in principle, while field experience reveals what is achievable under the constraints of resource-dependent settings, and the gap between them is precisely where the conditions governing durability operate. The synthesis treats this gap as a central feature of the technical literature on control architectures for distributed energy resources, arguing that the realism of the conditions under which a result was obtained should weigh heavily in assessing its relevance to deployment (Dagodzo et al., 2022; Ewim et al., 2021; Liadi, 2022).

The technical synthesis also considers how the literature handles the cumulative and interacting effects that arise when technologies are combined into complete systems, finding that component-level analysis predominates over system-level understanding (Jessel et al., 2019). Studies frequently characterize the behavior of individual technologies in isolation while giving less attention to the interactions that emerge when they operate together under field conditions. The synthesis argues that this emphasis leaves the field with detailed knowledge of parts alongside a thinner understanding of wholes, and that the behavior of complete systems under realistic conditions warrants greater attention than the prevailing component focus has afforded it (Ijiga et al., 2022; International Energy Agency, n.d.).

4. Thematic Synthesis: Socio-Technical Dimensions

The socio-technical synthesis finds that the governance implications of control architecture choices have been recognized in the literature but have rarely been systematically analyzed, leaving the field without a shared framework for reasoning about how technical design choices embed institutional arrangements (Jasanoff, 2004; Winner, 1980). The synthesis contributes to filling this gap by organizing the scattered observations about governance in the technical literature alongside the more developed accounts in the regulatory and social-science literature, identifying the dimensions along which architectures differ in their governance implications and the mechanisms through which these differences manifest. This synthesis positions the governance dimension of

control architecture not as a peripheral concern but as a central feature of the design problem that technical and regulatory communities must address together (Liadi, 2022).

A recurring theme in the socio-technical synthesis concerns the relationship between architecture choices and the distribution of economic value among distributed energy resource owners, grid operators, and energy consumers, since different control architectures create different market arrangements and different allocations of the value created by flexible distributed resources (Olivares et al., 2014). Architectures that aggregate distributed resources under centralized control may enable system-level efficiency gains but may also transfer economic value from resource owners to aggregators or operators; architectures that preserve resource owner autonomy may sustain stronger ownership incentives but may sacrifice some system-level optimization. The synthesis maps these distributional implications, treating them as a dimension of architecture evaluation alongside technical performance.

The synthesis also finds a growing literature on the social acceptance and community engagement dimensions of distributed energy resource control, since the households and small businesses that own controllable resources must agree to participate in control schemes and the terms of that participation shape both adoption rates and the governance structure of the resulting system (Wustenhagen et al., 2007). Acceptance of demand response and distributed storage control programs depends on factors including the perceived intrusiveness of the control, the clarity and fairness of the compensation arrangements, and the trust that participants have in the entities controlling their assets. The synthesis identifies these acceptance conditions as determinants of both the adoption rate and the stability of participation, arguing that they must inform architecture design as much as technical performance metrics.

A further dimension of the socio-technical synthesis concerns the regulatory and market frameworks that create the institutional context for distributed energy resource control architecture, since the viability of particular architectures depends on whether existing regulations permit the coordination arrangements they require and whether market structures create appropriate incentives for participation (IEA, 2021; IRENA, 2022). In many jurisdictions, regulations developed for centrally controlled power systems create barriers to distributed control architectures that require real-time coordination among resource owners, and the legal status of the data flows and control signals that distributed architectures involve may be ambiguous or contested. The synthesis documents these regulatory and market barriers, identifying where institutional reform is a precondition for deploying technically capable distributed control architectures.#A final theme in the socio-technical synthesis concerns the distributional implications of connectivity requirements, since distributed control architectures that require reliable broadband communication access to function effectively may effectively exclude participation by resource owners in underserved or rural areas where connectivity is limited (Winner, 1980; Jasanoff, 2004). If the value of distributed energy resource participation is accessible only to households and businesses with adequate connectivity, the transition to distributed control architectures may deepen existing inequalities in the distribution of energy benefits, creating a governance challenge that architecture design must address. The synthesis identifies connectivity equity as a socio-technical consideration that has been largely absent from the technical control architecture literature and argues for its inclusion as a design criterion alongside technical performance.

Synthesizing the socio-technical literature on control architectures for distributed energy resources brings into focus a body of evidence that performance in the field is shaped decisively by social and institutional conditions that technical evaluation typically omits (Mbonu et al., 2021a). Across

the studies reviewed, the conditions most consistently associated with durable outcomes, including participation, local capacity, governance legitimacy, and procedural fairness, recur with a regularity that suggests they reflect general features of how socio-technical systems behave rather than the idiosyncrasies of particular cases. This review treats that regularity as significant, reading it as evidence for the proposition that social conditions function as determinants of technical outcomes and not merely as context surrounding them (Liu et al., 2014; Mbonu et al., 2020a).

A central strand of this synthesis concerns control topology as an implicit governance model that must align with ownership and trust structures, which appears across the literature as a recurring but inadequately formalized influence on outcomes (Mbonu et al., 2019a). Studies repeatedly identify it as consequential, yet they less often render it in terms that would allow it to enter design and evaluation systematically, with the result that its influence is acknowledged in interpretation but excluded from analysis. This review draws these scattered observations together, arguing that the consistency with which the factor appears across otherwise diverse studies is itself reason to treat it as a first-order variable, and that the field's failure to measure it is a methodological gap rather than evidence of its unimportance (Mbonu et al., 2021b; Mbonu et al., 2022a). These themes and their relationships are mapped in Figure 2.

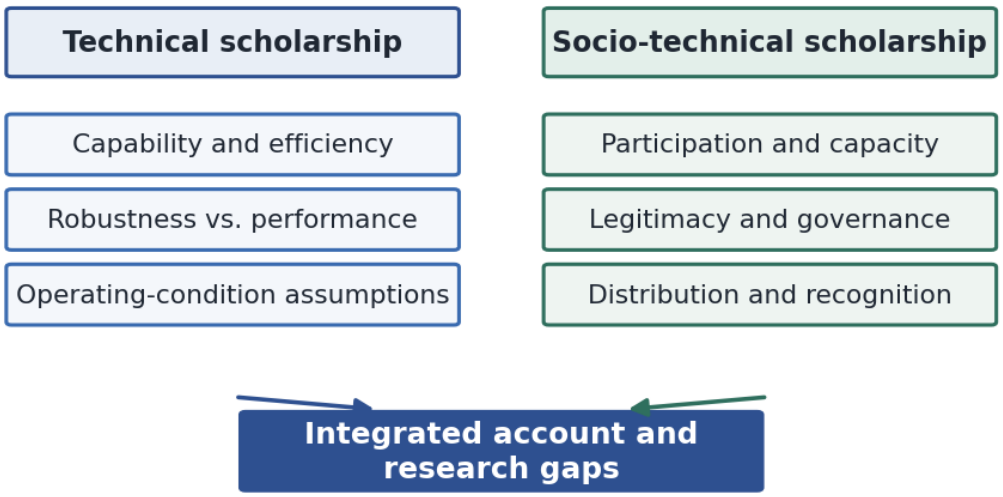

Figure 2. Thematic synthesis of the technical and socio-technical literature toward an integrated account.

An additional theme in the socio-technical synthesis concerns distribution, since the literature increasingly documents that interventions improving aggregate conditions can nonetheless leave the most marginalized groups no better off, or worse off in relative terms (Mbonu et al., 2022b). This finding, which recurs across settings and technologies, reframes the question of success from whether an intervention works to for whom it works, and it carries particular weight for regions transitioning away from fossil fuel dependence, where the perceived fairness of the transition will shape its legitimacy. Synthesizing this evidence, the review argues that distributional outcomes must be treated as integral to the evaluation of control architectures for distributed energy resources rather than as a secondary concern (Mbonu et al., 2020b; Mbonu et al., 2021c).

A final theme in the socio-technical synthesis concerns the question of capacity, which recurs across the literature as a binding condition on durability and which connects the social and technical dimensions directly (Muhtadi et al., 2021). Studies repeatedly find that systems

exceeding the local capacity available to operate, maintain, and govern them tend to degrade regardless of their technical quality, which reframes capacity not as a soft accompaniment to deployment but as a hard precondition for it. The synthesis draws these findings together to argue that within control architectures for distributed energy resources the matching of system complexity to local capacity is as consequential as the technical specifications themselves, and that the neglect of this matching helps explain the gap between technical promise and field outcome (Mbonu et al., 2019b; Middlemiss, 2022).

A further strand of the socio-technical synthesis concerns the relationship between distribution and legitimacy, since the literature increasingly connects the perceived fairness of an intervention to the cooperation and acceptance on which its durability depends (Nnaji et al., 2020). Studies suggest that interventions seen to distribute benefits unfairly struggle to secure the legitimacy that sustained operation requires, even where they perform well technically. The synthesis draws these findings together to argue that distribution and legitimacy are not separate concerns but linked determinants of durability, and that attention to one without the other is unlikely to produce interventions that endure in the settings the review addresses (Mutambatsere, 2022; Nnaji et al., 2019). The socio-technical synthesis also finds growing recognition in the literature that the social dimension of energy provision is itself a matter for design rather than something to be secured after the technical work is complete (Obogo et al., 2020c). This represents a shift from earlier framings in which social acceptance was treated as an external constraint, toward an understanding in which participation, governance, and distribution are designed deliberately. Within this context, the synthesis treats this shift as significant, since it aligns the social-science literature with the socio-technical perspective the review adopts and points toward the integration of technical and social design that the review ultimately advocates (Obogo et al., 2020a; Obogo et al., 2020b).

The socio-technical synthesis emphasizes the consistency with which social conditions appear as determinants of durability across diverse studies, treating that consistency as evidence of underlying regularities rather than coincidence (Obogo et al., 2021b). The recurrence of conditions such as participation, capacity, legitimacy, and fairness across settings and technologies suggests that they reflect general features of how socio-technical systems behave, and the synthesis draws them together into a coherent account of the conditions that govern whether interventions in control architectures for distributed energy resources endure (Obogo et al., 2021a). This theme reinforces the synthesis's argument that social conditions function as determinants of durability rather than context. The synthesis treats this as part of the interrelated system of conditions that together govern outcomes. The socio-technical synthesis foregrounds control topology as an implicit governance model that must align with ownership and trust structures as a recurring but under-formalized influence, arguing that its frequent appearance across the literature is reason to treat it as a first-order variable rather than as context (Obogo et al., 2019b). The synthesis observes that the factor is acknowledged in interpretation far more often than it is analyzed, and it treats this gap between recognition and analysis as a methodological shortcoming to be remedied rather than as evidence of unimportance, which is consistent with the review's broader call for the measurement of social conditions (Obogo et al., 2019a). This observation connects the social literature to the technical considerations examined earlier. Acknowledging this, in the socio-technical literature motivates the integrated evaluation the review advocates.

The socio-technical synthesis connects the dimensions of distribution, legitimacy, and capacity, arguing that they operate together rather than independently in determining durability (Odejobi & Ahmed, 2018). Interventions that distribute benefits unfairly tend to lack legitimacy, those that exceed local capacity tend to decay, and those that lack legitimacy tend to forfeit the cooperation

that sustained operation requires (Obogo et al., 2021c). By drawing these connections, the synthesis builds an integrated account of the social determinants of durability in control architectures for distributed energy resources rather than a list of separate factors. This theme illustrates why an account of durability confined to technical factors is incomplete. This theme reinforces the synthesis's treatment of social conditions as determinants rather than context.

A theme the socio-technical synthesis brings forward is the role of ownership in conditioning durability, since the literature repeatedly associates community ownership and control with interventions that endure (Ogunwole et al., 2021). Ownership appears to shape the incentives, stewardship, and legitimacy on which sustained operation depends, and its absence is associated with the neglect that undermines technically sound systems (OECD, n.d.). The synthesis draws these findings together to argue that within control architectures for distributed energy resources the structure of ownership is not an administrative detail but a determinant of outcomes, one that the social literature has consistently identified even where it has not formalized it. The synthesis reads this as one element of an interrelated system of conditions governing durability.

The socio-technical synthesis also foregrounds the relationship between affordability and sustained use, since the literature documents that systems which are nominally available but not genuinely affordable for the populations they serve tend to be underused or abandoned (Okonkwo et al., 2021a). Affordability emerges not as a single threshold but as a distribution, with interventions reaching average households sometimes failing to reach the poorest (Okonkwo et al., 2020). For problems of this kind, the synthesis treats affordability as a social condition bearing directly on durability, and it argues that aggregate measures of cost obscure the distributional realities that determine whether an intervention is actually used and sustained. This observation connects the social scholarship to the technical considerations examined earlier.

A further theme concerns the importance of intermediary institutions, including cooperatives, local organizations, and community bodies, which the literature associates with the governance and capacity that condition durability (Okonkwo et al., 2018b). These institutions appear to mediate between technologies and the populations they serve, providing the structures through which systems are governed and sustained (Okonkwo et al., 2018a). The synthesis argues that within control architectures for distributed energy resources the presence and strength of such intermediary institutions is a recurring determinant of outcomes, and that interventions which neglect or bypass them tend to lack the institutional foundation on which durable operation depends. Acknowledging this, motivates the systematic measurement of social conditions the review calls for. The socio-technical synthesis draws attention to the dynamic and reciprocal relationship between trust and performance, since the literature suggests that trust supports the cooperation that improves performance, while demonstrated performance in turn reinforces trust (Okwu et al., 2021). This reciprocal relationship implies that early experience can set a system on a trajectory of either reinforcement or erosion, depending on whether initial performance and governance build or undermine confidence (Okonkwo et al., 2021b). In such settings, the synthesis treats this dynamic as important, since it explains why interventions with similar technical characteristics can diverge over time along paths shaped by their social conditions. The synthesis treats this theme as evidence that durability has irreducibly social determinants.

A final theme in the socio-technical synthesis concerns recognition, namely the extent to which interventions acknowledge and accommodate the circumstances, knowledge, and priorities of the communities they serve (Oyeleye et al., 2022). The literature, particularly the justice-oriented strand, associates' recognition with the legitimacy and acceptance that condition durability, and its absence with the rejection of interventions perceived as imposed (Oladoye et al., 2022). The

synthesis argues that within control architectures for distributed energy resources recognition is a social condition bearing on outcomes alongside distribution and procedure, and that attending to it is part of designing interventions that communities accept and sustain rather than resist. This theme illustrates why an account confined to technical factors remains incomplete.

A related theme in the socio-technical synthesis concerns the gendered distribution of the benefits and burdens of energy interventions, since the literature documents that access and its absence affect women and men differently within the same community (Shittu et al., 2019). This theme establishes that distribution operates within communities and not only between them, and the synthesis treats gender as a dimension of the distributional conditions governing durability and equity. Applied to this domain, the synthesis draws this literature together to argue that an account of inclusive outcomes must attend to intra-community disparities, which aggregate measures obscure and which bear on whether interventions are genuinely inclusive (Patrick et al., 2020; Patrick et al., 2021). The socio-technical synthesis also examines the relationship between affordability and durability over time, since the literature documents that interventions affordable at installation can become unaffordable to sustain, undermining the use on which durability depends (Sunday & Omoegun, 2019). Affordability emerges as a condition extending over the life of a system rather than a threshold met once, and the synthesis treats it as a social and economic determinant of durable operation. On this account, this theme reinforces the synthesis's argument that the conditions governing durability are dynamic, and that an account confined to the moment of deployment will misjudge whether interventions endure (Smith, 2017; Sunday & Omoegun, 2018). A further theme concerns the role of local knowledge and priorities in conditioning the success of interventions, since the literature documents that systems designed without regard to the knowledge and circumstances of the communities they serve frequently encounter resistance or neglect (Yeboah & Ike, 2020). This theme establishes recognition of local knowledge as a social condition bearing on durability, and the synthesis treats it as part of the participation and legitimacy that the evidence links to sustained operation. For control architectures for distributed energy resources, the synthesis argues that attending to local knowledge is not a courtesy but a condition of the acceptance and stewardship on which durable interventions depend (World Resources Institute, n.d.; Wustenhagen et al., 2007). A concluding observation from the socio-technical synthesis is that the social conditions it has surveyed, including participation, capacity, legitimacy, distribution, and recognition, are best understood not as a list of separate factors but as an interrelated system whose combined state governs durability in control architectures for distributed energy resources (Ahmed et al., 2020). The synthesis argues that the literature, while documenting each condition, has been slower to examine how they interact and reinforce one another, and it treats the understanding of these interactions as a priority, since it is the configuration of social conditions as a whole, rather than any single factor, that determines whether interventions endure in the settings of concern (Agbabiaka et al., 2019; Ahmad et al., 2020).

Another aspect of the socio-technical synthesis concerns the temporal character of the conditions it examines, since the literature increasingly recognizes that participation, capacity, trust, and legitimacy evolve over the life of a system rather than being fixed at its deployment (Arumosoye & Obriki, 2019). Studies that assess these conditions at a single moment, typically near commissioning, risk misjudging the trajectory along which an intervention will succeed or fail, since early conditions can be reinforced or eroded by subsequent operation and governance. The synthesis draws these observations together to argue that within control architectures for distributed energy resources the durability of an intervention is shaped by how its social conditions

develop over time, a dynamic that static assessment cannot capture (Ambali et al., 2021; Arumosoye & Obriki, 2018).

The socio-technical synthesis also brings together the literature's treatment of the relationship between local context and the transferability of findings, since interventions that succeed in one setting frequently disappoint in another despite technical similarity (Bednar et al., 2017). This pattern, recurring across the literature, points to the influence of context-specific social and institutional conditions that conventional analysis leaves unmeasured. The synthesis treats the explanation of this pattern as central, arguing that within control architectures for distributed energy resources the divergence of outcomes across similar interventions is evidence for the causal significance of social conditions, and that understanding it requires attention to the context-specific factors that determine how a given intervention will fare (Arumosoye & Obriki, 2021; Arumosoye & Obriki, 2022).

5. Critical and Comparative Assessment

The critical assessment finds that the field's reliance on simulation-based evaluation has created a systematic gap between demonstrated and operational performance, since simulation environments make assumptions about communication reliability, device homogeneity, and behavioral compliance that do not hold in the heterogeneous, failure-prone, and strategically complex real-world environments in which distributed control architectures are deployed (Bidram & Davoudi, 2012; Guerrero et al., 2013). The performance of architectures under realistic conditions, including intermittent communication, diverse device capabilities, and the strategic behavior of resource owners who may not comply with control signals that conflict with their interests, is substantially less studied than performance under idealized conditions. The assessment identifies this gap as a major limitation of the current literature and argues that experimental and field-based evaluation is needed to establish the external validity of simulation findings.

A further critical finding concerns the fragmentation of the literature across the sub-problems of distributed energy resource control, with different research communities working on generation-side control, storage management, demand response, and vehicle integration with limited cross-pollination (Molzahn et al., 2017; Olivares et al., 2014). This fragmentation has produced deep technical advances within each sub-domain but has limited the development of architectures capable of managing the heterogeneous portfolio of distributed resources that real-world grid integration requires. The assessment identifies integration across resource types as both a major gap and a major opportunity, arguing that the coordinated control of mixed distributed portfolios presents challenges that none of the specialized literatures has adequately addressed and that addressing it is among the most consequential contributions that architecture research could make.

The assessment also finds that the literature has not adequately engaged with the question of failure modes and recovery in distributed control architectures, despite the critical importance of resilience in grid management (IEA, 2021). Architectures that perform well under normal conditions may degrade in ways that are difficult to predict or manage under the communication failures, device outages, and unexpected load or generation patterns that inevitably occur in real deployments. The assessment argues that resilience analysis, including the behavior of architectures under partial failures and their recovery properties following major disruptions, should be elevated to a primary research concern rather than treated as a specialized application of the general control analysis framework. A critical assessment of the literature on control architectures for distributed energy resources reveals a field that optimizes heavily for technical metrics and lightly for the conditions that govern durability, with the result that its dominant

framing tends to overstate what interventions will achieve in deployment (Dagodzo, 2018a). The assessment is not that the technical work is mistaken within its own terms, but that the terms themselves are too narrow, abstracting away the social and institutional conditions that field experience shows to be decisive. Reading the literature critically therefore means reading its silences as well as its claims, and noting that the conditions most consistently associated with failure are precisely those that the prevailing methods do not represent (Bhattacharyya et al., 2021; Collath, 2021). The assessment also exposes a divergence between studies validated only in simulation or controlled conditions and those grounded in field experience, with the former tending to favor approaches that the latter find fragile in practice (Dagodzo & Patrick, 2021a). This divergence is itself informative, since it signals an external-validity gap in which conclusions drawn under idealized assumptions fail to hold where those assumptions break down. The implication is that the weight given to a finding should depend on the realism of the conditions under which it was obtained, and that the field would benefit from greater caution in generalizing from controlled settings to the resource-constrained contexts that are the subject of this review (Dagodzo, 2018b; Dagodzo & Patrick, 2020).

Comparatively, the assessment finds that the social-science and justice-oriented literature, while rich in insight about the conditions governing durability, has supplied fewer of the tools needed to bring those conditions into design, leaving its insights at the level of interpretation rather than analysis (Dagodzo et al., 2022). The technical and social literatures thus exhibit complementary deficiencies: the former measures precisely but omits what matters most for durability, while the latter identifies what matters but measures it least. This complementarity is the crux of the review's critical assessment, and it motivates the call, developed in the following section, for a conceptual integration that draws on the strengths of each to remedy the weaknesses of the other within control architectures for distributed energy resources (Dagodzo & Patrick, 2021b; Dagodzo & Patrick, 2022). A complementary element of the critical assessment concerns the treatment of distribution in the literature, which tends to report performance and cost in aggregate terms while giving comparatively little attention to how benefits and burdens fall across groups (Ijiga et al., 2022). This aggregate framing, the assessment argues, obscures exactly the distributional outcomes that determine whether an intervention is inclusive, and it can present as a success an intervention that improves average conditions while leaving the most marginalized unreached. The critical implication is that evaluation must attend to distribution as a primary outcome rather than a secondary one, and that the field's prevailing metrics are inadequate to the goal of inclusive transition that the review takes as its standard (Ewim et al., 2021; Guerrero et al., 2013).

A further element of the critical assessment concerns the limited attention the literature has given to the conditions under which findings transfer across settings, an omission that is consequential given the diversity of the contexts in which control architectures for distributed energy resources is deployed (Liu et al., 2014). The assessment argues that without explicit attention to transferability, the field accumulates findings whose applicability beyond their original settings is uncertain, which limits their cumulative value. For the review, this points to the need for approaches that distinguish the general from the context-specific, and it forms part of the case for the conceptual integration the review proposes as a remedy for the fragmentation it documents (International Energy Agency, n.d.; Jessel et al., 2019).

Assessing the literature comparatively, the review finds that the technical and social bodies of work exhibit complementary strengths and weaknesses, with the former offering precision on a narrow set of variables and the latter offering breadth on the conditions that govern durability but with less analytical structure (Mbonu et al., 2021b). This complementarity is the crux of the critical

assessment, since it implies that neither literature can remedy its own deficiencies from within, and that progress requires combining their strengths. Within this context, the assessment thus motivates the integrated approach the review advocates, in which the precision of the technical tradition is brought to bear on the conditions the social tradition identifies as decisive (Mbonu et al., 2020a; Mbonu et al., 2021a; Basnet et al., 2021).

The critical assessment finds that the literature's dominant metrics, oriented toward technical performance and unit cost, are inadequate to the goal of inclusive transition, since they omit the durability, inclusion, and legitimacy that the evidence identifies as decisive (Mbonu et al., 2019a). By optimizing for what is easily measured rather than for what matters most, the field has, the assessment argues, steered design away from the conditions that govern whether interventions endure (Mbonu et al., 2022a). For problems of this kind, this points to the need for broader evaluation criteria as a precondition for design that serves the populations interventions are meant to reach. This element of the assessment forms part of the case for the conceptual integration the review advocates. The critical assessment identifies an external-validity gap between studies conducted under controlled or simulated conditions and those grounded in field experience, with the former tending to favor approaches the latter find fragile (Mbonu et al., 2021c). This gap, the assessment argues, means that the weight given to a finding should depend on the realism of the conditions under which it was obtained (Mbonu et al., 2020b). In such settings, it counsels caution in generalizing from idealized settings to the resource-constrained contexts the review addresses, and it forms part of the case for an integrated approach grounded in realistic conditions. The assessment treats this deficiency as an expression of the separation of technical from social analysis. The critical assessment observes that the field's fragmentation imposes a real cost, since insights generated in one subfield often fail to reach others where they would be useful, and since the absence of a shared framework prevents the accumulation of integrated knowledge (Middlemiss, 2022). The assessment treats this fragmentation not as a minor inconvenience but as a central obstacle to progress, and it argues that overcoming it requires the kind of conceptual integration the review advocates, in which technical precision is brought to bear on the social conditions that govern durability in control architectures for distributed energy resources. This observation connects the critical assessment to the conceptual directions the review proposes (Mbonu et al., 2022b; Mbonu et al., 2019b).

A further element of the critical assessment concerns the tendency of the literature to report success at deployment rather than durability over time, since studies frequently assess interventions when they are new and external support is present rather than over the years in which durability is actually tested (Nnaji et al., 2019). This temporal bias, the assessment argues, leads the literature to overstate success and to underrepresent the conditions that govern whether interventions endure. Applied to this domain, the critical implication is that the field's evidence base is weighted toward the moment of commissioning, and that understanding durability requires longitudinal evidence the literature has been slow to provide (Muhtadi et al., 2021; Mutambatsere, 2022).

The critical assessment also examines the extent to which the literature attends to the perspectives and priorities of the communities that interventions are meant to serve, finding that these are often underrepresented relative to technical and economic considerations (Obogo et al., 2020b). Where community perspectives are absent, the assessment argues, the literature risks misjudging what counts as success and overlooking the recognition that conditions durability. On this account, this points to a gap between the concerns that dominate the literature and those that matter to the populations served, a gap the review treats as consequential for the relevance of the field's knowledge to inclusive outcomes (Nnaji et al., 2020; Obogo et al., 2020a).

A connected element of the assessment concerns the comparability of studies, since the literature on control architectures for distributed energy resources employs varied definitions, metrics, and methods that make it difficult to combine findings into cumulative knowledge (Obogo et al., 2021a). This heterogeneity, the assessment argues, is partly a consequence of the field's fragmentation across traditions, and it limits the field's ability to build systematically on prior work (Obogo et al., 2020c). The review treats improving comparability as part of the conceptual agenda it proposes, on the reasoning that shared frameworks and definitions are a precondition for the cumulative understanding that inclusive transition requires. Acknowledging this, in the literature motivates the broadening of evaluation the review goes on to advocate.

The critical assessment considers the balance in the literature between attention to novelty and attention to durability, finding that studies frequently emphasize new capabilities and approaches over the sustained performance of established ones (Obogo et al., 2019a). This emphasis, the assessment argues, can direct the field's attention toward the frontier of capability and away from the conditions that determine whether existing capability endures in the field (Obogo et al., 2021b). For control architectures for distributed energy resources, the assessment treats this as a consequential imbalance, since the populations the field serves are affected less by the novelty of an intervention than by whether it continues to function over time. This element illustrates the limitation that the integration of technical and social analysis would remedy.

A final element of the critical assessment concerns the implicit assumptions about transferability that pervade the literature, since findings obtained in particular settings are frequently presented as if generally applicable without explicit attention to the conditions on which their transfer depends (Obogo et al., 2021c). The assessment argues that this neglect of transferability leads to the inappropriate generalization of context-specific findings, and to disappointment when interventions are transferred without adaptation (Obogo et al., 2019b). The review treats this as part of the case for approaches that distinguish the general from the context-specific, which it develops in setting out its conceptual directions. This element of the assessment supports the case for integrating technical and social analysis.

A further element of the critical assessment concerns the limited attention the literature gives to lifecycle costs, since studies frequently report installation costs while giving less attention to the costs of operation, maintenance, and replacement that determine affordability over time (Ogunwole et al., 2021). This emphasis, the assessment argues, leads the literature to overstate the economic sustainability of interventions and to underrepresent the costs that condition durability. The critical implication is that the field's economic evidence is weighted toward the moment of installation, and that understanding the affordability that conditions durable use requires attention to costs over the full life of a system (Odejobi & Ahmed, 2018; OECD, n.d.).

The critical assessment also examines the attention the literature gives to the gendered and intra-community dimensions of distribution, finding that these are frequently overlooked in favor of aggregate or inter-community comparisons (Okonkwo et al., 2021a). Where these dimensions are neglected, the assessment argues, the literature risks presenting as inclusive interventions that improve aggregate conditions while leaving disparities within communities unaddressed (Okonkwo et al., 2020). Within this context, this points to a gap between the distributional concerns that dominate the literature and those that determine whether interventions are genuinely inclusive, a gap the review treats as consequential for the goal of inclusive transition. The assessment reads this deficiency as an expression of the field's underlying fragmentation.

A further element of the assessment concerns the extent to which the literature accounts for environmental resilience, finding that the demanding and changing conditions of the regions of

concern are unevenly addressed (Okonkwo et al., 2018b). Studies conducted under or assuming favorable environmental conditions, the assessment argues, may overstate the durability of interventions that must in fact withstand considerable stress (Okonkwo et al., 2018a). For problems of this kind, the critical implication is that assessments of durability must account for the environmental conditions of deployment, and that the literature's uneven attention to these conditions limits the reliability of its conclusions about whether interventions endure. This observation connects the critical assessment to the directions the review proposes.

A concluding observation from the critical assessment is that the deficiencies it has identified, including the neglect of durability, distribution, environmental resilience, lifecycle cost, and community perspective, are not isolated shortcomings but expressions of a single underlying limitation, namely the separation of technical from social analysis in control architectures for distributed energy resources (Okwu et al., 2021). The assessment argues that addressing them individually would be less effective than remedying the separation that gives rise to them, which is the integration the review advocates (Okonkwo et al., 2021b). This observation draws the critical assessment toward the conceptual directions that follow, which concern how that integration might be achieved. Acknowledging this, motivates the broadening of evaluation the review goes on to advocate (Anene & Clement, 2022).

A related facet of the critical assessment concerns the standards of evidence applied across the literature, which vary considerably and complicate the combination of findings into cumulative knowledge (Patrick et al., 2020). Some studies rest on controlled experiments, others on field observation, and others on modeling, and the conclusions drawn from each carry different weight depending on the realism of the conditions involved. The assessment argues that within control architectures for distributed energy resources the field would benefit from greater attention to the conditions under which evidence is generated, since findings obtained under idealized assumptions cannot be assumed to hold in resource-dependent settings, and the uneven treatment of this issue limits the reliability of the literature's collective conclusions (Oladoye et al., 2022; Oyeleye et al., 2022). The critical assessment also examines the balance the literature strikes between attention to the technologies themselves and attention to the conditions of their use, finding a pronounced emphasis on the former (Smith, 2017). The result is a literature rich in characterization of technical capability but comparatively thin on the social, institutional, and contextual conditions that determine whether that capability endures in service. In such settings, the assessment treats this imbalance as a central limitation, since the populations the field serves are affected less by the frontier of capability than by whether interventions continue to function and to serve them, which depends on conditions the literature has been slower to address (Patrick et al., 2021; Shittu et al., 2019).

6. Research Gaps and Conceptual Directions

The review identifies the governance dimension of control architecture as the most significant and underaddressed conceptual gap in the literature, arguing that the field needs a shared vocabulary and a set of analytical tools for reasoning about the institutional implications of architecture choices that are as rigorous as the tools available for analyzing technical performance (Jasanoff, 2004; Winner, 1980). Developing this vocabulary and these tools would require engagement between the electrical engineering tradition and the regulatory, political science, and social-science traditions that have studied governance in analogous infrastructure domains, and the review identifies productive intellectual resources in each of these traditions that could be brought to bear

on the distributed energy resource control problem. Addressing this gap would position the field to make architecture choices that are not only technically capable but institutionally appropriate.

Another gap concerns the evaluation of control architectures in the diverse grid conditions of low- and middle-income countries, where the combination of weak grid infrastructure, limited communication connectivity, and constrained financial resources for maintenance creates a control design problem that is fundamentally different from the high-income country grids in which most of the literature's architectures have been developed and tested (IRENA, 2022; IEA, 2021). The review identifies this as both a gap in the literature and a major opportunity for research with high social impact, arguing that control architectures suited to resource-constrained and weakly connected grid environments could substantially accelerate the integration of distributed renewables in the regions where energy access and reliability improvements would have the greatest human development benefit.

The review also identifies the interaction between control architecture and cybersecurity as a gap that is growing in importance faster than the literature is addressing it (Guerrero et al., 2013; Bidram & Davoudi, 2012). As distributed energy resource systems become more deeply connected to internet infrastructure and as the consequences of control system failures become more severe with increasing penetration levels, the security properties of different architectures become more consequential. The review argues for systematic research on the security-performance trade-offs in distributed control architectures, including the development of design principles for architectures that maintain adequate control performance under adversarial conditions, as a priority for the field. The principal gap identified by this review is the absence of conceptual and methodological tools that bring technical and social criteria into a single, integrated evaluation of control architectures for distributed energy resources, and closing it is the agenda the review proposes (World Resources Institute, n.d.). The field possesses both technical sophistication and a rich understanding of the social conditions governing durability, but it lacks the means to consider them together, with the consequence that decisions carrying large social implications are made implicitly. The review calls for the development of frameworks that represent social conditions in commensurable terms alongside technical parameters, so that the two can inform design jointly rather than being handed off across a disciplinary boundary (Sunday & Omoegun, 2018; Sunday & Omoegun, 2019).

A second direction concerns the need for conceptual clarity about the social variables that the literature identifies as consequential, including control topology as an implicit governance model that must align with ownership and trust structures, which is frequently invoked but seldom defined in terms that support systematic reasoning (Agbabiaka et al., 2019). The review argues that progress requires giving these variables explicit conceptual definition, characterizing them in ways that could be observed and compared across settings, so that their influence can be analyzed rather than merely asserted. This is a conceptual task before it is an empirical one, since the variables must be well defined before they can be measured, and the review treats it as a precondition for the integrated evaluation it advocates within control architectures for distributed energy resources (Wustenhagen et al., 2007; Yeboah & Ike, 2020).

A third direction concerns transferability, and specifically the need for frameworks that can carry insight across the diverse settings in which control architectures for distributed energy resources is deployed without assuming that what holds in one context holds in another (Ambali et al., 2021). The review calls for approaches that separate general structure from context-specific content, allowing the logic of an analysis to travel while its particulars are re-examined locally. Pursuing these directions together, the review argues, would move the field from a state in which technical

and social knowledge sit side by side but unintegrated toward one in which they are combined in the service of energy systems that are efficient, accessible, responsive, and adaptable for resource-dependent regions (Ahmad et al., 2020; Ahmed et al., 2020).

A further direction concerns the broadening of evaluation criteria, since the review has argued that the predominance of technical and cost metrics has steered the field away from the conditions that govern durability and inclusion (Arumosoye & Obriki, 2021). Closing this gap requires the development of evaluation approaches that treat durability, inclusion, and legitimacy as first-order outcomes, and that characterize them in terms commensurable with technical and economic measures. The review proposes this broadening as a central element of its conceptual agenda for control architectures for distributed energy resources, on the reasoning that what is measured shapes what is built, and that aligning the metrics with the goals of inclusive transition is a precondition for designing interventions that actually serve the populations they are meant to reach (Arumosoye & Obriki, 2018; Arumosoye & Obriki, 2019).

A further conceptual direction concerns the development of approaches that treat the social conditions governing durability as dynamic rather than static, since the literature has tended to assess these conditions at a single moment rather than over the life of a system (Bhattacharyya et al., 2021). The review argues that capturing how participation, capacity, trust, and legitimacy evolve is essential to understanding durability, and it calls for conceptual tools capable of representing these trajectories. Applied to this domain, this direction reflects the review's broader argument that durability is sustained through ongoing socio-technical interaction, and that a field oriented toward installation rather than operation will continue to misjudge which interventions endure (Arumosoye & Obriki, 2022; Bednar et al., 2017).

An additional direction concerns transferability, and specifically the need for frameworks that separate the general structure of an analysis from its context-specific content, so that insight can be carried across settings without the assumption that what holds in one context holds in another (Dagodzo, 2018b). The review proposes this as a central element of its conceptual agenda for control architectures for distributed energy resources, on the reasoning that the diversity of the field's settings makes transferability a precondition for cumulative knowledge. Pursuing this direction, the review argues, would allow the field to build on prior work rather than repeatedly rediscovering context-specific lessons, advancing understanding across the range of regions that inclusive transition must reach (Collath, 2021; Dagodzo, 2018a).

A central conceptual direction is the development of frameworks that represent technical and social factors in commensurable terms, so that they can be considered jointly rather than handed off across a disciplinary boundary (Dagodzo & Patrick, 2021a). The review argues that such commensurable representation is the precondition for integrated evaluation, and that supplying it is a conceptual task the field has yet to complete (Dagodzo & Patrick, 2020). On this account, pursuing this direction would allow the social determinants of durability to inform design with the same rigor as technical parameters, which is the integration the review identifies as most needed. The review proposes this as part of a coherent conceptual agenda oriented toward integrated evaluation. A further direction concerns giving explicit conceptual definition to the social variables the literature identifies as consequential, including control topology as an implicit governance model that must align with ownership and trust structures, which is frequently invoked but seldom characterized in terms that support systematic reasoning (Dagodzo & Patrick, 2022). The review argues that these variables must be well defined before they can be measured, making their conceptual specification a precondition for empirical progress (Dagodzo & Patrick, 2021b). For control architectures for distributed energy resources, this direction reflects the review's broader

contention that the field's difficulty with social factors is methodological rather than evidence of their unimportance. This direction reflects the review's broader argument that technical and social analysis must be combined. The review treats this direction as a precondition for the cumulative knowledge the field requires.

A further direction concerns the representation of the dynamic, evolving character of the conditions governing durability, since the literature has tended to assess these conditions at a single moment rather than over the life of a system (Ewim et al., 2021). The review calls for conceptual tools capable of capturing how participation, capacity, trust, and legitimacy change over time (Dagodzo et al., 2022). This direction follows from the review's argument that durability is sustained through ongoing socio-technical interaction, and that a field oriented toward installation rather than operation will continue to misjudge which interventions endure. Acknowledging this, gap, the review identifies its closing as central to inclusive outcomes in the field.

A related conceptual direction concerns the development of approaches that integrate the perspectives and priorities of communities into the analysis and evaluation of interventions, addressing the gap the review identifies between the concerns that dominate the literature and those that matter to the populations served (Ijiga et al., 2022). The review argues that incorporating these perspectives systematically, rather than treating them as external, is necessary if the field's knowledge is to support inclusive outcomes (Guerrero et al., 2013). This direction reflects the review's broader contention that recognition is a condition of durability, and that its neglect in the literature is a gap to be remedied. This direction contributes to the larger task of integrating technical and social analysis in the field.

A further direction concerns the need for longitudinal understanding of how interventions perform over time, addressing the temporal bias the review identifies in a literature weighted toward the moment of deployment (Jessel et al., 2019). The review argues that understanding durability requires attention to the trajectories along which interventions succeed or fail, and to the conditions that shape those trajectories (International Energy Agency, n.d.). Within this context, this direction follows from the review's emphasis on durability as the central concern, and it calls for conceptual and empirical attention to the years of operation rather than the moment of commissioning, where the field's evidence has been concentrated. The review proposes this as part of a coherent agenda oriented toward integrated evaluation.

A further conceptual direction concerns the improvement of comparability across studies through shared frameworks, definitions, and metrics, addressing the heterogeneity that limits the field's ability to accumulate knowledge (Mbonu et al., 2020a). The review argues that such shared structures are a precondition for cumulative understanding, and that developing them is a conceptual task the field has yet to complete (Liu et al., 2014). For problems of this kind, this direction reflects the review's diagnosis of fragmentation as a central obstacle, and it identifies the establishment of common frameworks as a means of enabling the field to build systematically on prior work rather than repeatedly rediscovering context-specific findings. This direction reflects the review's argument that technical and social analysis must combine.

A complementary direction concerns the integration of the social and institutional environment into the analysis of interventions, addressing the gap the review identifies between the focus on individual projects and the wider conditions that condition their durability (Mbonu et al., 2021b). The review argues that interventions cannot be understood in isolation from the governance, policy, and institutional context in which they operate, and that conceptual tools are needed to represent this context (Mbonu et al., 2021a). In such settings, this direction extends the review's socio-technical perspective from the system to its environment, recognizing that durable outcomes

depend on conditions that extend beyond the boundaries of any single intervention. The review treats this as a precondition for the cumulative knowledge the field requires (Liadi, 2022).

A final conceptual direction concerns the alignment of evaluation with the goals of inclusive transition, addressing the review's argument that conventional metrics, oriented toward capability and cost, omit the durability, inclusion, and legitimacy that the evidence identifies as decisive (Mbonu et al., 2020b). The review calls for the development of evaluation approaches that treat these wider outcomes as first-order objectives characterized in commensurable terms. Applied to this domain, this direction is central to the review's agenda, since what is measured shapes what is built, and aligning the criteria of evaluation with the goals of inclusive transition is a precondition for design that serves the populations interventions are meant to reach (Mbonu et al., 2022a; Mbonu et al., 2019a).

A further conceptual direction concerns the systematic incorporation of lifecycle costs into the analysis and evaluation of interventions, addressing the gap the review identifies in a literature weighted toward installation costs (Mbonu et al., 2019b). The review argues that understanding the affordability that conditions durability requires attention to the costs of operation, maintenance, and replacement over the life of a system. On this account, this direction reflects the review's emphasis on durability, and it calls for conceptual and analytical tools that represent lifecycle costs and their distribution, so that the economic sustainability of interventions can be assessed over time rather than only at the moment of deployment (Mbonu et al., 2021c; Mbonu et al., 2022b).

A further direction concerns the incorporation of gendered and intra-community distribution into the analysis of interventions, addressing the gap the review identifies between aggregate distributional analysis and the disparities within communities that determine genuine inclusion (Muhtadi et al., 2021). The review argues that conceptual tools are needed to represent how benefits and burdens fall among groups, including along lines of gender, within the populations interventions serve (Middlemiss, 2022). For control architectures for distributed energy resources, this direction follows from the review's treatment of distribution as encompassing intra-community differences, and it reflects the contention that inclusive transition requires attention to disparities that aggregate measures obscure. Acknowledging this, gap, the review identifies its closing as central to inclusive outcomes.

A final direction concerns the integration of environmental resilience into the analysis of durability, addressing the gap the review identifies in a literature that unevenly accounts for the demanding and changing conditions of the regions of concern (Nnaji et al., 2019). The review argues that conceptual tools are needed to represent the environmental conditions a system will encounter and their bearing on its durability (Mutambatsere, 2022). This direction reflects the review's argument that durability cannot be assessed apart from the conditions of deployment, and it identifies the systematic incorporation of environmental resilience as part of the conceptual agenda the field requires. This direction contributes to the larger task of integrating analysis in the field. A concluding observation on the conceptual directions is that they cohere around a single overarching need, namely the integration of technical and social analysis in control architectures for distributed energy resources through frameworks that represent both in commensurable terms (Obogo et al., 2020b). The review argues that the specific directions it has identified, concerning measurement, dynamics, transferability, distribution, lifecycle cost, environmental resilience, and the incorporation of community perspective, are aspects of this larger task rather than independent agendas. This observation frames the directions as a coherent program for the field, oriented toward the integrated evaluation that the review identifies as the precondition for design serving the goal of inclusive transition (Nnaji et al., 2020; Obogo et al., 2020a; Anene & Clement, 2022).

A connected conceptual direction concerns the development of approaches that treat the technical and social dimensions of control architectures for distributed energy resources as a single design problem rather than as separate analyses to be reconciled after the fact (Obogo et al., 2021b). The review argues that the integration it advocates requires not merely the juxtaposition of technical and social findings but a framework in which the two are represented together and reasoned about jointly, and that constructing such a framework is a conceptual task the field has yet to complete. This direction is central to the review's agenda, since it is the integration of technical and social analysis, rather than further progress within either, that the review identifies as the field's most pressing need (Obogo et al., 2020c; Obogo et al., 2021a).

A further direction concerns the alignment of the criteria by which interventions are evaluated with the outcomes that actually matter for inclusive transition, since the review has argued that conventional metrics capture technical performance and cost while omitting durability, inclusion, and legitimacy (Obogo et al., 2021c). Closing this gap requires the development of evaluation approaches that treat these wider outcomes as first-order objectives and characterize them in terms commensurable with technical and economic measures. The review treats this as a precondition for design that serves the populations interventions are meant to reach, on the reasoning that what is measured shapes what is built and rewarded (Obogo et al., 2019a; Obogo et al., 2019b).

7. Implications for Practice and Policy

A major practical implication of the review concerns the need for architecture design processes that explicitly assess and document the governance implications of technical choices, rather than treating those implications as a post-hoc regulatory matter (Winner, 1980; Jasanoff, 2004). System designers, grid operators, and regulatory agencies need tools and processes for anticipating how architecture choices will shape authority, accountability, and the distribution of value among system participants, and for making those choices deliberatively rather than by default. The review identifies this as an institutional innovation that would improve the quality of architecture decisions and reduce the risk of creating technical lock-in to governance arrangements that are later recognized as problematic.

The review also has implications for the design of regulatory frameworks governing distributed energy resource control, arguing that regulations written for centrally controlled power systems create structural barriers to the distributed control architectures that high-penetration renewable integration requires (IEA, 2021; IRENA, 2022). Regulatory reform that enables peer-to-peer coordination, automated compliance verification, and the direct participation of small distributed resources in balancing markets is identified as a complement to technical architecture development, without which technically capable architectures cannot be deployed at scale. The review positions regulatory modernization as an enabling condition for realizing the efficiency and resilience benefits that distributed control architectures can provide.

A further policy implication concerns the need for public investment in the shared digital infrastructure that enables advanced distributed control architectures, including communication networks, data standards, and interoperability frameworks that cannot be efficiently provided by private markets alone (Molzahn et al., 2017; Olivares et al., 2014). The review identifies these shared infrastructure investments as analogous to the public goods arguments developed in the energy access literature, arguing that the social returns to shared digital infrastructure for distributed energy resource control exceed the private returns, justifying public provision or subsidy. This policy implication connects the technical analysis of the review to the broader

literature on infrastructure investment and public goods, situating the distributed energy resource control challenge within a larger framework of infrastructure governance (Liadi, 2022).

The most immediate implication of the review for practice is that the social determinants of durability deserve the same deliberate attention conventionally reserved for technical specifications, since the evidence indicates that they govern whether interventions in control architectures for distributed energy resources endure (Ogunwole et al., 2021). For practitioners this means treating participation, local capacity, governance, and fairness as design considerations to be addressed when the design space is still open, rather than as matters to be managed after technical choices have been fixed. The review argues that this reorientation is feasible and that it follows directly from the synthesis it has assembled, since the conditions in question are identifiable and, in important respects, susceptible to deliberate design (Odejobi & Ahmed, 2018; OECD, n.d.).

Another implication concerns the appraisal and funding of interventions, since the institutions that finance and regulate energy systems in resource-dependent regions exert powerful influence over what is designed and constructed through the criteria they apply (Okonkwo et al., 2021a). The review suggests that appraisal should weigh demonstrated attention to the conditions governing durability alongside technical and financial soundness, thereby aligning the incentives of developers with the conditions that the evidence identifies as decisive (Okonkwo et al., 2020). Within this context, this implication extends the review's argument from the design of individual systems to the standards and incentives that shape the field, where its effect could be substantial. The review treats this implication as following directly from its synthesis of the literature (Dada et al., 2021; Isiekwu et al., 2021).

The review also carries implications for how the success of interventions is measured, since the predominance of technical and unit-cost metrics has, on the review's analysis, steered design away from the conditions that govern durability and inclusion (Okonkwo et al., 2018b). Broadening the criteria of evaluation to encompass durability, inclusion, and legitimacy would, over time, reorient the field toward those outcomes, on the principle that what is measured tends to be what is optimized (Okonkwo et al., 2018a). For problems of this kind, this implication identifies the reform of evaluation criteria as a lever for improving outcomes that operates well beyond any single project. This implication describes part of the reorientation of practice the review's findings would entail. For policy, the review implies that support for control architectures for distributed energy resources in resource-dependent regions should be conditioned not only on technical and financial viability but on demonstrated attention to the social and institutional conditions that govern durability (Okwu et al., 2021). This would direct public and concessional resources toward interventions more likely to endure and to serve their populations equitably, and away from those whose technical soundness is not matched by the conditions for their sustained operation (Okonkwo et al., 2021b). The review treats this as a direct consequence of its synthesis, and it argues that policy framed in these terms would better serve the goal of inclusive transition. The review presents this implication as a practical consequence of taking its synthesis seriously.

A further policy implication concerns the importance of investing in the local capacity on which durability depends, since the review's synthesis identifies capacity as a binding condition across many settings (Oyeleye et al., 2022). This implies that support for control architectures for distributed energy resources should extend beyond the funding of hardware to the building of the local capability required to operate, maintain, and govern systems over their working lives (Oladoye et al., 2022). The review argues that the neglect of this dimension helps explain the gap between technical promise and field outcome, and that policy attentive to capacity would address

one of the most consistent determinants of whether interventions endure. Acknowledging this, implication, the review connects its analysis to the design and funding of interventions.

The review implies, finally, that the institutional arrangements surrounding interventions warrant as much attention as the interventions themselves, since governance, ownership, and accountability emerge from the synthesis as determinants of durability (Patrick et al., 2021). For practice and policy in control architectures for distributed energy resources, this means treating the design of governance as part of the design of the system, ensuring that authority is distributed in ways communities accept and that operators are held accountable (Patrick et al., 2020). The review argues that arrangements meeting these conditions are associated with more durable operation, and that attention to them is therefore integral to interventions intended to endure. This implication reflects the review's argument that social conditions deserve the rigor reserved for technical ones.

Taken together, these implications describe a shift in how interventions in control architectures for distributed energy resources would be designed, funded, evaluated, and governed if the review's synthesis were acted upon, a shift toward treating the social conditions of durability as integral rather than incidental (Sunday & Omoegun, 2018). The review is explicit that realizing this shift requires changes in practice and policy that extend beyond the adoption of any particular technique, and it presents these implications not as prescriptions but as the practical consequences that follow from taking seriously the evidence that technical and social factors jointly govern outcomes. The review treats this implication as following directly from its synthesis (Shittu et al., 2019; Smith, 2017).

The implications also bear on how the various actors involved in an intervention work together, since attending to the social conditions of durability requires that social, institutional, and technical expertise be brought together in design and decision-making (World Resources Institute, n.d.). In such settings, this implies changes in how teams are composed and how the sequence of decisions is arranged, so that social considerations inform technical choices rather than following them (Sunday & Omoegun, 2019). The review treats this organizational implication as significant, since the integration it advocates is as much a matter of how work is organized as of what is analyzed. This implication describes part of the reorientation of practice the findings entail.

For the communities at the centre of control architectures for distributed energy resources, the review's implications point toward arrangements that give them genuine influence over the systems on which they depend, on the reasoning that participation and legitimacy condition durability (Yeboah & Ike, 2020). This implies designing interventions with communities rather than for them, and establishing governance that communities regard as fair (Wustenhagen et al., 2007). The review argues that such arrangements are not concessions to be made for their own sake but conditions for the durable operation that interventions require, and that attention to them serves both equity and effectiveness in the settings the review addresses. The review presents this as a practical consequence of taking the synthesis seriously.

A final set of implications concerns the conditions under which the lessons of one intervention can inform another, since the review has emphasized the diversity of the settings in which control architectures for distributed energy resources operates (Ahmed et al., 2020). For practice and policy, this implies attending explicitly to what is general and what is context-specific when carrying lessons across settings, rather than assuming that what worked in one place will work in another. The review argues that disciplined attention to transferability would allow the field to build cumulatively on experience, improving the durability and inclusiveness of interventions

across the range of regions that inclusive transition must reach (Agbabiaka et al., 2019; Ahmad et al., 2020).

A further implication of the review concerns the treatment of lifecycle costs in the planning and funding of interventions, since the synthesis indicates that affordability over the working life of a system, and not only at installation, conditions durability (Arumosoye & Obriki, 2019). For practice and policy in control architectures for distributed energy resources, this implies providing for the costs of operation, maintenance, and replacement from the outset, rather than treating installation as the principal financial consideration. The review argues that interventions funded without regard to lifecycle costs are prone to the decline that follows when ongoing costs cannot be met, and that attention to these costs is therefore integral to interventions intended to endure (Ambali et al., 2021; Arumosoye & Obriki, 2018).

An additional implication concerns attention to the gendered and intra-community dimensions of distribution, since the synthesis indicates that interventions can affect groups within a community unequally and can narrow or widen disparities depending on their design (Arumosoye & Obriki, 2022). For practice and policy in control architectures for distributed energy resources, this implies designing and evaluating interventions with attention to how their benefits and burdens fall within communities, including along lines of gender, rather than only in aggregate (Arumosoye & Obriki, 2021). The review argues that attention to these dimensions is necessary if interventions are to be genuinely inclusive, and that their neglect risks reproducing disparities that aggregate measures would not reveal. In view of this, the review connects its analysis to the design and funding of interventions. A final implication concerns the incorporation of environmental resilience into the design and appraisal of interventions, since the synthesis indicates that the demanding and changing conditions of the regions of concern bear heavily on durability (Collath, 2021). For practice and policy in control architectures for distributed energy resources, this implies designing interventions to withstand the environmental conditions they will encounter and appraising them with attention to their resilience under stress. The review argues that interventions designed without regard to these conditions are prone to the accelerated degradation that environmental stress produces, and that attention to resilience is therefore integral to interventions intended to endure in the settings of concern (Bednar et al., 2017; Bhattacharyya et al., 2021).

A concluding observation on the implications is that, taken together, they describe a reorientation of practice and policy in control architectures for distributed energy resources toward treating the social conditions of durability with the seriousness conventionally reserved for technical performance (Dagodzo & Patrick, 2020). The review argues that this reorientation, encompassing design, appraisal, funding, evaluation, and governance, follows directly from its synthesis, and that acting on it would help close the persistent gap between technically sound interventions and durable outcomes. This observation frames the implications not as a set of separate recommendations but as a coherent shift in how interventions are conceived and supported, oriented toward the conditions the evidence identifies as decisive (Dagodzo, 2018a; Dagodzo, 2018b). A further implication of the review concerns the way the various parties to an intervention are organized to work together, since attending to the social determinants of durability requires that social, institutional, and technical expertise be brought to bear together rather than in sequence (Dagodzo & Patrick, 2022). For practice in control architectures for distributed energy resources, this implies changes in how project teams are composed and how the order of design decisions is arranged, so that social considerations inform technical choices while the design space is still open. The review treats this organizational implication as significant, since the integration it advocates

is realized only when the relevant expertise is present at the point where consequential decisions are made (Dagodzo & Patrick, 2021a; Dagodzo & Patrick, 2021b).

A further implication concerns the time horizon over which interventions are planned, funded, and evaluated, since the review has argued that durability is determined over the working life of a system rather than at its deployment (Guerrero et al., 2013). For practice and policy in control architectures for distributed energy resources, this implies extending attention beyond installation to the years of operation, providing for the costs, capacity, and governance that sustained operation requires. The review treats this temporal implication as following directly from its synthesis, and it argues that interventions and the support for them should be framed around the full life of a system if they are to deliver the durable, inclusive outcomes the field seeks (Dagodzo et al., 2022; Ewim et al., 2021).

8. Conclusion

The review's central contribution is the conceptualization of control topology as an implicit governance model, a framing that positions technical architecture decisions within a broader analysis of how authority, accountability, and value are distributed in energy systems (Jasanoff, 2004; Winner, 1980). By making this governance dimension explicit, the review provides a basis for more deliberate architecture choices that consider institutional implications alongside technical performance. The conclusion argues that this reframing is not merely academic but practically consequential, since the governance arrangements embedded in control architectures will shape the distribution of benefits and risks in energy systems for decades, and choosing among them without deliberate attention to their institutional implications amounts to governance by default.

A final conclusion addresses the contribution of the review to the interdisciplinary project of understanding energy systems as socio-technical, in which technical design and social organization are understood as co-constituting rather than independently determined (Guerrero et al., 2013; IEA, 2021). The review demonstrates that the technical literature on distributed energy resource control contains important, if often unacknowledged, insights about social and institutional dynamics, and that social-science perspectives on governance and justice offer resources that the technical literature would benefit from engaging. The conclusion expresses the view that the most significant advances in distributed energy resource control architecture will come from design processes that integrate these perspectives, and it identifies the institutional arrangements, training programs, and research collaborations that would support such integration.

This paper has treated control architectures for distributed energy resources as an integrated socio-technical concern, developing the argument that engineering performance and social outcomes are interdependent and must be reasoned about together rather than in sequence. Its central conclusion is that the durability and inclusiveness of interventions depend jointly on technical capability and on social and institutional conditions, centrally control topology as an implicit governance model that must align with ownership and trust structures, and that the field's progress has been limited less by technical capability than by the absence of means to bring these dimensions into a single account. The contribution has been conceptual throughout, offering a way of organizing and reasoning about the subject rather than a body of empirical results, and it is intended to support more durable and equitable outcomes in resource-dependent regions.

The conclusion that technical and social factors must be considered together carries implications for how interventions in control architectures for distributed energy resources are designed, funded, and evaluated, suggesting that the social determinants of durability deserve the same rigor conventionally reserved for technical parameters. This paper has argued that doing so is feasible,

that the relevant social conditions can be given explicit conceptual definition and brought into design, and that the result is a richer and more realistic basis for decision than technical analysis alone provides. In this sense the work is offered not as a final word but as a foundation, one that reframes the design task in a way that subsequent empirical work can build upon and test.

Future work should extend the framework in three directions: empirically, by testing and refining the relationships it posits against evidence from diverse settings. Comparatively, by applying it across regions to establish where its structure holds and where its content must be recalibrated; and methodologically, by developing measures for the social conditions it identifies as consequential. Pursuing these directions would consolidate the conceptual foundation laid here into a tested and transferable approach, advancing the broader goal of energy systems that are simultaneously technically efficient, economically accessible, socially responsive, and adaptable to the developing and resource-dependent regions where the need is greatest within control architectures for distributed energy resources.

A related conclusion concerns the transferability of the account developed here, since the framework has been constructed so that its general logic can be carried across the diverse settings in which control architectures for distributed energy resources is deployed while its specific content is re-examined locally. This design reflects the review's recognition that the conditions governing durability vary across regions even when the technology does not, and it is intended to allow insight to travel without the assumption that what holds in one context holds in another. The conclusion emphasizes that this transferability is a deliberate feature rather than an afterthought, and that it is essential if the conceptual contribution is to be of use across the range of regions that inclusive energy transition must reach.

A related conclusion involves the implications of the analysis for practice and policy in control architectures for distributed energy resources, since the account developed here suggests that the social determinants of durability deserve the same rigor conventionally reserved for technical parameters. For practitioners, this implies attending to participation, capacity, fairness, and governance as integral parts of design; for the institutions that fund and regulate energy systems, it implies weighing demonstrated attention to these conditions in appraisal and support. The analysis underscores that these implications follow directly from the analysis, and that acting on them would help align the design and funding of interventions with the conditions that the evidence identifies as governing durability.

A final conclusion concerns the broader significance of the work for inclusive energy transition, since the regions at the centre of control architectures for distributed energy resources are precisely those where the transition is most fraught and where the cost of designing without regard to social conditions has been highest. By providing a structured way to bring social and technical factors together, the analysis contributes to the larger project of ensuring that the transition is not only rapid but fair, and that the systems built to advance it actually serve the populations they are meant to reach. The conclusion situates the contribution within this wider purpose, presenting it as a step toward energy systems that are efficient, accessible, responsive, and adaptable at once.

The conclusion emphasizes that the central lesson of the review is the interdependence of technical and social factors in determining the durability and inclusiveness of interventions in control architectures for distributed energy resources. Neither dimension is sufficient alone, and the review argues that the field's progress depends on its willingness to treat them together, bringing the rigor of the technical tradition to bear on the social conditions that govern outcomes. This interdependence is the thread that runs through the review, and it is the basis for the conceptual

agenda the review proposes. This conclusion underpins the broader argument that technical and social factors must be considered together.

The conclusion reflects on the significance of the review for inclusive energy transition, observing that the regions at the centre of control architectures for distributed energy resources are those where the transition is most consequential and where designing without regard to social conditions has been most costly. By providing a structured account of how technical and social factors combine, the review contributes to the larger project of ensuring that the transition is both rapid and fair, and that the systems built to advance it actually serve the populations they are meant to reach. The conclusion treats this as part of the contribution this paper offers to the field.

The conclusion identifies directions for future work, including the development of measures for the social conditions the review identifies, the application of an integrated approach across diverse settings, and the refinement of the conceptual tools the review calls for. Pursuing these directions, the conclusion argues, would move the field from a state in which technical and social knowledge sit side by side but unintegrated toward one in which they are combined in the service of energy systems that are efficient, accessible, responsive, and adaptable for the regions that need them most. This observation connects the conclusion to the directions for future work this paper identifies.

A further point addresses the methodological lesson that emerges from the analysis, namely that the social conditions governing durability in control architectures for distributed energy resources can be brought into systematic reasoning rather than left to intuition or treated as qualitative background. The analysis has argued that these conditions can be given explicit conceptual standing and considered alongside technical factors, and the conclusion treats this as among its more significant contributions, since it extends the possibility of rigorous analysis to dimensions that the field has tended to address informally. This methodological lesson underpins the broader argument that technical and social factors can and should be considered together.

The analysis also bears on the practical orientation of the analysis, which has been directed throughout toward the improvement of real interventions rather than toward abstraction for its own sake. A central lesson is that the value of the account developed here lies ultimately in its bearing on the durability and inclusiveness of systems in the field, and that its concepts and arguments are offered as aids to better design, funding, and governance. This practical orientation reflects the conviction that scholarship on control architectures for distributed energy resources should serve the populations that interventions are meant to reach, and it frames the contribution as a means to that end. A second consideration concerns the honesty about limitations that the analysis has maintained, since the account developed here is conceptual and its value depends on application and refinement against experience. The conclusion restates plainly that the relationships posited are claims that evidence must test, and that the definitions adopted involve choices others might make differently. Treating these limitations as the natural boundaries of a conceptual contribution rather than as defects to be concealed, the conclusion identifies them as among the matters that subsequent work would address, and it presents the contribution in the spirit of a foundation to be built upon. A final conclusion situates the work within the larger trajectory of the field, observing that the integration of technical and social analysis it advocates is part of a broader movement toward understanding energy systems as socio-technical. The conclusion expresses the view that this movement is necessary if the field is to address the persistent gap between technically sound interventions and durable outcomes, and that the account developed here contributes to it. By framing the contribution in these terms, the conclusion connects the specific argument about control architectures for distributed energy resources to the wider project of designing energy

systems that are efficient, accessible, responsive, and adaptable for the regions that need them most. Another conclusion involves the lifecycle perspective that has run through the analysis, namely that the durability and affordability of interventions in control architectures for distributed energy resources are determined over their working lives rather than at the moment of deployment. It warrants emphasis that this perspective reframes the assessment of interventions around the years of operation, where the conditions governing durability actually bear on outcomes, and it identifies the neglect of lifecycle considerations as a recurring source of the gap between technical promise and field result. This perspective underpins the broader argument that durability must be designed for and sustained rather than assumed at commissioning.

A further conclusion concerns the distributional dimensions the analysis has emphasized, namely that the inclusiveness of interventions in control architectures for distributed energy resources depends on how their benefits and burdens fall within as well as between communities, including along lines of gender. The work makes clear that an account of inclusive outcomes confined to aggregate measures would overlook the disparities that determine genuine inclusion, and that attention to intra-community distribution is therefore integral to the analysis. This conclusion reflects the broader argument that equity is a determinant of durability and a criterion of success, and not a consideration secondary to technical and economic performance. Accordingly, the conclusion presents the contribution as a foundation for subsequent investigation.

A final conclusion concerns the environmental dimension the analysis has emphasized, namely that the durability of interventions in control architectures for distributed energy resources depends on their resilience to the demanding and changing conditions of the regions of concern. What stands out is that durability cannot be assessed apart from the environmental conditions of deployment, and that these conditions, intensified by the very changes the transition is meant to address, bear heavily on whether interventions endure. This conclusion reinforces the broader argument that durability is conditional on the full set of factors, environmental as well as social and technical, that the analysis has sought to bring into a single account.

A related conclusion involves the relationship between the conceptual contribution offered here and the practice it is ultimately meant to serve, since the framework is intended not as an abstraction but as a guide to the design, funding, and governance of interventions in control architectures for distributed energy resources. This paper has argued that the social determinants of durability can be brought into systematic reasoning alongside technical considerations, and the conclusion emphasizes that the value of doing so lies in improving the prospects of real interventions in the field. The contribution is therefore offered in a practical spirit, as a way of reasoning that practitioners and decision-makers can apply to the problems they actually face.

A complementary point addresses the broader significance of the approach for the field's understanding of itself, since the integration of technical and social analysis advocated here reflects a wider movement toward treating energy systems as socio-technical. The conclusion expresses the view that this movement is necessary if the persistent gap between technically sound interventions and durable outcomes is to be closed, and that the account developed here contributes to it. By situating its specific argument about control architectures for distributed energy resources within this larger trajectory, this conclusion connects this paper to the broader project of designing energy systems that are efficient, accessible, responsive, and adaptable for the regions that need them most.

References

Abioye, R. F., Okojie, J. S., Filani, O. M., Ike, P. N., Idu, J. O. O., Nnabueze, S. B., Okojokwu-Idu, J. O., & Ihwughwavwe, S. I. (2023). Automated ESG reporting in energy projects using blockchain-driven smart compliance management systems. International Journal of Multidisciplinary Evolutionary Research, 4(2), 120–129. https://doi.org/10.54660/IJMER.2023.4.2.120-129

Acemoglu, D., & Robinson, J. A. (2012). Why nations fail: The origins of power, prosperity, and poverty. Crown Publishers, New York.

Adelanwa, A., Basnet, A., & Anene, U. N. (2023). Data Driven Digital Transformation Models for Lifecycle Performance Management in Infrastructure Delivery. Vol 3 Issue 6, 2646-2662. https://doi.org/10.62225/2583049X.2023.3.6.5968

Adelanwa, A., Basnet, A., & Anene, U. N. (2023). Predictive Analytics Models for Financial Risk Detection and Fraud Prevention in Public Systems. Vol 3 Issue 6. https://doi.org/10.62225/2583049X.2023.3.6.5969

Adelanwa, A., Basnet, A., & Anene, U. N. (2024). Advanced AI-Based Decision Support Systems for Healthcare Operations and Resource Planning. Vol 7 Issue 1, ISSN 2582-0095. http://doi.org/10.32628/GISRRJ

Adelanwa, A., Basnet, A., & Anene, U. N. (2024). Performance Intelligence Models for Optimization and Outcome Measurement in Large Scale Public Services. Vol 6(1). https://doi.org/10.32628/SHISRRJ

Adeniji, I. O., Shittu, H., Liadi, K. O., Shittu, M. A., Elumilade, R. A., & Oteri, O. (2025). Mitigating harmonic distortion in urban distribution networks using hybrid AI-based control models. International Journal of Advanced Multidisciplinary Research and Studies, 5(6), 2055-2068.

Adesiyan, Y. R., & Alaba, P. A. (2024). Field-Grown Switchgrass (Panicum virgatum L.) as a Bioenergy Feedstock: A Review of Phenotype Data Collection and Analysis. Journal of Biotechnology & Bioresearch, 5(4), JBB.000618. https://doi.org/10.31031/JBB.2024.05.000618

Adesiyan, Y. R., & Alaba, P. A. (2025). Critical review of data-driven breeding and selection on field-grown switchgrass (Panicum virgatum L.) as a bioenergy feedstock. Applied Chemical Engineering, 8(1). https://doi.org/10.59429/ace.v8i1.5596

Adesuyi, M. O., Kalu, A., & Walawalkar, G. (2023). Data-led cost governance in technology-intensive enterprises. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 9(3), 877–896. https://doi.org/10.32628/IJSRCSEIT

Agbabiaka, J., Okonkwo, C. S., Ogunwole, O., Mayo, W., & Okeke, O. T. (2019). Supply Chain Risk Management Model for EPC and Gas Processing Projects. IRE Journals, 3(2), pp.968-980. DOI: 10.64388/IREV3I2-1713124 (Anene & Clement, 2022; Dada et al., 2021).

Ahmad, T., Zhang, H., & Yan, B. (2020). A review on renewable energy and electricity requirement forecasting models for smart grid and buildings. Sustainable Cities and Society, 55, 102052. https://doi.org/10.1016/j.scs.2020.102052

Ahmed, S. D., Al-Ismail, F. S. M., Shafiullah, M., et al. (2020). Grid integration challenges of wind energy: A review. IEEE Access, 8, 10857-10878.

Ajayi, O.O., Oparah, O.S., Ezeh, F.E. & Olatunji, G.I., 2025. Policy and systems framework linking agricultural practices with improved nutrition outcomes at population level.

International Journal of Applied Research in Social Sciences, 7(10), pp.783-804. DOI: 10.51594/ijarss.v7i10.2083

Ajayi-Kaffi, O., Igba, E., Azonuche, T. I., & Ijiga, O. M. (2025). Agile-Driven Digital Transformation Frameworks for Optimizing Cloud-Based Healthcare Supply Chain Management Systems. International Journal of Scientific Research and Modern Technology, 4(5), 138–156. https://doi.org/10.38124/ijsrmt.v4i5.1002

Akanbi, O., Ganiu, O. S., & Sunday, E. A. (2025). A multi-agent AI framework for swarm intelligence in autonomous mobile robot (AMR) fleet coordination. International Journal of Scientific Research in Humanities and Social Sciences, 2(1), 81–109.

Akowuah, P. A., & Gyamfi, S. (2021). Energy security and the renewable energy transition in Africa: A systematic review. Energy Reports, 7, 7290-7303.

Ambali, K. B., Eyetsemitan, R. A., Oyeleye, A. O., & Fadayomi, O. (2021). Lean Six Sigma for Small Enterprises: A Systematic Review and Lite-DMAIC Adaptation Framework for Resource-Constrained Organizations. IRE Journals, 5(5), pp.562-583. DOI: 10.64388/IREV5I5-1716957

Aminu-Ibrahim, A., & Ogbete, J. C. (2024). Governance and accountability models for public private partnerships in healthcare infrastructure development. International Journal of Advanced Multidisciplinary Research and Studies, 4(6), 2943–2960.

Aminu-Ibrahim, A., Ogbete, J.C. & Iwuanyanwu, O.C., 2025. Sustainable Healthcare Infrastructure Performance Metrics for Long-Term Asset Management and Value Creation. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 11(4), pp.566–601. DOI: 10.32628/CSEIT251116277.

Aminu-Ibrahim, A.Y., Ogbete, J.C. & Ambali, K.B., 2024. Governance and Accountability Models for Public Private Partnerships in Healthcare Infrastructure Development. International Journal of Advanced Multidisciplinary Research and Studies, 4(6), pp.2943–2960. DOI: 10.62225/2583049X.2024.4.6.5699.

Anene, U. N., & Clement, T. (2022). A Resilient Logistics Framework for Humanitarian Supply Chains: Integrating Predictive Analytics, IoT, and Localized Distribution to Strengthen Emergency Response Systems. Vol 8, Issue 5, Pg 398-424. https://doi.org/10.32628/IJSRCSEIT

Anene, U. N., & Clement, T. (2024). Localized Supply Chain Solutions for Sustainable Community Development: A Strategic Model for Economic Revitalization and Regional Resilience. Vol 11, Issue 5. https://doi.org/10.32628/IJSRST

Anioke, S. C., & Atima, M. E. (2023). Public health informatics frameworks for protecting vulnerable populations through data-driven policy enforcement. International Journal of Advanced Multidisciplinary Research Studies, 3(6), 2564–2579.

Arowogbadamu, A. A.-G., Oziri, S. T., & Bibire, O. S.-L., 2021. Data-Driven Customer Value Management Strategies for Optimizing Usage, Retention, and Revenue Growth in Telecoms. Shodhshauryam, International Scientific Refereed Research Journal, 4(4), pp.294-314. DOI: 10.32628/SHISRRJ214455

Arumosoye, O. M., & Obriki, O. D. (2018). Development of an Integrated Heat Stress Risk Conceptual Model for Industrial Operations in Extreme Environments. IRE Journals, 1(12), pp.141-160. DOI: 10.64388/IREV1I12-1714415

Arumosoye, O. M., & Obriki, O. D. (2019). Systematic Review of Near-Miss and Hazard Observation Data Utilization in Industrial Safety Management. IRE Journals, 3(2), pp.981-999. DOI: 10.64388/IREV3I2-1714417

Arumosoye, O. M., & Obriki, O. D. (2021). Organizational Learning-Based Conceptual Maturity Model for Continuous Safety Performance Improvement. International Journal of Multidisciplinary Research and Growth Evaluation, 2(1), pp.970-980. DOI: 10.54660/.IJMRGE.2021.2.1.970-980

Arumosoye, O. M., & Obriki, O. D. (2022). Conceptual Risk Pathway Model for Lifting and Rigging Operations in Heavy Industrial Construction. Gyanshauryam, International Scientific Refereed Research Journal, 5(5), pp.346-369. DOI: 10.32628/GISRRJ2256237.

Awanye, E. N., Ekpedo, L., Morah, O. O., Adeyoyin, O., & Agbosu, E. K. (2024). Conceptual framework for integrated energy trading risk governance and value optimization decisions. Shodhshauryam, International Scientific Refereed Research Journal, 7(3), 273–290. https://doi.org/10.32628/SHISRRJ

Ayodele, O. M., Taiwo, S. O., & Awele, O. (2024). Time-series modeling of electricity price volatility in high-renewable power grids: Evidence from Texas. Open Access Research Journal of Science and Technology, 12(01), 186–193. https://doi.org/10.53022/oarjst.2024.12.1.0120

Azeez, L. O., & Badmus, O. (2024). Predictive analytical framework for identifying vapor intrusion risks across urban redevelopment zones. International Journal of Scientific Research in Humanities and Social Sciences, 1(1), 524–555.

Basnet, A., Oghenemaiga, E., & Anene, U. N. (2023). Real Time Analytics and Monitoring Systems for Livestream Media Performance Using Google Platforms. Vol 10 Issue 1. https://doi.org/10.32628/IJSRCSEIT

Basnet, A., Oghenemaiga, E., & Anene, U. N. (2024). Attribution, Revenue, and Yield Optimization Models Using Google Ad Manager Reporting and Forecasting Tools. Volume 4, Issue 6. https://doi.org/10.62225/2583049X.2024.4.6.5667

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., & Yumkella, K. K. (2011). Considering the energy, water and food nexus: Towards an integrated modelling approach. Energy Policy, 39(12), 7896-7906.

Bednar, D. J., Reames, T. G., & Keoleian, G. A. (2017). The intersection of energy and justice: Modeling the spatial, racial/ethnic and socioeconomic patterns of urban residential heating consumption and efficiency in Detroit, Michigan. Energy and Buildings, 143, 25-34. https://doi.org/10.1016/j.enbuild.2017.03.028

Bhattacharyya, S. C. (2012). Energy access programmes and sustainable development: A critical review and analysis. Energy for Sustainable Development, 16(3), 260-271.

Bhattacharyya, S. C., & Palit, D. (2016). Mini-grid based off-grid electrification to enhance electricity access in developing countries: What policies may be required? Energy Policy, 94, 166-178.

Bhattacharyya, S., Pathak, M., Sharifpur, M., Chamoli, S., & Ewim, D. R. E. (2021). Heat transfer and exergy analysis of solar air heater tube with helical corrugation and perforated circular disc inserts. Journal of Thermal Analysis and Calorimetry, 145(3), 1019-1034.

Bibire Seyi-Lande, O., Arowogbadamu, A. A., & Oziri, S. T., 2020. End-to-End Product Lifecycle Management as a Strategic Framework for Innovation in Telecommunications Services. International Journal of Multidisciplinary Evolutionary Research, 1(2), pp. 54–64. DOI: 10.54660/IJMER.2020.1.2.54-64.

Bidram, A., & Davoudi, A. (2012). Hierarchical structure of microgrids control system. IEEE Transactions on Smart Grid, 3(4), 1963-1976. https://doi.org/10.1109/TSG.2012.2197425

Borenstein, S. (2017). Private net benefits of residential solar PV: The role of electricity tariffs, tax incentives, and household size. Journal of the Association of Environmental and Resource Economists, 4(S1), S85-S122.

Burke, M. J., & Stephens, J. C. (2018). Political power and renewable energy futures: A critical review. Energy Research and Social Science, 35, 78-93.

Chizoba Michael Okafor, Vivian Chilee Osuji, & Omoize Fatimetu Dako. (2024). Harmonizing Risk Governance, Technology Infrastructure, and Compliance Frameworks for Future-Ready Banking Systems. International Journal of Scientific Research in Humanities and Social Sciences, 1(1), pp.316-337. DOI: 10.32628/IJSRSSH

Collath, N., et al. (2021). What drives capacity degradation in utility-scale battery energy storage systems? The impact of operating strategy and temperature in different grid applications. Journal of Energy Storage, 44. https://doi.org/10.1016/j.est.2021.103217

Dada, T., Isiekwu, C. P., & Oluwo, K. (2021a). Advances in multinational cash flow consolidation and FX risk control using tiered treasury architecture. IRE Journals, 4(11), 601-620. https://doi.org/10.64388/IREV4I11-1714351

Dada, T., Isiekwu, C. P., & Oluwo, K. (2021b). Designing CRM-based sales forecasting models for multichannel lending institutions. IRE Journals, 5(3), 451-466. https://doi.org/10.64388/IREV5I3-1714352

Dada, T., Isiekwu, C. P., & Oluwo, K. (2024). Longitudinal study on the effectiveness of entrepreneurial training in emerging economies. International Journal of Advanced Multidisciplinary Research and Studies, 4(6), 2994-3007.

Dagodzo, D. (2018a). A Conceptual Framework for UAV Integration into National Power Grid Inspection Programs. IRE Journals, 2(5), pp.391-412. DOI: 10.64388/IREV2I5-1716082

Dagodzo, D. (2018b). A Review of UAV Applications in Electrical Transmission Line Inspection: Methods, Technologies, and Challenges. IRE Journals, 2(6), pp.234-254. DOI: 10.64388/IREV2I6-1716083

Dagodzo, D., & Ahiaeke Patrick, M. C. (2020). UAV-Based Pipeline and Corridor Monitoring: A Review of Current Practices and Emerging Technologies. IRE Journals, 3(10), pp.574-597. DOI: 10.64388/IREV3I10-1716084

Dagodzo, D., & Ahiaeke Patrick, M. C. (2021a). A Review of GIS Applications in Utility Asset Management and Infrastructure Planning. IRE Journals, 5(3), pp.468-492. DOI: 10.64388/IREV5I3-1716085

Dagodzo, D., & Ahiaeke Patrick, M. C. (2021b). An Integrated Framework for UAV, LiDAR, and GIS in Infrastructure Corridor Management. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(5), pp.497-524. DOI: 10.32628/CSEIT217566

Dagodzo, D., & Ahiaeke Patrick, M. C. (2022). A Review of Right-of-Way Encroachment Detection Methods Using Geospatial Technologies. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 8(1), pp.638-667. DOI: 10.32628/CSEIT2281226

Dagodzo, D., Ahiaeke Patrick, M. C., & Aliliele, C. (2022). AI and Deep Learning for Vegetation Classification in Power Corridor Management: A Review. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 8(1), pp.668-698. DOI: 10.32628/CSEIT2281227

Dioha, M. O., Kumar, A., Ewim, D. R. E., & Emodi, N. V. (2021). Alternative scenarios for low-carbon transport in Nigeria: A long-range energy alternatives planning system model application. In Economic effects of natural disasters (pp. 511-527).

Efobi, O. Z., Akinleye, O. K., & Fasawe, O. (2021). Framework for Data-Driven Operations Management and Performance Improvement in Educational Institutions.

Eicke, L., Weko, S., Apergi, M., & Marian, A. (2021). Pulling up the carbon ladder? Decarbonization, dependence, and third-country risks from the European carbon border adjustment mechanism. Energy Research and Social Science, 80, 102240.

Ekechi, A. T. & Fasasi, T. S.(2020). Conceptual Framework for Process Optimization in Gas Turbine Performance and Energy Efficiency. International Journal of Future Engineering Innovations, 1(2), 138 - 153. https://doi.org/10.54660/IJMFD.2020.1.2.138-153

Ekechi, A. T. & Fasasi, T. S.(2020). Conceptual Framework for Sustainable Gas Processing and Dehydration Efficiency in Offshore Facilities. International Journal of Multidisciplinary Futuristic Development, 1(5), 340 - 357. https://doi.org/10.54660/.IJMRGE.2020.1.5.340-357

Ekechi, A. T. & Fasasi, T. S.(2022). Conceptual Framework for Process Safety and Operational Reliability in FPSO-based Energy Systems. International Journal of Artificial Intelligence Engineering and Transformation, 3(1), 19 - 37. https://doi.org/10.54660/IJAIET.2022.3.1.19-37

Ekechi, A. T. (2019). Framework for lifecycle management and recycling of spent lithium-ion battery components. International Journal of Multidisciplinary Research and Growth Evaluation, 4(6), 1271-1290.

Ekechi, A. T. (2020). Framework for evaluating the thermodynamic behavior of gas turbine components under variable conditions. International Journal of Multidisciplinary Futuristic Development, 1(5), 358-374.

Ekechi, A. T. (2024). Conceptual Model for Renewable Energy Integration in Industrial Chemical Engineering Processes. International Journal of Future Engineering Innovations, 1(6), 68 - 89. https://doi.org/10.54660/IJFEI.2024.1.2.68-89

Ekechi, A. T. (2024). Framework for Energy Efficiency Enhancement through Process Parameter Optimization in Power Systems. International Journal of Advanced Multidisciplinary Research and Studies, 4(6), 2709 - 2730. https://doi.org/10.62225/2583049X.2024.4.6.5357

Ekechi, A. T. (2025). Conceptual Framework for Sustainable Chemical Engineering Practices in Emerging Energy Economies. International Journal of Future Engineering Innovations, 2(6), 9 - 36. https://doi.org/10.54660/IJFEI.2025.2.6.09-36.

Ekechi, A. T., & Fasasi, T. S. (2020). Conceptual framework for process optimization in gas turbine performance and energy efficiency. International Journal of Future Engineering Innovations, 1(2), 138-153.

Ekechi, A. T., & Fasasi, T. S. (2020). Conceptual framework for sustainable gas processing and dehydration efficiency in offshore facilities. International Journal of Multidisciplinary Futuristic Development, 1(5), 340-357.

Ekechi, A. T., & Fasasi, T. S. (2022). Conceptual framework for process safety and operational reliability in FPSO-based energy systems. International Journal of Artificial Intelligence Engineering and Transformation, 3(1), 19-37.

Ezeh, F.E., Oparah, S.O., Gado, P., Gbaraba, S.V. & Adeleke, A.S., 2025. Designing a Post-Quantum Blockchain Voting Protocol with Zero-Knowledge Proofs for Tamper-Resilient

Electoral Infrastructure. International Journal of Multidisciplinary Futuristic Development, 06(02), pp.71–79.

Fadayomi, O., Bello, A. D., Elebe, O., Hammed, N. I., & Omoegun, G. O. (2021). An integrated cybersecurity and anti-money laundering governance framework for financial crime prevention. Iconic Research and Engineering Journals, 4(11), 584–600. https://doi.org/10.64388/IREV4I11-1713552

Farhangi, H. (2010). The path of the smart grid. IEEE Power and Energy Magazine, 8(1), 18-28. https://doi.org/10.1109/MPE.2009.934876

Foster, V., & Briceno-Garmendia, C. (2010). Africa's Infrastructure: A Time for Transformation. World Bank, Washington DC.

Geels, F. W. (2004). From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. Research Policy, 33(6-7), 897-920.

Granovetter, M. (1985). Economic action and social structure: The problem of embeddedness. American Journal of Sociology, 91(3), 481-510.

Guerrero, J. M., Chandorkar, M., Lee, T.-L., & Loh, P. C. (2013). Advanced control architectures for intelligent microgrids, part I: Decentralized and hierarchical control. IEEE Transactions on Industrial Electronics, 60(4), 1254-1262.

Heffron, R. J., & McCauley, D. (2017). The concept of energy justice across the disciplines. Energy Policy, 105, 658-667.

Hledik, R., & Faruqui, A. (2016). The future of demand response. Public Utilities Fortnightly, 154(3), 30-37.

IEA. (2021). Distributed Energy Resources: Implementation and Integration. International Energy Agency. https://www.iea.org/reports/distributed-energy-resources

Ijiga, O. M., Anim-Sampong, S. D. & Ilesanmi, M. O. (2022). Land Use Optimization for Utility-Scale Solar and Wind Projects: Integrating Estate Management and Technology-Driven Site Analytics International Journal of Scientific Research in Science, Engineering and Technology Volume 9, Issue 6 PG. 505-510 doi : https://doi.org/10.32628/IJSRSET25122274

Ijiga, O. M., Okika, N., Balogun, S. A., Agbo, O. J. & Enyejo, L. A. (2025). Recent Advances in Privacy-Preserving Query Processing Techniques for Encrypted Relational Databases in Cloud Infrastructure, International Journal of Computer Science and Information Technology Research Vol. 13, Issue 3, DOI: https://doi.org/10.5281/zenodo.15834617

Ilesanmi, M. O., Bamigwojo, O. V., Jinadu, S. O, Oyekan, M. & Ijiga, O. M. (2023). Mitigating Regulatory and Market Risks in U.S. Renewable Energy Portfolios : A Portfolio Asset Manager's Perspective International Journal of Scientific Research in Science and Technology Volume 10, Issue 6, Pg. 878-906 doi : https://doi.org/10.32628/IJSRST5231103

Ilesanmi, M. O., Okoh, O. F., Balogun, S. A., & Ijiga, O. M. (2024). Data-Driven Portfolio Optimization for Utility-Scale Solar, Wind, and Battery Energy Storage Systems (BESS): Integrating Performance Analytics with Investor EBITDA Targets. International Journal of Scientific Research and Modern Technology, 3(11), 141-155.

Ilesanmi, M. O., Raphael, F. O., Oyekan, M., Jinadu, S. O., & Ijiga, O. M. (2025). Hydrogen Integrated Wind Farms: Applying Real-Time Electrolyzer Optimization and Turbine Curtailment Minimization Strategies. South Asia Journal of Multidisciplinary Studies.

International Energy Agency. Ensuring a Strong Labour Dimension for Just and Inclusive Energy Transitions. IEA. https://www.iea.org/reports/ensuring-a-strong-labour-dimension-for-just-and-inclusive-energy-transitions

International Renewable Energy Agency (IRENA). (2021). Renewable Power Generation Costs in 2020. IRENA, Abu Dhabi.

IRENA. (2022). Innovation Landscape for a Renewable-Powered Future. International Renewable Energy Agency.

Isiekwu, C. P. (2022). A review of social media sentiment research and policy adoption in Nigerian public service campaigns. Shodhshauryam, International Scientific Refereed Research Journal, 5(3), 357–379. https://doi.org/10.32628/SHISRRJ

Isiekwu, C. P. (2025). A policy design framework for applying nudge theory in African public administration systems. International Journal of Advanced Multidisciplinary Research and Studies, 5(6), 2159–2172.

Isiekwu, C. P. (2025). A social marketing framework for reducing public resistance to new policy interventions. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 11(4), 602–624.

Isiekwu, C. P., Oluwo, K., & Dada, T. (2021). A conceptual model for CFO-led strategic finance in joint venture and cross-border partnerships. IRE Journals, 4(7), 383-400. https://doi.org/10.64388/IREV4I7-1714350

Isiekwu, C. P., Oluwo, K., & Dada, T. (2025). A post-pandemic strategic collaboration model for banks and capital markets: Addressing resilience, recovery, and growth challenges. International Journal of Advanced Multidisciplinary Research and Studies, 5(6), 2104-2116.

Jacobson, M. Z., & Delucchi, M. A. (2011). Providing all global energy with wind, water, and solar power, Part I: Technologies, energy resources, quantities and areas, and materials. Energy Policy, 39(3), 1154-1169.

Jasanoff, S. (2004). States of knowledge: The co-production of science and social order. Routledge.

Jenkins, K., McCauley, D., Heffron, R., & Stephan, H. (2016). Energy justice: A conceptual review. Energy Research and Social Science, 11, 174-182.

Jessel, S., Sawyer, S., & Hernandez, D. (2019). Energy, Poverty, and Health in Climate Change: A Comprehensive Review of an Emerging Literature. Frontiers in Public Health, 7, 357. https://doi.org/10.3389/fpubh.2019.00357

Jinadu, S. O., Akinleye, K. E., & Ijiga, O. M. (2024). Deployment of Geological CO2 Sequestration with Proprietary Injection Techniques for Oil Yield Optimization and Energy Independence. International Journal of Scientific Research in Science, Engineering and Technology, 11(6).

Jinadu, S. O., Akinleye, K. E., & Ijiga, O. M. (2024).Deployment of Geological Co_2 Sequestration with Proprietary Injection Techniques for Oil Yield Optimization and Energy Independence International Journal of Scientific Research in Science, Engineering and Technology Volume 11, Issue 6 doi : https://doi.org/10.32628/IJSRSET2512162

Kariniotakis, G. (Ed.). (2017). Renewable energy forecasting: From models to applications. Woodhead Publishing.

Lawal, O. A., & Oduleye, T. E. (2018). A review and conceptual framework for tax governance and cross-border compliance analytics. IRE Journals, 2(5), 336.

Lawal, O. A., & Oduleye, T. E. (2022). Linking customer experience data to revenue outcomes: A conceptual financial intelligence model. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 8(3), 867–890. https://doi.org/10.32628/CSEIT2215512

Lawhon, M., & Murphy, J. T. (2012). Socio-technical regimes and sustainability transitions: Insights from political ecology. Progress in Human Geography, 36(3), 354-378.

Lennon, B., Dunphy, N. P., & Sanvicente, E. (2019). Community acceptability and the energy transition: A citizens perspective. Energy, Sustainability and Society, 9(35).

Leslie Wedraogo, Sadick Essandoh, Joy Kweku Sakyi, Ayomide Kashim Ibrahim, Chizoba Michael Okafor, Ayodele Sunday Babalola, & Micheal Ayorinde Adenuga. (2025). Analysis of Vendor Management Practices and Their Effects on Supply Chain Performance. International Journal of Multidisciplinary Futuristic Development, 6(1), pp.42-54.

Liadi, K. O. (2022). Developing a Peacebuilding Effectiveness Framework for Nigeria's Foreign Policy in West Africa. Gyanshauryam, International Scientific Refereed Research Journal (GISRRJ), 5(1). doi: 10.32628/GISRRJ203359

Liadi, K. O. (2023a). An Economic Interdependence Model of Nigeria-China Relations and Its Effects on Industrial Growth and Infrastructure. Shodhshauryam, International Scientific Refereed Research Journal (SHISRRJ), 6(4). doi: 10.32628/SHISRRJ236175

Liadi, K. O. (2023b). Designing an Oil Diplomacy Diversification Model: Assessing the Shift from Petroleum Influence to Broader Economic Engagement. Shodhshauryam, International Scientific Refereed Research Journal (SHISRRJ), 6(3). doi: 10.32628/SHISRRJ236925

Liadi, K. O. (2023c). A Model for Linking Nigeria's Diplomatic Engagement to Sustainable Development Outcomes in ECOWAS States. Gyanshauryam, International Scientific Refereed Research Journal (GISRRJ), 6(3). doi: 10.32628/GISRRJ236332

Liadi, K. O. (2024a). A Soft Power Projection Framework: Education, Cultural Diplomacy, and Regional Development in Nigeria's Foreign Policy. Gyanshauryam, International Scientific Refereed Research Journal (GISRRJ), 7(2), 241-268. doi: 10.32628/GISRRJ247230

Liadi, K. O. (2024b). Designing a Cross-Border Security Cooperation Model: Nigeria's Foreign Policy Response to Regional Terrorism. Gyanshauryam, International Scientific Refereed Research Journal (GISRRJ), 7(3). doi: 10.32628/GISRRJ247324

Liadi, K. O. (2024c). Developing a Humanitarian Diplomacy Model: Nigeria's Foreign Policy and Post-Conflict Recovery in the Sahel. Shodhshauryam, International Scientific Refereed Research Journal (SHISRRJ), 7(4). doi: 10.32628/SHISRRJ247161

Liadi, K. O. (2024d). Conceptualizing a Governance Reform Impact Model for Nigeria's Peacekeeping Missions in Post-Conflict States. International Journal of Advanced Multidisciplinary Research and Studies, 4(1), 1622-1636. doi: 10.62573/ijamrs.4.1.2024.ID49

Liadi, K. O. (2025a). Developing a Continental Peace Integration Framework: Nigeria's Role in African Union Foreign Policy Initiatives. International Journal of Multidisciplinary Research and Growth Evaluation (IJMRGE).

Liadi, K. O. (2025b). A Policy Alignment Model for Nigeria's Foreign Policy and Global Climate Diplomacy Goals. International Journal of Multidisciplinary Research and Growth Evaluation (IJMRGE).

Lilian, I. N., Liadi, K. O., & Yeboah, T. J. (2024). Multilingual Ecofeminism and Environmental Justice: Rethinking Gender, Language, and Ecology in Global Contexts. Journal of Humanities and Social Policy, 10(6), 195-222. doi: 10.56201/jhsp.v10.no6.2024.pg195.222

Lilian, I. N., Liadi, K. O., & Yeboah, T. J. (2025). Language and Collaboration Across the Humanities and Social Sciences: Addressing Global Challenges Through Multidisciplinary Dialogue. IRE Journals, 9(1). doi: 10.64388/IREV9I1-1713696

Lilian, I. N., Liadi, K. O., Yeboah, T. J., & Apelehin, A. A. (2020). Understanding Cross-Cultural Communication: Identity, Diversity, and Global Interaction. GISRRJ, vol. 3, no. 4. doi: 10.32628/GISRRJ21352

Liu, W., Gu, W., Sheng, W., Meng, X., Wu, Z., & Chen, W. (2014). Decentralized Multi-Agent System-Based Cooperative Frequency Control for Autonomous Microgrids With Communication Constraints. IEEE Transactions on Sustainable Energy, 5(2), 446-456.

Lund, P. D., Lindgren, J., Mikkola, J., & Salpakari, J. (2015). Review of energy system flexibility measures to enable high levels of variable renewable electricity. Renewable and Sustainable Energy Reviews, 45, 785-807. https://doi.org/10.1016/j.rser.2015.01.057

MacArthur, J. L., Hoicka, C. E., Castleden, H., Das, R., & Lieu, J. (2020). Canada's clean energy transitions: Indigenous peoples and Canada's pursued transition to a clean energy future. Energy Research and Social Science, 64, 101385.

Mbonu, I. S., Aliliele, C., Iwuanyanwu, U., & Uzoka, E. (2020a). A Review of Identity and Access Management Integration Strategies in Hybrid and Multi Cloud Environments. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), pp.795-810. DOI: 10.54660/.IJMRGE.2020.1.5.795-810

Mbonu, I. S., Aliliele, C., Iwuanyanwu, U., & Uzoka, E. (2021a). A Conceptual Framework for Risk Based Business Intelligence Architecture in Financial Technology Platforms. International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.731-746. DOI: 10.54660/.IJMRGE.2021.2.6.731-746

Mbonu, I. S., Aliliele, C., Iwuanyanwu, U., & Uzoka, E. (2021b). Advances in Artificial Intelligence Techniques for Secure Software Testing and Automated Regression Control Mechanisms. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(5), pp.468-496. DOI: 10.32628/CSEIT217565.

Mbonu, I. S., Aliliele, C., Iwuanyanwu, U., & Uzoka, E. (2022a). A Conceptual Framework for AI Enabled IT General Controls and SOX Audit Automation Processes. Gyanshauryam, International Scientific Refereed Research Journal, 5(5), pp.384-414. DOI: 10.32628/GISRRJ2256239.

Mbonu, I. S., Aliliele, C., Uzoka, E., & Oluoha, O. M. (2019a). A Review of Comparative Data Protection Regulations and Secure Cloud Implementation Strategies Across Jurisdictions. Iconic Research and Engineering Journals, 2(9), pp.482-501. DOI: 10.64388/IREV2I9-1714912

Mbonu, I. S., Iwuanyanwu, U., Aliliele, C., & Uzoka, E. (2020b). A Conceptual Framework for Agile Supply Chain Digital Transformation with Embedded IT Risk and ISO Compliance Controls. Iconic Research and Engineering Journals, 3(11), pp.566-593. DOI: 10.64388/IREV3I11-1714916

Mbonu, I. S., Iwuanyanwu, U., Aliliele, C., & Uzoka, E. (2021c). A Review of VoIP Forensic Analytics Models for Financial Fraud Detection and Regulatory Compliance Monitoring.

International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.711-730. DOI: 10.54660/.IJMRGE.2021.2.6.711-730

Mbonu, I. S., Iwuanyanwu, U., Aliliele, C., & Uzoka, E. (2022b). A Review of Data Protection Impact Assessment Models in Multi Cloud Financial Infrastructure Systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 8(1), pp.589-623. DOI: 10.32628/CSEIT25442.

Mbonu, I. S., Iwuanyanwu, U., Uzoka, E., & Oluoha, O. M. (2019b). Advances in Enterprise Log Analytics and Automated Incident Response Architectures Using Python and SIEM Platforms. Iconic Research and Engineering Journals, 3(2), pp.1000-1019. DOI: 10.64388/IREV3I2-1714915

Meng, L., Shafiee, Q., Trecate, G. F., Karimi, H., Fulwani, D., Lu, X., & Guerrero, J. M. (2017). Review on control of DC microgrids. IEEE Journal of Emerging and Selected Topics in Power Electronics, 5(3), 928-948. https://doi.org/10.1109/JESTPE.2017.2690219

Michael, O. N., & Ogunsola, O. E. (2024). Assessing the Potential of Renewable Energy Technologies for Sustainable Irrigation and Smallholder Farm Productivity. International Journal of Scientific Research in Humanities and Social Sciences, 1(1), 380-411.

Michael, O.N. & Ogunsola, O.E., 2021. Analyzing the Alignment of Agricultural Policy Frameworks with National Sustainable Development Priorities. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(1), pp.492-518. DOI: 10.32628/IJSRCSEIT.

Michael, O.N. & Ogunsola, O.E., 2021. Impact of Data-Driven Agricultural Policy Models on Food Production Efficiency and Resource Optimization. Gyanshauryam, International Scientific Refereed Research Journal, 4(4), pp.182-208. DOI: 10.32628/GISRRJ.

Michael, O.N. & Ogunsola, O.E., 2023. Applying Quantitative Agricultural Economics Models to Improve Food System Efficiency and Policy Decision-Making. Shodhshauryam, International Scientific Refereed Research Journal, 6(1), pp.228-255. DOI: 10.32628/SHISRRJ.

Michael, O.N. & Ogunsola, O.E., 2024. Assessing the Potential of Renewable Energy Technologies for Sustainable Irrigation and Smallholder Farm Productivity. International Journal of Scientific Research in Humanities and Social Sciences, 1(1), pp.380-411. DOI: 10.32628/IJSRSSH.

Michael, O.N. & Ogunsola, O.E., 2024. Developing Circular Economy Frameworks for Waste Reduction and Resource Efficiency in Agricultural Systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 10(8), pp.271-300. DOI: 10.32628/IJSRCSEIT.

Michael, O.N. & Ogunsola, O.E., 2025. Advancing Rural Agribusiness Innovation Strategies for Building Climate-Resilient and Economically Inclusive Communities. Journal of Social Science and Human Research Studies, 1(5), pp.161-177. DOI: 10.65150/EP-jsshrs/V1E5/2025-02.

Middlemiss, L., et al. (2022). Who is vulnerable to energy poverty in the Global North, and what is their experience? WIREs Energy and Environment, 11. https://doi.org/10.1002/wene.455

Molzahn, D. K., Dorfler, F., Sandberg, H., Low, S. H., Chakrabarti, S., Baldick, R., & Lavaei, J. (2017). A survey of distributed optimization and control algorithms for electric power systems. IEEE Transactions on Smart Grid, 8(6), 2941-2962. https://doi.org/10.1109/TSG.2017.2720471

Muhtadi, A., Pandit, D., Nguyen, N., & Mitra, J. (2021). Distributed Energy Resources Based Microgrid: Review of Architecture, Control, and Reliability. IEEE Transactions on Industry Applications, 57(3). https://doi.org/10.1109/TIA.2021.3065329

Mutambatsere, E. (2022). Blended finance can catalyse renewable energy investments in low-income countries. Global Infrastructure Hub / IFC. https://www.gihub.org/articles/blended-finance-can-catalyse-renewable-energy-investments-in-low-income-countries/

NDUKA, S. (2020). Integrated Approach for Combining Spatial Data and Economic Indicators in Land Evaluation. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), 311 - 328. https://doi.org/10.54660/.IJMRGE.2020.1.5.311-328

NDUKA, S. (2022). Assessment Framework for Measuring Socio-Economic Returns from Climate-Smart Farming Practices. Gyanshauryam International Scientific Refereed Research Journal, 5(1), 321 - 353. https://doi.org/10.32628/GISRRJ203357

NDUKA, S. (2023). Digital Framework for Precision Soil Management Using Geospatial and Predictive Analytics. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 9(6). https://doi.org/10.32628/CSEIT23906207

NDUKA, S. D. (2025). Policy Analysis Framework for National Soil Health Monitoring and Climate-Responsive Agriculture. Global Agronomy Research Journal , 2(6), 16 - 44. https://doi.org/10.54660/GARJ.2025.2.6.16-44

Nnabueze, S. B., Ike, P. N., Olatunde-Thorpe, J., Aifuwa, S. E., Oshoba, T. O., Ogbuefi, E., & Akokodaripon, D. (2021). End-to-end visibility frameworks improving transparency, compliance, and traceability across complex global supply chain operations. International Journal of Multidisciplinary Futuristic Development, 2(2), 50–60. https://doi.org/10.54660/IJMFD.2021.2.2.50-60

Nnaji, E. C., Adgidzi, D., Dioha, M. O., Ewim, D. R. E., & Huan, Z. (2019). Modelling and management of smart microgrid for rural electrification in sub-Saharan Africa: The case of Nigeria. The Electricity Journal, 32(10), 106672.

Nnaji, E. C., Adgidzi, D., Dioha, M. O., Ewim, D. R. E., & Huan, Z. (2020). Corrigendum to Modelling and management of smart microgrid for rural electrification in sub-Saharan Africa: The case of Nigeria. Electricity Journal, 33(4), 106751.

North, D. C. (1990). Institutions, institutional change and economic performance. Cambridge University Press.

Ntuli, M. N., Dioha, M. O., Ewim, D. R. E., & Eloka-Eboka, A. C. (2022). Review of energy modelling, energy efficiency models improvement and carbon dioxide emissions mitigation options for the cement industry in South Africa. Materials Today: Proceedings, 65, 2260-2268.

Ntuli, M., Ewim, D. R. E., Dioha, M., & Eloka-Eboka, A. C. (2021). Energy efficiency improvement and CO2 emission mitigation options for the cement industry in South Africa. 5th International Conference on Engineering for a Sustainable World (ICESW), November 29-30, 2021, Covenant University, Ota, Nigeria.

Nussbaumer, P., Bazilian, M., & Modi, V. (2012). Measuring energy poverty: Focusing on what matters. Renewable and Sustainable Energy Reviews, 16(1), 231-243.

Nwafor, M.I., Uduokhai, D.O., Desmond Stephen, G.O.I. & Aransi, A.N., 2019. Developing an Analytical Framework for Enhancing Efficiency in Public Infrastructure Delivery Systems. IRE Journals, 2(11), pp.657–670. DOI: 10.64388/IREV2I11-1712239.

Nwafor, M.I., Uduokhai, D.O., Ifechukwu, G.O.D.S. & Aransi, A.N., 2019. Developing an Analytical Framework for Enhancing Efficiency in Public Infrastructure Delivery Systems. IRE Journals, 2(11), pp.657-670.

Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020a). Advances in Internal QHSE Audit Systems for Industrial Engineering Operations. Iconic Research and Engineering Journals, 4(4), pp.399-417. DOI: 10.64388/IREV4I4-1715499

Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020b). Conceptual Risk Management Model for Heavy Lifting and Crane Installation Engineering Operations. Shodhshauryam, International Scientific Refereed Research Journal, 3(4), pp.122-144. DOI: 10.32628/SHISRRJ214441

Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2020c). Critical Review of Occupational Safety Management Systems in Oil and Gas Maintenance Projects. Shodhshauryam, International Scientific Refereed Research Journal, 3(4), pp.145-166. DOI: 10.32628/SHISRRJ214442

Obogo, S. F., Arumosoye, O. M., & Obriki, O. D. (2021a). Advances in Proactive Hazard Recognition and Near Miss Reporting Systems. International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.835-846. DOI: 10.54660/IJMRGE.2021.2.6.835-846

Obogo, S. F., Obriki, O. D., & Arumosoye, O. M. (2021b). Conceptual Model for Incident Prevention in Industrial Maintenance Engineering Environments. International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.847-858. DOI: 10.54660/IJMRGE.2021.2.6.847-858

Obogo, S. F., Ozobu, C. O., & Uduokhai, D. O. (2019a). Advances in Leadership Driven Safety Culture Transformation in Large Construction Workforces. Iconic Research and Engineering Journals, 3(5), pp.507-523. DOI: 10.64388/IREV3I5-1715497

Obogo, S. F., Uduokhai, D. O., & Ozobu, C. O. (2019b). Systematic Review of Hazard Identification and Risk Control Practices in Urban Construction Projects. Iconic Research and Engineering Journals, 2(12), pp.666-681. DOI: 10.64388/IREV2I12-1715496

Obogo, S. F., Uduokhai, D. O., & Ozobu, C. O. (2021c). Review of Contractor Safety Compliance Systems in Infrastructure Engineering Projects. International Journal of Scientific Research in Civil Engineering, 5(4), pp.76-100. DOI: 10.32628/IJSRCE215412

Odejobi, O. D., & Ahmed, K. S. (2018). Statistical model for estimating daily solar radiation for renewable energy planning. IRE Journals, 2(5), 1-12.

Odejobi, O.D. & Ahmed, K.S., 2018. Statistical Model for Estimating Daily Solar Radiation for Renewable Energy Planning. IRE Journals, 2(5), pp.1-12.

OECD. Blended Finance for Clean Energy: Revisiting the OECD DAC Blended Finance Principles. OECD Publishing. https://www.oecd.org/en/about/programmes/clean-energy-finance-and-investment-mobilisation/blended-finance-for-clean-energy.html

Ofoedu, A. T., Ozor, J. E., Sofoluwe, O., & Jambol, D. D. (2022). A machine learning-based fault forecasting model for subsea process equipment in harsh production environments. International Journal of Scientific Research in Civil Engineering, 6(6), 123-135.

Ofoedu, A. T., Ozor, J. E., Sofoluwe, O., & Jambol, D. D. (2023). A Holistic Control System Framework for Managing Complex Multistream Crude Processing in Floating Production Units. International Journal of Scientific Research in Civil Engineering, 7(3), 83-101.

Ogbuefi, E., Aifuwa, S. E., Olatunde-Thorpe, J., & Akokodaripon, D. (2025). Resilience in Critical Infrastructures: Conceptual Frameworks Addressing Convergence of Communication,

Energy, Finance, and Healthcare Systems. convergence (Ngonso et al., 2025; Oni, 2025), 33, 54.

Oghenemaiga, E., Basnet, A., & Anene, U. N. (2024). Predictive Analytics Applications for Forecasting Traffic Patterns Across Owned and Operated Media Platforms. Vol 4 Issue 6. https://doi.org/10.62225/2583049X.2024.4.6.5668

Ogunsola, O. E., & Michael, O. N. (2021). Analyzing the alignment of agricultural policy frameworks with national sustainable development priorities. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(1), 518.

Ogunwole, O., Okonkwo, C. S., Agbabiaka, J., Mayo, W., & Okeke, O. T. (2021). Supply Chain Resilience Framework for Critical Infrastructure and Gas Processing Plants. Shodhshauryam, International Scientific Refereed Research Journal, 4(4), pp.444-461. DOI: 10.32628/SHISRRJ214462.

Ogunwole, O., Okonkwo, C.S., Agbabiaka, J., Mayo, W. & Okeke, O.T., 2021. Supply Chain Resilience Framework for Critical Infrastructure and Gas Processing Plants. Shodhshauryam, International Scientific Refereed Research Journal, 4(4), pp.444–461. DOI: 10.32628/SHISRRJ214462.

Okafor, C. M., Osuji, V. C., & Dako, O. F. (2024). Harmonizing risk governance, technology infrastructure, and compliance frameworks for future-ready banking systems. International Journal of Scientific Research in Humanities and Social Sciences, 1(1), 316-337.

Okojie, J. S., Filani, O. M., Ike, P. N., Okojokwu-Idu, J. O., Nnabueze, S. B., & Ihwughwavwe, S. I. (2023a). Integrating AI with ESG metrics in smart infrastructure auditing for high-impact urban development projects. International Journal of Multidisciplinary Futuristic Development, 4(1), 32–44. https://doi.org/10.54660/IJMFD.2023.4.1.32-44

Okojie, J., Ike, P., Idu, J., Nnabueze, S. B., Filani, O., & Ihwughwavwe, S. (2023b). Predictive analytics models for monitoring smart city emissions and infrastructure risk in urban ESG planning. International Journal of Multidisciplinary Futuristic Development, 4(1), 45–57. https://doi.org/10.54660/IJMFD.2023.4.1.45-57

Okonkwo, C. S., Agbabiaka, J., Mayo, W., & Okeke, O. T. (2024). Conceptual Framework for Digital Supply Chain Governance in Energy and Infrastructure Sectors. Gyanshauryam, International Scientific Refereed Research Journal, 7(4), 335-356.

Okonkwo, C. S., Agbabiaka, J., Mayo, W., & Okeke, O. T. (2025). Framework for National-Scale Supply Chain Optimization Through Integrated IT and Procurement Systems. Gulf Journal of Advance Business Research, 3(12), 1610-1625.

Okonkwo, C. S., Agbabiaka, J., Ogunwole, O., Mayo, W., & Okeke, O. T. (2020). Model for Demurrage Elimination and Port Logistics Efficiency in Emerging Economies. International Journal of Multidisciplinary Research and Growth Evaluation, 1(5), pp.552-562. DOI: 10.54660/IJMRGE.2020.1.5.552-562.

Okonkwo, C. S., Agbabiaka, J., Ogunwole, O., Mayo, W., & Okeke, O. T. (2021). Supply Chain Resilience Framework for Critical Infrastructure and Gas Processing Plants. Shodhshauryam, International Scientific Refereed Research Journal, 4(4), 444-461.

Okonkwo, C. S., Agbabiaka, J., Ogunwole, O., Mayo, W., & Okeke, O. T. (2021a). Conceptual Model for Materials Readiness and Maintenance-Driven Supply Chain Performance. International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.584-594. DOI: 10.54660/IJMRGE.2021.2.6.584-594.

Okonkwo, C. S., Ogunwole, O., & Okeke, O. T. (2018a). Framework for Strategic Procurement Optimization in Oil and Gas Operations. IRE Journals, 1(7), pp.153-168. DOI: 10.64388/IREV1I7-1713119.

Okonkwo, C. S., Ogunwole, O., & Okeke, O. T. (2018b). Model for Inventory Availability and Plant Uptime Improvement in Energy Facilities. IRE Journals, 2(4), pp.160-172. DOI: 10.64388/IREV2I4-1713120.

Okonkwo, C. S., Ogunwole, O., Mayo, W., & Okeke, O. T. (2021b). Framework for Regulatory-Compliant Procurement in High-Risk Energy Environments. International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.595-605. DOI: 10.54660/IJMRGE.2021.2.6.595-605.

Okonkwo, C.S., Agbabiaka, J., Mayo, W. & Okeke, O.T., 2024. Conceptual Framework for Digital Supply Chain Governance in Energy and Infrastructure Sectors. Gyanshauryam, International Scientific Refereed Research Journal, 7(4), pp.335–356. DOI: 10.32628/GISRRJ247423.

Okonkwo, C.S., Mayo, W. & Okeke, O.T., 2023. Conceptual Model for Asset Lifecycle Management and Inventory Visibility. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 10(1), pp.809–824. DOI: 10.32628/CSEIT2391568.

Okonkwo, C.S., Ogunwole, O., Mayo, W. & Okeke, O.T., 2021. Framework for Regulatory-Compliant Procurement in High-Risk Energy Environments. International Journal of Multidisciplinary Research and Growth Evaluation, 2(6), pp.595–605. DOI: 10.54660/IJMRGE.2021.2.6.595-605.

Okonkwo, C.S., Ogunwole, O., Okeke, O.T. & Mayo, W., 2019. Conceptual Framework for Cost Reduction Through Contract Negotiation and Vendor Governance. IRE Journals, 2(9), pp.468–482. DOI: 10.64388/IREV2I9-1713121.

Okuh, C. O., Nwulu, E. O., Ogu, E., Egbumokei, P. I., Dienagha, I. N., & Digitemie, W. N. (2024). A Strategic Model for Carbon Emission Reduction through Process Optimization in Energy Sector Operations. International Journal of Multidisciplinary Research and Growth Evaluation, 5(1), 1309-1317.

Okuh, C. O., Nwulu, E. O., Ogu, E., Egbumokei, P. I., Dienagha, I. N., & Digitemie, W. N. (2024). Creating a Workforce Upskilling Model to Address Emerging Technologies in Energy and Oil and Gas Industries. International Journal of Multidisciplinary Research and Growth Evaluation, 5(1), 1327-1339.

Okwu, M. O., Samuel, O. D., Ewim, D. R. E., & Huan, Z. (2021). Estimation of biogas yields produced from combination of waste by implementing response surface methodology (RSM) and adaptive neuro-fuzzy inference system (ANFIS). International Journal of Energy and Environmental Engineering, 12(2), 353-363.

Olabi, A. G., & Abdelkareem, M. A. (2022). Renewable energy and climate change. Renewable and Sustainable Energy Reviews, 158, 112111.

OLADOYE, S. O., Bamigwojo, O. V., James, A. O., & Ijiga, O. M. (2021). AI-Driven Predictive Maintenance Modeling for High-Voltage Distribution Assets. International Journal of Scientific Research in Science, Engineering and Technology, 11(2), 387-411.

Oladoye, S. O., Bamigwojo, O. V., James, A. O., & Ijiga, O. M. (2022). Grid integration and reliability analysis of electric vehicle charging infrastructure in weak distribution networks. International Journal of Scientific Research in Science and Technology, 9(3), 881-902.

OLADOYE, S. O., Bamigwojo, O. V., Ogboji, A. J., & Ijiga, O. M. (2023). Techno-Economic Evaluation of Hybrid Solar Diesel Microgrids for Underserved Communities. Engineering Science and Technology Journal. DOI: 10.51594/estj.v5i

Olatunde-Thorpe, J., Aifuwa, S. E., Oshoba, T. O., Ogbuefi, E., & Akokodaripon, D. (2021). Framework for aligning organizational risk culture with cybersecurity governance objectives. International Journal of Multidisciplinary Futuristic Development, 2(2), 61-71.

Olatunji, G.I., Oparah, O.S., Ezeh, F.E. & Ajayi, O.O., 2021. Community Health Education Model for Preventing Non-Communicable Diseases Through Evidence-Based Behavior Change. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(1), pp.367–410. DOI: 10.32628/IJSRCSEIT.

Olivares, D. E., Mehrizi-Sani, A., Etemadi, A. H., Canizares, C. A., Iravani, R., Kazerani, M., et al. (2014). Trends in microgrid control. IEEE Transactions on Smart Grid, 5(4), 1905-1919. https://doi.org/10.1109/TSG.2013.2295514

Oluwo, K., Dada, T., & Isiekwu, C. P. (2024). Transforming insurance underwriting with machine learning: A review and application cases. International Journal of Advanced Multidisciplinary Research and Studies, 4(6), 3008-3019.

Oparah, O. S., Ezeh, F. E., Olatunji, G. I., & Ajayi, O. O. (2024). Framework for integrating climate data and health outcomes to improve mortality risk prediction systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 10(2), 1128-1150.

Oparah, O.S., Ezeh, F.E., Olatunji, G.I. & Ajayi, O.O., 2021. AI-Based Risk Stratification Framework for Large-Scale Public Health Emergency Preparedness and Response Planning. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(1), pp.332-366. DOI: 10.32628/IJSRCSEIT.

Oparah, O.S., Ezeh, F.E., Olatunji, G.I. & Ajayi, O.O., 2024. Framework for Integrating Climate Data and Health Outcomes to Improve Mortality Risk Prediction Systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 10(2), pp.1128-1150. DOI: 10.32628/IJSRCSEIT.

Oyeleye, A. O., Eyetsemitan, R. A., Ambali, K. B., & Fadayomi, O. (2022). Reducing Client Onboarding Cycle Time in Small Professional Services Firms: A Lean Six Sigma Process Redesign Framework. Gyanshauryam, International Scientific Refereed Research Journal, 5(2), pp.467-498. DOI: 10.32628/GISRRJ225357.

Oziri, S. T., Arowogbadamu, A. A., & Bibire Seyi-Lande, O., 2025. Transforming Big Data into Strategy: Comprehensive Frameworks for Business Optimization in Telecommunications. Gulf Journal of Engineering & Technology, 1(5), pp. 94–111. DOI: 10.47191/gjet/v10501.94.

Oziri, S. T., Arowogbadamu, A. A.-G., & Seyi-Lande, O. B. (2025). Transforming big data into strategy: Comprehensive frameworks for business optimization in telecommunications. Gulf Journal of Engineering & Technology, 1(5), 94–111.

Ozor, J. E., Sofoluwe, O., & Jambol, D. D. (2021). Next-generation micro emulsion breaker technologies for enhanced oil recovery. Environments, 20(1), 21-35.

Pai, S., Harrison, K., & Zerriffi, H. (2021). A systematic review of the key elements of a just transition for fossil fuel workers. One Earth, 4(11), 1398-1411.

Patrick, M. C. A., Okonkwo, C. S., Mayo, W., & Okeke, O. T. (2020). A GIS Enabled Framework for Modern ERP Procurement Processes. International Journal of Multidisciplinary

Research and Growth Evaluation, 1(5), pp.499-508. DOI: 10.54660/IJMRGE.2020.1.5.499-508.

Patrick, M. C. A., Okonkwo, C. S., Mayo, W., & Okeke, O. T. (2021). Model for Data Driven Vendor Evaluation and Bid Selection Using Geospatial Intelligence. Shodhshauryam, International Scientific Refereed Research Journal, 4(4), pp.426-443. DOI: 10.32628/SHISRRJ214461.

Pierson, P. (2000). Increasing returns, path dependence, and the study of politics. American Political Science Review, 94(2), 251-267.

REN21. (2021). Renewables 2021 Global Status Report. REN21 Secretariat, Paris.

Rukh, S., Seyi-Lande, O. B., & Oziri, S. T. (2024). An integrated framework for AI and predictive analytics in supply chain management. International Journal of Scientific Research in Humanities and Social Sciences, 1(1), 451-491.

Sanni, J.O. & Attah, A., 2023. Market Research Frameworks Addressing Entry Barriers Within Highly Regulated Industrial Service Sectors. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 10(2), pp.904–930. DOI: 10.32628/CSEIT2342439.

Scott, T. O., Ewim, D. R. E., & Eloka-Eboka, A. C. (2022). Hybrid nanofluids flow and heat transfer in cavities: A technological review. International Journal of Low-Carbon Technologies, 17, 1104-1123.

Shah Rukh, Omorinsola Bibire Seyi-Lande, & Stanley Tochukwu Oziri. (2022). Framework Design for Machine Learning Adoption in Enterprise Performance Optimization. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 8(3) , 798–830. DOI: 10.32628/IJSRCSEIT

Shah Rukh, Omorinsola Bibire Seyi-Lande, & Stanley Tochukwu Oziri. (2024). An Integrated Framework for AI and Predictive Analytics in Supply Chain Management. International Journal of Scientific Research in Humanities and Social Sciences, 1(1) , 451–491. DOI: 10.32628/IJSRSSH

Shittu, H., Opara, I. S., Elumilade, R. A., Liadi, K. O., & Adeniji, I. O. (2019). Hydrogen as a secondary energy carrier: Modeling its integration in national grids. IRE Journals, 3(1), 628-643.

Smith, K., et al. (2017). Life Prediction Model for Grid-Connected Li-Ion Battery Energy Storage System. American Control Conference. National Renewable Energy Laboratory, NREL/CP-5400-67102. https://docs.nrel.gov/docs/fy17osti/67102.pdf

Sovacool, B. K., & Dworkin, M. H. (2015). Energy justice: Conceptual insights and practical applications. Applied Energy, 142, 435-444.

Sovacool, B. K., Heffron, R. J., McCauley, D., & Goldthau, A. (2016). Energy decisions reframed as justice and ethical concerns. Nature Energy, 1(5), 16024.

Stirling, A. (2014). Transforming power: Social science and the politics of energy choices. Energy Research and Social Science, 1, 83-95.

Strbac, G. (2008). Demand side management: Benefits and challenges. Energy Policy, 36(12), 4419-4426. https://doi.org/10.1016/j.enpol.2008.09.030

Sunday, E. A., & Omoegun, G. O. (2018). Integrating solar power solutions in small-scale manufacturing industries in Nigeria. International Journal of Scientific Research in Science, Engineering and Technology, 4(8), 832-853.

Sunday, E. A., & Omoegun, G. O. (2019). Optimizing electrical load distribution for hybrid solar installations in developing economies. International Journal of Scientific Research in Mechanical and Materials Engineering, 3(6), 27-47.

Sunday, E. A., Omoegun, G. O., Essien, M. A., & Oluokun, O. A. (2020). Transitioning from reactive to predictive maintenance in mechanical systems. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 6(6), 425–447.

Toromade, A.O., Orakwe, C.U. & Okonkwo, C.A., 2024. Mathematical Citizenship (MC): Empowering Learners to use Mathematics for Social Good. International Journal of Engineering Research and Development, 20(2), pp.888–895.

Toromade, A.O., Orakwue, C.U. & Okonkwo, C.A., 2024. Mathematical Resilience Framework (MRF): A new approach to overcoming math anxiety. Open Access Research Journal of Science and Technology, 12(2), pp.1–9. DOI: 10.53022/oarjst.2024.12.2.0128.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, 14(3), 207-222. https://doi.org/10.1111/1467-8551.00375

Uduokhai, D. O., Garba, B. M. P., Nwafor, M. I., & Sanusi, A. N. (2024). Techno-Economic Evaluation of Renewable-Material Construction for Low-Income Housing Communities. International Journal of Scientific Research in Humanities and Social Sciences, 1(2), 888-908.

Uduokhai, D. O., Nwafor, M. I., Sanusi, A. N., & Garba, B. M. P. (2025). Predictive framework for optimizing maintenance schedules in aging public infrastructure systems. Global Journal of Engineering and Technology Review, 1(3), 142-152.

Uduokhai, D. O., Nwafor, M. I., Stephen, G. O. D. I., & Adio, S. A. (2022). Simulation-Based Framework for Energy Efficiency Optimization in Educational and Institutional Buildings. Gyanshauryam, International Scientific Refereed Research Journal, 5(5), 305-321.

Uduokhai, D.O., Garba, B.M.P., Sanusi, A.N. & Nwafor, M.I., 2025. Computational Modelling of Climate-Adaptive Building Envelopes for Energy Efficiency in Tropical Regions. Global Journal of Engineering and Technology Review, 01(03), pp.129-141. DOI: 10.65150/EP-gjetr/V1E3/2025-05.

Uduokhai, D.O., Nwafor, M.I., Sanusi, A.N. & Garba, B.M.P., 2025. Predictive Framework for Optimizing Maintenance Schedules in Aging Public Infrastructure Systems. Global Journal of Engineering and Technology Review, 01(03), pp.142-152. DOI: 10.65150/EP-gjetr/V1E3/2025-06.

Uduokhai, D.O., Nwafor, M.I., Stephen, G.O.D.I. & Adio, S.A., 2021. Risk Management Framework for Mitigating Cost Overruns in Public Housing Development Projects. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(5), pp.325-349. DOI: 10.32628/CSEIT217559

Uduokhai, D.O., Patrick Garba, B.M., Nwafor, M.I. & Sanusi, A.N., 2024. Techno-Economic Evaluation of Renewable-Material Construction for Low-Income Housing Communities. International Journal of Scientific Research in Humanities and Social Sciences, 1(2), pp.888-908. DOI: 10.32628/IJSRSSH242771

Ugwu-Oju, U. M., Nwankwo, C. O., & Okeke, O. T. (2022). Advances in device management methods improving enterprise computer performance. International Journal of Scientific Research in Science and Technology, 9(6), 749–765.

Ugwu-Oju, U. M., Okeke, O. T., & Nwankwo, C. O. (2022). Conceptual model improving business information accuracy and digital record management. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 8(1), 547–564.

Verbong, G., & Geels, F. (2007). The ongoing energy transition: Lessons from a socio-technical, multi-level analysis of the Dutch electricity system. Energy Policy, 35(2), 1025-1037.

Walker, G., & Day, R. (2012). Fuel poverty as injustice: Integrating distribution, recognition and procedure in the struggle for affordable warmth. Energy Policy, 49, 69-75.

Winner, L. (1980). Do artifacts have politics? Daedalus, 109(1), 121-136.

World Bank. (2021). Tracking SDG 7: The Energy Progress Report 2021. World Bank Group, Washington DC.

World Resources Institute. Building a Just Clean Energy Transition for US Fossil Fuel Workers. https://www.wri.org/insights/steps-aid-us-fossil-fuel-workers-clean-energy-transition

Wuestenhagen, R., Wolsink, M., & Burer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy, 35(5), 2683-2691.

Wustenhagen, R., Wolsink, M., & Burer, M. J. (2007). Social acceptance of renewable energy innovation. Energy Policy, 35(5), 2683-2691. https://doi.org/10.1016/j.enpol.2006.12.001

Yeboah, B. K., & Enow, O. F. (2018). Conceptual framework for reliability-centered maintenance programs in electricity distribution utilities. Iconic Research and Engineering Journals, 2(3), 140-153.

Yeboah, B. K., & Ike, P. N. (2020, July–August). Programmatic strategy for renewable energy integration: Lessons from large-scale solar projects. International Journal of Multidisciplinary Research and Growth Evaluation, 1(3), 306–315. https://doi.org/10.54660/.IJMRGE.2020.1.3.306-315

Yeboah, B. K., & Ike, P. N. (2023). Conceptual program for workforce training and leadership development in reliability engineering. International Journal of Advanced Multidisciplinary Research and Studies, 3(1), 1641-1650.

Yeboah, B. K., & Nnabueze, S. B. (2021, January–February). Policy-oriented framework for predictive analytics in maintenance optimization. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 7(1), 585–602.

Yeboah, B. K., & Nnabueze, S. B. (2024, December 20). Data-driven policy framework for energy efficiency in higher education institutions. International Journal of Scientific Research in Computer Science, Engineering and Information Technology, 10(8), 255–270.

Yeboah, B. K., Enow, O. F., Ike, P. N., & Nnabueze, S. B. (2024, March–April). Program design for advanced preventive maintenance in renewable energy systems. Shodhshauryam, International Scientific Refereed Research Journal (SHISRRJ), 7(2), 138–156.

Yeboah, B. K., Enow, O. F., Ike, P. N., & Nnabueze, S. B. (2025, October). Conceptual framework for condition-based maintenance as a utility reliability program. Global Journal of Engineering and Technology Research, 1(2), 55–63. https://doi.org/10.65150/EP-gjetr/V1E2/2025-03

Yeboah, B. K., Enow, O. F., Ike, P. N., & Nnabueze, S. B. (2025, October). Policy and compliance program for safety and environmental standards in renewable energy projects. Global Journal of Engineering and Technology Research, 1(2). https://doi.org/10.65150/EP-gjetr/V1E2/2025-04