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Case study analysis of regulatory frameworks for promoting distributed energy generation and mini-grids in Africa and Europe

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Abstract

Distributed energy generation and mini-grids are increasingly crucial to electrification strategies and decarbonisation efforts in advanced and developing economies. Their deployment is shaped primarily by regulatory frameworks. This study investigates how regulatory frameworks influence the development of mini-grids and distributed energy generation by comparing approaches in Africa and Europe. It focuses on four case studies; Nigeria and Tanzania, where off-grid systems play a key role in expanding energy access, and Spain and Germany, where distributed generation is embedded within grid-connected markets. Using a qualitative comparative case study approach, the research analyses legal, institutional, and policy frameworks governing licensing, tariffs, grid integration, incentives, and stakeholder roles. The findings reveal a clear divergence in regulatory objectives and design. In Nigeria and Tanzania, mini-grids are explicitly recognised in energy acts and integrated into national electrification strategies. It is also supported by tiered licensing regimes, standardised tariff tools, and donor-backed financing mechanisms. However, regulatory uncertainty around grid arrival and long-term investment protection persists. In contrast, Spain and Germany have developed strong frameworks for self-consumption, prosumer participation, and energy communities within an interconnected grid, but lack clear legal recognition for fully autonomous off-grid mini-grids; therefore, creating regulatory gaps for self-sufficient community energy systems. The study concludes that regulatory frameworks reflect differing priorities, with energy access a primary focus in Africa and market integration in Europe. However, both face misalignments that constrain future system needs. Addressing these gaps through strong regulatory frameworks is essential to enabling sustainable energy systems.

Keywords

Keywords: mini-grids, Distributed Energy Generation, Regulatory Frameworks, Off-Grid Electrification, Energy Communities

Contents

LIST OF ACRONYMS

ADB – African Development Bank

BMWK – Federal Ministry for Economic Affairs and Climate Action (Germany)

CAGR – Compound Annual Growth Rate

CEC - Citizen Energy Community

CNMC – Comisión Nacional de los Mercados y la Competencia (Spain's National Commission on Markets and Competition)

DER – Distributed Energy Resources

DFI – Development Finance Institution

DisCo – Distribution Company

DSO - Distribution System Operator

EEG – Erneuerbare-Energien-Gesetz (Renewable Energy Sources Act, Germany)

ECJ – European Court of Justice

ERDF – European Regional Development Fund

ESMAP – Energy Sector Management Assistance Program

EU – European Union

EWURA – Energy and Water Utilities Regulatory Authority (Tanzania)

FCDO – Foreign, Commonwealth & Development Office (UK)

FIT – Feed in Tariff

GIZ – Deutsche Gesellschaft für Internationale Zusammenarbeit (German Development Agency)

GW – Gigawatt

IBI – Impuesto sobre Bienes Inmuebles (Spanish Property Tax)

IDAE – Institute for the Diversification and Saving of Energy (Spain)

kW – Kilowatt

MW – Megawatt

NECPs – National Energy and Climate Plans

NERC – Nigerian Electricity Regulatory Commission

NEP – Nigeria Electrification Project

O&M – Operation and Maintenance

PPA – Power Purchase Agreement

PV – Photovoltaic

RBF – Results-Based Financing

RD – Royal Decree (Spain)

RD-Law – Royal Decree-Law (Spain)

REA – Rural Electrification Agency

REC – Renewable Energy Community

RMI – Rocky Mountain Institute

SPP – Small Power Producer

SPPA – Small Power Purchase Agreement

TANESCO – Tanzania Electric Supply Company Limited

VDE – Verband der Elektrotechnik, Elektronik und Informationstechnik

(Association for Electrical, Electronic & Information Technologies, Germany)

1 Introduction

1.1 Context and Rationale

Mini-grids are power generation and distribution systems that provide electricity to multiple customers in urban areas (towns and cities) and, particularly, remote communities (ESMAP, 2022). Over the past few years, distributed energy generation, particularly mini-grids and localized renewable systems, has been expanding rapidly.

Global momentum behind decentralised energy solutions has accelerated significantly: the IEA recorded an unprecedented 440 GW of new renewable capacity additions in 2023 alone, with distributed solar PV accounting for approximately half of all solar deployment that year, a volume exceeding the total annual deployment of onshore wind (IEA, 2023). Investment in off-grid renewable energy reached USD 558 million in 2021, though IRENA and the Climate Policy Initiative estimate that USD 2.3 billion per year is needed through 2030 to meet universal energy access targets, underscoring both the scale of opportunity and the financing gap that remains (IRENA and CPI, 2023).

As of 2023, the Asia-Pacific region leads the way in terms of solar-based DER installations (60%) and mini-grid deployment. Europe also has a strong market force, which is led by Germany, the UK, and France. North America recorded a 45% increase in DER installations. As of 2024, Sub-Saharan Africa deployed over 25 million users through approximately 600 operational mini- grids (Africa Minigrid Developers Association, 2024). The splurge in growth is mainly due to a decline in renewable energy technology costs and strong regulatory frameworks.

Regulations are crucial for providing an enabling environment that encourages investment in mini-grid projects (IRENA, 2018). Key aspects of mini-grid regulations include licensing and permitting, tariff setting, technical standards, grid interconnection, consumer protection, and dispute resolution. A country may have well-designed regulations, but a lack of effective implementation may pose challenges. This challenge is further worsened by bureaucratic inefficiencies, lack of technical expertise, limited enforcement capacity, etc. As a result, the potential contributions of mini-grids may not be fully realized.

Mini-grids could play crucial roles in bridging the gap in energy access, act as flexible platforms that facilitate renewable integration and protect communities from energy deficits and strengthen energy system sustainability in the face of climate risks.

1.2 Objective of the Research

The objective of this research is threefold. It is listed as follows;

1. It seeks to understand how regulatory frameworks shape the deployment of off-grid systems, including mini-grids and community-based models. By examining the legal, institutional, and policy instruments that govern their development, the study aims to assess how regulation either enables or constrains off-grid electrification.

2. It aims to compare approaches between Africa and Europe, focusing on two African countries (Nigeria and Tanzania) where off-grid energy is a central pillar of electrification strategies, and two European countries (Spain and Germany) where distributed generation is framed largely within a grid-connected paradigm. This comparison highlights how different policy priorities, i.e., universal access in Africa versus decarbonisation and prosumer participation in Europe, shape regulatory design.

3. It seeks to identify gaps, contradictions, and opportunities for better alignment. This includes assessing inconsistencies between national and regional policies, the treatment of autonomous off-grid systems, and the degree to which regulatory frameworks anticipate future integration with the grid. The ultimate goal is to

provide insights that can inform more coherent, inclusive, and adaptive regulation of distributed energy across both continents.

1.3 Methodology and Country Selection

1.3.1 Research Design

This study employs a qualitative comparative case study methodology to examine how regulatory frameworks shape the deployment of distributed energy generation and mini-grids across Africa and Europe. The comparative case study approach was selected because it is well-suited to research questions that ask *how* and *why* institutional and policy conditions produce particular outcomes across different contexts (Yin, 2018), enabling analytical generalisation, the identification of patterns and transferable insights across a deliberately chosen set of cases.

The research is desk-based and relies on systematic analysis of primary legal, regulatory, and policy documents supplemented by secondary literature. A thematic comparative framework structured the analysis consistently across all four case studies, examining each country's regulatory framework along six dimensions: legal recognition of mini-grids and distributed energy systems; licensing and permitting requirements; tariff-setting and cost-recovery mechanisms; integration with national electrification strategies; subsidies and support mechanisms; and the roles of private developers, utilities, and public institutions.

A key limitation of this approach is that regulatory texts and implementation reality frequently diverge. Eberhard et al. (2016) and Baker (2015) both highlight how institutional weaknesses routinely undermine sound regulatory designs in sub-Saharan Africa, while Frieden et al. (2020) note similar transposition gaps in Europe, where EU directives on energy communities have been unevenly implemented across member states. This study therefore reflects what frameworks prescribe rather than what they consistently deliver, and future research should incorporate interviews with regulators and developers to assess real-world outcomes.

1.3.2 Selection Criteria

Case selection was guided by three criteria. First, relevance to off-grid policy, each country selected has a formal and documented regulatory framework specifically addressing mini-grids or distributed generation, rather than treating them as incidental to broader energy legislation. Second, availability of publicly accessible regulatory and policy documentation, which ensures that the analysis is transparent and replicable by other researchers. Third, diversity of approaches, so that the comparison illuminates how differing policy priorities, institutional conditions, and energy system realities produce different regulatory designs rather than simply confirming a single model.

1.3.3 Case Study Selection

Country selection followed a purposive strategy (Tajik, Golzar, and Noor, 2024), guided by three criteria: the presence of formal regulatory frameworks for mini-grids or distributed generation; availability of publicly accessible documentation; and sufficient contextual diversity to reveal how differing policy priorities shape regulatory design.

Nigeria and Tanzania represent Sub-Saharan African contexts where mini-grids are central to national electrification strategies. Nigeria's NERC Mini-Grid Regulations (2023) provide comprehensive provisions on licensing, tariffs, and grid arrival compensation, backed by the Nigerian Electrification Project (REA and RMI, 2017). Tanzania was a regional pioneer through its Small Power Producer Framework, which introduced standardised tariff methodologies and power purchase agreements with World Bank support (EWURA, 2009). Together, they illustrate both the potential and persistent challenges of mini-grid regulation in low-electrification contexts.

Spain and Germany represent contrasting European approaches to distributed generation within already-electrified markets. Spain's Royal Decree 244/2019 operationalises the EU Clean Energy Package through a community-centred model enabling self-consumption and Renewable Energy Communities (Government of Spain, 2019). Germany's longer-standing market-integrated trajectory under the EEG, recently updated through Solarpaket I (2024), extends prosumer participation through innovations such as the Mieterstrommodell tenant electricity model (BMWK, 2024). Both countries exhibit regulatory maturity but, as this study shows, retain unresolved gaps around fully autonomous off-grid systems.

Together, these four countries highlight two African models of integrating mini-grids into national electrification strategies and two European approaches to distributed and community energy in already electrified markets, offering complementary perspectives for cross-regional comparison.

1.4 Data Sources

The analysis is based exclusively on secondary sources, including:

1. National laws, regulations, and decrees governing electricity markets, mini-grids, and distributed generation.
2. Regulatory guidelines and tariff methodologies issued by national energy regulators.
3. Relevant Journal Articles from Science direct.
4. Government policy documents and national electrification strategies.
5. Reports and evaluations from international organisations, development finance institutions, and research bodies (i.e. World Bank, the European Commission, etc.)

No primary data such as interviews, surveys, or field observations were collected.

2 Framing the Debate: Perception of Off-Grid Energy

Decentralized energy systems encompass a broad range of configurations in which electricity generation, distribution, and management occur closer to the point of consumption. These systems include distributed renewable generation, community energy initiatives, prosumer-based models, and mini-grids operating either grid-connected or autonomously. Within this wider landscape, off-grid mini-grids represent a distinct subset, particularly relevant in contexts where centralized grid expansion is limited or strategically deprioritized. Understanding how off-grid solutions are perceived therefore requires situating them within the broader evolution of decentralized energy governance, which differs significantly across regions such as Africa and Europe.

2.1 In Africa: A Development and Electrification Tool

Off-grid mini-grids systems have become central pillars of electrification strategies across Sub-Saharan Africa, driven by the urgent need to close the continent's persistent energy access gap while complementing, rather than competing with, national grid expansion. Around 600 million people in Sub-Saharan Africa remain unelectrified, primarily in rural and remote areas where grid extension is technically complex and financially prohibitive. For these regions, off-grid solutions provide a least-cost, rapidly deployable pathway to deliver reliable electricity where conventional infrastructure cannot reach in the short to medium term (ESMAP, 2022).

Contrary to the perception that mini-grids are merely temporary stopgaps, they are increasingly being designed as integrated components of national electrification plans. Many governments now use least-cost geospatial planning tools, such as those developed by the World Bank's Energy Sector Management Assistance Program (ESMAP), to determine where populations are best served by grid extension, mini-grids, or standalone solar systems. This "integrated planning" approach ensures that off-grid investments are strategically deployed where the grid is unlikely to arrive within 5–10 years, thereby reducing the risk of stranded assets and improving system-wide cost efficiency. A World Bank analysis estimates that approximately 40% of all new electricity connections needed by 2030 to achieve universal access in Africa will come from off-grid mini-grids systems, highlighting their central role (ESMAP, 2022).

Beyond addressing access gaps, off-grid systems are increasingly being built to be grid-compatible, meaning they can operate independently today but integrate seamlessly with the national grid when it eventually reaches the area. This interoperability prevents asset redundancy and ensures that infrastructure such as generation units, distribution lines, and meters remain valuable long-term. A practical example comes from Kenya, where community-based solar mini-grids are designed to function autonomously but connect to the central network when grid extension becomes economically feasible. Similarly, in Nigeria, "under-grid" mini-grids now coexist with the national network by serving communities where the central grid is unreliable, maintaining consistent power for households and small businesses while complementing distribution company efforts. This growing integration of off-grid systems within national energy strategies has been supported by strong collaboration between governments, donors, and private developers, who collectively shape the policies, financing mechanisms, and operational models driving rural electrification (ESMAP, 2022).

2.2 In Europe: A Niche, Permission-Based Approach

With electrification rates exceeding 99% across mainland European Union countries, the challenge is not connecting the unconnected but rather transforming an aging, centralised system into a decentralised, decarbonised, and digitally enabled network. Yet this aggregate figure masks important variations: many islands, remote mountain communities, and peripheral regions remain dependent on expensive diesel generation, unreliable undersea cables, or seasonal grid connections. For these areas, mini-grids offer not first time access but rather improved reliability, lower costs, and renewable integration, still a form of system optimisation rather than foundational electrification.

Where African mini-grids serve as primary electricity providers for first time users, European mini-grids typically function as supplementary, strategic assets embedded within or alongside existing infrastructure. Their purposes are diverse but consistently oriented toward system enhancement: increasing local energy independence and resilience, particularly for islands and remote communities; integrating high shares of variable renewable energy at the distribution level; enabling peer to peer energy trading and collective self-consumption within energy communities; and providing flexibility services such as demand response, voltage regulation, and congestion management to support grid stability.

This distinction reflects Europe's energy transition priorities. mini-grids are used as tools for achieving climate targets, empowering prosumers, and reducing reliance on centralised fossil fuel infrastructure. They are often community led or cooperative owned, designed to keep energy value local while contributing to national renewable energy goals.

However, this system optimisation focus has created a different set of regulatory challenges. European frameworks were built around the assumption of a single, vertically integrated or unbundled grid operator serving all consumers. mini-grids, especially autonomous ones, challenge this paradigm by introducing parallel infrastructure, local generation, and peer-to-peer transactions. As a result, regulatory frameworks have been slow to adapt. Many countries lack clear definitions of "autonomous mini-grids" or "energy communities" in legislation, leaving developers navigating a patchwork of rules designed for centralised systems.

This permission-based approach reflects both the maturity of Europe's grid infrastructure and the complexity of integrating new actors into tightly regulated markets. Yet as climate ambitions intensify and the need for resilient, flexible systems grows, particularly in the face of extreme weather, geopolitical energy security concerns, and accelerating renewable deployment, European policymakers are beginning to recognise that mini-grids require not just permission, but proactive regulatory support.

3 Regulatory Frameworks in Africa (Case Studies)

3.1 Nigeria

3.1.1 Energy access context and off-grid targets

Nigeria is known to be Africa's largest economy. Despite this, many rural and peri-urban communities are not connected to the main grid. As of 2024, around 45% of the population had no access to energy (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)., 2024). mini-grids in Nigeria are seen as a tool to achieve universal access, create jobs, and improve livelihoods. They have been given priority by the Federal Government and the Rural Electrification Agency (REA) in national electrification projects like the Nigeria Electrification Project, in order to speed up connections, lessen dependency on diesel, and encourage productive uses in rural communities. These programs provide financial support through competitive tendering and performance-based grants to expand mini-grid rollout and subsidise connections (Rural Electrification Agency, 2025).

3.1.2 Legal recognition of mini-grids

Nigeria has a standalone mini-grid regulatory framework that governs the construction, operation, and maintenance of mini-grids, therefore providing electricity to unserved and underserved areas. Nigeria's NERC Mini-Grid Regulations, first published in 2016 and revised/reissued in 2023, explicitly recognise mini-grids within the law. It legally defines isolated & interconnected mini-grids of ≤1 MW. It provides permitting, tariff setting, and compensation in the event the main grid is established. The 2016 Regulations involved registration and permit categories, tariff approval processes, interconnection and grid-arrival rules, and basic service quality and metering requirements. The 2023 Regulations update and expand the regime to clarify the relationship between mini-grid operators and Distribution Companies (DisCos), refine compensation/interconnection procedures upon grid arrival, and modernize schedules and implementation arrangements. These regulations constitute the primary legal pathway for developers and community operators (NERC, 2016; NERC, 2023).

3.1.3 Licensing and permitting requirements

The national energy regulator (Nigerian Electricity Regulatory Commission) grants permits for developing mini-grids in Nigeria. The developer must register or apply for a permit, depending on the size. Small projects (<100 kW) only need to register, whilst larger projects (up to 1 MW) must get a full permit. Some private sector actors still go for the full licensing under 100kWc to ensure good compensation in case the national grid arrives in the villages. Developers are required to present tariff proposals, service quality and metering plans, and technical documentation. A simple tariff calculator is offered by NERC to assist in proposal preparation. Coordination and tripartite arrangements may be necessary when a mini-grid is located near an existing DisCo's region in order to prevent overlap and guarantee orderly integration in the event that the main grid expands in the future. The 2023 Regulations refine permit conditions and require standardised connection agreements and compliance with the national metering code (NERC, 2016; NERC, 2023).

3.1.4 Tariff methodologies

Tariffs must be cost-reflective while maintaining customer affordability, according to NERC. Developers can calculate capital, Operation & Maintenance, demand growth, and revenue to create a proposed tariff path for approval using NERC's Mini-Grid Tariff Tool, an Excel calculator, which standardizes proposals and speeds up review. Permitted projects adhere to more comprehensive cost recovery techniques, while registered micro-projects often propose community-agreed rates that are subject to NERC review. Tariff treatment varies depending on whether the project is eligible for performance-based incentives or subsidies, which might lower the tariff needed for cost recovery, and if the mini-grid is isolated or connected. The proposed tariff is evaluated based on affordability for customers, cost reflectivity (ability to realistically cover developers' costs), and benchmarking (against national guidelines) (GElias, 2024).

3.1.5 Integration with the National Electrification Strategy

Mini-grids are formally embedded in Nigeria's national electrification strategy. Nigeria is considered a leading case in Africa due to the presence of a strong regulatory framework for mini-grids (NERC, 2016; NERC, 2023), which establishes clear licensing categories, tariff-setting procedures, and provisions for compensation or interconnection in the event of main grid extension. This framework is operationalised through national programs (e.g., the Nigeria Electrification Project under REA), supported by regulatory documentation and donor-backed evaluations. The REA's Nigeria Electrification Project (NEP) uses geospatial targeting and tendering to allocate performance-based grants and minimum-subsidy tenders for mini-grid roll-out. The national strategy explicitly treats mini-grids as complementary to grid expansion and includes procedures for grid-arrival (asset transfer, compensation, or integration) to avoid stranded investments and enable coexistence (Rural Electrification Agency, 2025).

3.1.6 Subsidies, incentives, and donor-funded support mechanisms

Nigeria's mini-grid market is actively supported through REA's Nigeria Electrification Project, which provides performance-based grants allocated via competitive minimum-subsidy tenders. These grants reduce upfront risk, bridge the affordability gap between cost-reflective tariffs and community willingness to pay, and are disbursed upon verified milestones such as connections delivered. Geospatial targeting ensures subsidies go to areas where mini-grids are the least-cost option and grid arrival is unlikely in the medium term.

International donors and DFIs, including the World Bank, African Development Bank, GIZ, and UK FCDO, complement government support with concessional finance, risk guarantees, technical assistance, and capacity building for NERC, REA, and developers. This blended approach has established Nigeria as one of Africa's most attractive mini-grid markets.

Subsidies are integrated into tariff design through NERC's Mini-Grid Tariff Tool, which accounts for capital costs, operations, and expected revenues. When grants are available, they lower the required end-user tariff while maintaining cost-reflective principles. However, subsidy levels are not always sufficient for full affordability, disbursement delays strain developer cash flows, and long-term reliance on donor funding raises sustainability concerns as the sector must eventually transition toward commercial finance.

3.1.7 Role of private developers vs. utilities

Nigeria's approach creates an enabling environment for private sector participation. Independent developers (both local and international) are expected to build, own, and operate most mini-grids under NERC permits/registrations and REA grant mechanisms. This brings innovation, efficiency, and capital mobilisation that would be difficult for utilities alone.

However, Distribution Companies (DisCos) retain territorial roles and responsibilities for grid expansion; the 2023 Regulations clarify the interplay between DisCos and mini-grid operators. For example, around tripartite agreements and compensation on grid arrival. In practice, developers negotiate PPAs/standardised contracts with communities while coordinating with DisCos where territory overlaps.

The dynamic is generally cooperative but sometimes tense. Developers seek legal clarity and strong compensation protections to reduce stranded asset risk, while DisCos aim to preserve system integrity and planned network expansions. Coordination gaps can create regulatory uncertainty, particularly when grid arrival is accelerated or unannounced. Effective implementation requires ongoing dialogue, transparent grid arrival mapping, and clear dispute resolution mechanisms to balance private investment incentives with utility planning prerogatives. (Dentons ACAS-Law, 2024).

3.2 Tanzania

3.2.1 Off-grid policy and EWURA's Small Power Producer (SPP) Framework

Tanzania is one of the first to develop a framework for mini-grids, and has a lot of case studies, technical guides, and ownership models, making it a strong learning case for African countries. The country has a regulatory framework and policies supporting mini-grids and established tariff tools and guidelines for their development. Tanzania was an early adopter of the Small Power Producer (SPP) enabling regulatory framework, originally introducing an enabling framework (the Electricity Act and SPP rules) to support decentralised power and small hydro/biomass projects with capacity up to 10MW (Government of the United Republic of Tanzania, 2008). EWURA (Energy and Water Utilities Regulatory Authority). An SPP in this context refers to a private entity generating electricity from renewable or hybrid sources with installed capacity between 100 kW and 10 MW that can sell power either to the national grid or to isolated mini-grids. The SPP framework provides standardized Power Purchase Agreements (SPPAs) and tariff methodologies that simplify licensing, ensure predictable tariffs, and lower barriers for private investment in small power and mini-grid projects. The Energy and Water Utilities Regulatory Authority (EWURA), the electricity regulator in Tanzania, developed the SPP framework and subsequent Small Power Projects (SPP) rules, which provide the main legal recognition for mini-grids and small power projects, encouraging private investment while offering a simplified rural context. The SPP approach has been central to Tanzania's strategy to facilitate rural electrification and private sector participation (World Resources Institute, 2017).

3.2.2 Licensing thresholds, templates, and size-based categorization

In Tanzania, the operation of a mini-grid requires several key steps overseen by the national regulator, the Energy and Water Utilities Regulatory Authority (EWURA). Developers must first obtain a license or permit, depending on the size of the project, which provides legal authority to build and operate. Under Tanzanian law (Electricity Act, subsequent SPP rules), generation and distribution projects specified capacity thresholds and in rural areas are often exempted from full license requirements and instead follow a registration/notification process. EWURA's guidance and standardised SPP templates lay out different requirements by size and by whether the plant will connect to the main grid. The legal regime has long used tiered categorization (small projects enjoy lighter procedures; larger ones face fuller licensing and PPA approvals). EWURA publishes standardized PPA and tariff templates to reduce transaction costs and make approval timelines more predictable (Energy and Water Utilities Regulatory Authority, 2025).

3.2.3 Tariff methodologies

Once licensed, the tariffs (electricity prices) charged to customers must be set using standardised tariff calculation tools provided by EWURA. This tool ensures that tariffs are both affordable for rural households and sufficient for developers to recover their costs. Tanzania introduced standardized tariff methodologies to replace case-by-case negotiations: The cases EWURA's Standardized Small Power Projects Tariff and the associated tariff order describe formulae and schedules for hydro, biomass and other technologies, and provide a mechanism to update tariffs if regulator approvals are delayed. These standardized tools make expected revenue profiles, cost recovery and tariff reviews transparent for developers and investors (Energy and Water Utilities Regulatory Authority, 2025).

3.2.4 Integration with national plans (REA, rural electrification)

Tanzania's SPP framework is formally integrated with national electrification planning through multiple institutional and policy mechanisms. The Electricity Act establishes the legal foundation, while ministerial powers over power system expansion and planning instruments identify rural electrification priorities and coordinate infrastructure investments (Government of the United Republic of Tanzania, 2008). EWURA's standardised approach operates in conjunction with the government's rural electrification initiatives, creating a coordinated environment where mini-grids are explicitly recognised as complementary to grid expansion rather than exclusively competitive alternatives (World Resources Institute, 2017).

The Rural Energy Agency (REA), Tanzania's primary implementing body for rural electrification, plays a central coordinating role. REA develops rural electrification master plans that use geospatial analysis to identify least cost electrification pathways, determining which communities are best served by grid extension, mini-grids, or standalone solar systems. These plans are updated periodically to reflect changing demographics, economic activity, and technology costs, providing developers with greater certainty about where mini-grid investments will not be undermined by imminent grid arrival.

Coordination between EWURA, REA, and the national utility (TANESCO) aims to prevent overlapping investments and stranded assets. REA maintains grid arrival forecasts and communicates expansion timelines to developers, while EWURA's licensing process considers planned grid extension routes when approving SPP applications (Energy and Water Utilities Regulatory Authority, 2025). This institutional alignment reduces regulatory uncertainty and encourages private sector confidence, though practical coordination gaps remain in some regions where communication between agencies is weak or grid expansion timelines shift unexpectedly.

3.2.5 Subsidies, tax benefits, and community-level incentives

Tanzania employs a combination of regulatory simplification, fiscal incentives, and donor supported programmes to reduce the financial barriers facing mini-grid developers and improve project viability in rural markets.

At the regulatory level, EWURA's standardised licensing templates and tariff methodologies reduce transaction costs and approval timelines, indirectly subsidising developers by lowering administrative expenses (Energy and Water Utilities Regulatory Authority, 2025). Simplified licensing procedures for smaller projects further reduce barriers to entry, particularly for community-based operators and local developers with limited resources. These process efficiencies function as implicit incentives by making market entry faster and cheaper.

Fiscal incentives include targeted tax benefits and duty exemptions for renewable energy equipment and mini-grid components. While these vary by region and are not always consistently applied, they reduce upfront capital costs for developers importing solar panels, batteries, inverters, and other hardware. Some local governments also offer land use incentives or streamlined permitting for mini-grid infrastructure, though the availability and transparency of such benefits differ across districts (Energy and Water Utilities Regulatory Authority, 2025).

Unlike Nigeria's centralised performance-based grant system, Tanzania's subsidy landscape is more fragmented and reliant on donor programmes. The World Bank, African Development Bank, and bilateral partners provide concessional finance, technical assistance, and results-based financing mechanisms that de-risk early stage projects and improve bankability. These programmes often include connection subsidies that reduce the cost burden on end users, capital grants that lower developer financing requirements, and performance incentives tied to verified connections or operational milestones.

Community level incentives focus on promoting local ownership and engagement. Some projects incorporate cooperative models where communities hold equity stakes, ensuring that economic benefits remain local and improving willingness to pay. Productive use promotion programmes, often supported by donors, provide financing or subsidies for income generating equipment such as milling machines, irrigation pumps, or cold storage, increasing electricity demand and improving mini-grid financial performance(Energy and Water Utilities Regulatory Authority, 2025).

However, challenges persist. Subsidy mechanisms are not always predictable or sufficient to fully bridge affordability gaps in low-income rural areas (Energy and Water Utilities Regulatory Authority, 2009). Donor dependency creates sustainability concerns, as scaling the sector will require transition toward commercial finance and reduced reliance on concessional capital. Additionally, limited coordination between fiscal authorities, EWURA, and REA sometimes results in inconsistent application of tax benefits or delays in subsidy disbursement, straining developer cash flows and project timelines.

3.2.6 Key challenges and private-sector participation

Key challenges in Tanzania include:

1. Limited regulatory & institutional capacity at sub-national levels to monitor and enforce standards
2. Financing gaps for many small developers (hence continued donor/DFI involvement)
3. Coordination with the national utility (TANESCO) and grid-extension plans to avoid stranded assets
4. Some developers are opting for fuller licensing even when exempt (i.e., seeking stronger legal protection).
5. Private sector participation is strong in SPP and mini-grid markets, but developer confidence depends on clear grid-arrival rules, predictable tariffs, and access to concessional finance or subsidies.

Beyond regulatory approval, developers are also required to engage with the local community before construction begins. This typically involves consultations to secure land access, explain service conditions, and build community support, which helps prevent conflicts and ensures that the system responds to local needs (Energy and Water Utilities Regulatory Authority, 2009; World Resources Institute, 2017)

3.3 Africa Section: Conclusion

3.3.1 Similarities

Both countries have explicit regulatory frameworks that recognise mini-grids and small power producers through tiered schemes based on project size. Nigeria has NERC's Mini-Grid Regulations (2016, 2023), while Tanzania operates under EWURA's SPP (Small Power Projects) rules and the Electricity Act (Government of the United Republic of Tanzania, 2008; NERC, 2016; NERC, 2023). This legal certainty creates an enabling environment for private sector participation, allowing independent developers to build, own, and operate projects.

Both regulators provide standardised templates for tariffs, PPAs, and contracts, enabling developers to prepare consistent applications while accelerating regulatory reviews (Energy and Water Utilities Regulatory Authority, 2025). Additionally, both countries rely significantly on World Bank, African Development Bank, and bilateral donor support in the form of grants, concessional finance, and technical assistance to improve project bankability and de-risk investments (NERC, 2023).

3.3.2 Divergences

From a regulatory framework perspective, Nigeria combines detailed standalone mini-grid regulations with a large scale, programmatic electrification instrument, the Nigeria Electrification Project (NEP), featuring competitive tenders and explicit per connection performance-based grants (Rural Electrification Agency, 2025). Tanzania pioneered SPP rules earlier and standardised tariffs, but its subsidy architecture is generally less centralised and less explicitly performance based than Nigeria's NEP (Energy and Water Utilities Regulatory Authority, 2025). The NEP's scale and financing make Nigeria's market particularly programme driven.

Regarding utility relationships, Nigeria's 2023 regulations place strong emphasis on grid arrival processes, including asset transfer, compensation, and integration mechanisms, while clarifying interactions with DisCos (NERC, 2023). Tanzania provides standardised procedures and templates, but in practice, developer concerns over stranded assets and coordination with TANESCO persist (Energy and Water Utilities Regulatory Authority, 2025). This makes Nigeria's legal framework more prescriptive on grid arrival protections.

Operationally, Tanzania's SPP approach historically targeted a broader set of small producers and emphasised early standardisation of tariff tools (Government of the United Republic of Tanzania, 2008). Nigeria's current push is explicitly targeted at rapid household connections and rural electrification scale up through the NEP's results based mechanisms (Rural Electrification Agency, 2025).

4 Regulatory Frameworks in Europe (Case Studies)

4.1 Spain

4.1.1 Legal framework for distributed generation (RD 244/2019)

Royal Decree (RD) 244/2019, approved on 5 April 2019, marked a turning point in Spain’s approach to self-consumption by repealing restrictive policies and establishing clear administrative, technical, and economic rules for distributed renewable generation. It replaced the controversial “sun tax” (RD 900/2015), which had hindered solar PV development, and aligned Spanish law with the EU’s Clean Energy for All Europeans Package (European Commission, 2019b). Two of its most important innovations were the differentiation between individual and collective self-consumption, and the recognition of systems with or without surplus injection to the grid.

4.1.2 Individual vs collective self-consumption

Before RD 244/2019, self-consumption was largely restricted to individual systems, where one consumer installed and benefited from their own PV system. The new regulation formally recognized collective self-consumption, which allows several consumers, such as the residents of an apartment block, industrial parks, or public buildings, to jointly benefit from a single renewable installation (Government of Spain, 2019).

This provision opened the door for energy-sharing schemes within cities and communities, making rooftop solar accessible even to those without suitable rooftops of their own. Collective projects are organized through agreements that specify distribution coefficients, i.e., how much electricity each participant is entitled to from the shared system. These agreements must be registered with the distribution company, ensuring regulatory compliance and grid transparency (Government of Spain, 2019).

Collective self-consumption has also provided the legal foundation for the emergence of Renewable Energy Communities (RECs) in Spain. Subsequent legal developments, including Royal Decree-Law 23/2020 and related measures, introduced formal provisions for RECs , although a fully detailed implementing framework is still evolving (Government of Spain, 2019). This has been critical for democratizing the energy transition, as it allows citizens to directly participate in renewable generation beyond the individual household level.

4.1.3 Systems with or without surplus injection to the grid.

RD 244/2019 also introduced a clear distinction between self-consumption with surplus injection and without surplus injection.

Without surplus injection: In this model, the installation is designed so that all electricity generated is consumed on-site. This configuration is technically simpler and involves fewer regulatory obligations, since there is no interaction with the public grid. Such systems are particularly attractive for households or businesses with high daytime consumption that can match solar generation profiles.

With surplus injection: In this case, excess generation can be fed into the distribution grid. To incentivize this, RD 244/2019 created the simplified compensation mechanism, whereby surplus energy exported to the grid is credited on the consumer's electricity bill at a regulated rate. The scheme applies to installations up to 100 kW, allowing them to receive a monthly credit for surplus without having to register as full electricity market participants (Government of Spain, 2019).These installations with total generation capacity up to 100 kW are eligible for the simplified compensation mechanism for surplus energy exported to the grid. Installations above this threshold are required to sell their electricity directly on the wholesale market.

This reform made small-scale solar significantly more financially attractive by ensuring that prosumers are not penalized for generating more than they consume. It also aligned Spain with other EU member states that had already implemented netting or compensation schemes. By combining administrative simplification with economic incentives, the regulation encouraged rapid growth: by 2023, Spain had accumulated nearly 7 GW of installed self-consumption capacity, most of it PV (PV Magazine, 2023).

4.1.4 Shared self-consumption models and energy communities

RD 244/2019 created the legal foundation for collective (shared) self-consumption. Multiple consumers may be associated with a single production installation and share generation according to pre-defined allocation coefficients. The law requires formal registration and special metering systems to track how much electricity each participant gets (Mariscal Abogados, 2023). Since the adoption of RD 244/2019, Spain has progressively amended its regulatory framework to expand and facilitate shared schemes and energy communities (Institute for the Diversification and Saving of Energy, 2020). Recent regulatory developments have focused on increasing the flexibility and scalability of shared self-consumption schemes. This includes expanding the permissible distance between photovoltaic installations and associated consumers, as well as simplifying coordination and management requirements for multi-user schemes. These changes enable households, businesses, and public entities to share renewable electricity across wider areas, even when not located within the same building, thereby supporting larger and more diverse energy communities. In parallel, Spain has continued to align its self-consumption framework with European Union policies promoting Renewable Energy Communities (RECs), strengthening citizen participation and local ownership in distributed energy systems(Interreg Europe, 2025).

4.1.5 Size thresholds and permission requirements

Under RD 244/2019 the regulatory framework depends on the type of self-consumption schemes and if they consume with or without surplus:

1. Self-consumption without surplus: Small installations that consume all generation onsite are typically exempted from formal access/connection permits but are subjected to technical/notification requirements (Clean Energy for EU Islands, 2022).
2. Self-consumption with surplus: Small systems may use a simplified compensation mechanism for surplus up to defined thresholds; larger systems and systems that interact with the market face full access/connection and market registration requirements. Compensation schemes include net billing, where they get credits or compensation for the extra electricity they send to the grid, but only up to certain limits.
3. Spain's connection regime has been clarified by subsequent measures (e.g., RD 1183/2020 and CNMC procedures) that streamline access/connection for projects above threshold levels. Recent RD-Law changes in 2025 also introduced provisional operating authorisations and extended shared-self-consumption

distance limits for certain facilities, which is beneficial for facility-scale mini-grid designs (Clifford Chance., 2021;nterreg Europe, 2025).

4.1.6 Subsidies, fiscal incentives, and municipal support

Spain uses a mix of policy instruments such as national subsidies, regional incentives and local fiscal measures to support distributed generation and storage. Many municipalities now offer property tax (IBI) reductions or building permit fee rebates for self-consumption installations. National and EU funds, such as Recovery & Resilience Facility lines and regional ERDF grants, support storage and community projects. RD-Law 7/2025 further targets storage and system flexibility with financial and permitting streamlining to accelerate hybrid PV and storage roll-outs (Strategic Energy Europe, 2025).

4.1.7 Gaps in regulation for fully off-grid systems

Spain's regulatory framework for distributed generation remains centered on systems that are, at least in principle, connected to the public grid. This focus reflects the broader policy assumption that grid expansion and reinforcement, rather than long-term off-grid solutions, should remain the backbone of the national electricity system. Royal Decree 244/2019 explicitly excludes isolated installations from the self-consumption regime: if a system has no physical point of connection, it is not classified as "autoconsumo" under the decree. This means that fully autonomous projects fall outside the scope of self-consumption incentives, simplified administrative procedures, or surplus-compensation mechanisms. The official guidance from IDAE (Institute for the Diversification and Saving of Energy) confirms this reading, noting that "instalaciones aisladas" (Isolated /off - grid systems) are not subject to, nor do they benefit from the rights conferred by RD 244/2019 (Government of Spain, 2019).

From a regulatory perspective, this exclusion is partly justified by the fact that off-grid systems do not interact with the public network and therefore do not raise issues of grid access, congestion management, or system balancing. However, this design choice also creates several practical regulatory gaps. First, there is no clear process for authorizing permanently off-grid commercial mini-grids. While a grid-connected project can apply for access and connection under RD 1183/2020, off-grid operators lack a comparable authorization pathway (Government of Spain, 2020). Second, current technical standards are written for grid-connected systems, focusing on interconnection, metering, and injection of surplus. Off-grid systems, however, face distinct challenges, such as maintaining voltage and frequency stability internally, which require a dedicated regulatory framework. Without specific rules, these systems are governed only by general building codes or electrical safety regulations, rather than energy law.

Third, there are no clear frameworks on pricing, trading, or regulation when running an off-grid mini-grid as a business. A commercial operator providing electricity to multiple clients (e.g. an industrial park or tourist complex) does not fall neatly under existing categories of distribution or retail supply, since those are defined with reference to the national grid. This leaves questions of tariff approval, consumer protection, and dispute resolution unresolved. The absence of a defined regulatory category for such actors creates uncertainty for investors and customers alike.

Recent policy discussions and draft reforms have reduced certain barriers for self-consumption and grid access, particularly by simplifying permitting and expanding support for renewables. However, these measures still assume a connection to the national network. As the Clean Energy for EU Islands Secretariat notes, full regulatory clarity for systems that are designed to remain off-grid, and especially for those that may later seek limited market participation (e.g. selling surplus under defined conditions), remains an area requiring further legal and regulatory refinement (Clean Energy for EU Islands, 2020).

In short, Spain has built a strong framework for prosumers and energy communities within the grid, but fully autonomous mini-grids remain in a legal grey area, with unresolved questions around authorization, technical standards, pricing, and market interaction. While this approach is coherent with Spain's grid-centric energy strategy, addressing these gaps would be necessary to give legal certainty to communities or businesses that deliberately choose autonomy from the public grid, particularly in remote or insular locations, in isolated tourist or industrial developments, in facilities requiring high levels of supply security, or in experimental and demonstrator projects where off-grid operation is a deliberate design choice rather than a transitional condition.

4.2 Germany

4.2.1 Distributed generation under the EEG Act

Germany's Renewable Energy Sources Act, EEG (most recently updated in the EEG 2023 package) sets the overall incentive architecture that enabled distributed generation. It was historically via feed-in tariffs which made it safe for households, farmers, and cooperatives to invest in renewables. Today, support is increasingly structured around auctions, tendering and market-oriented instruments particularly for larger installations, which help control costs and increase competition, while smaller systems continue to benefit from simplified remuneration schemes. Purely off-grid systems, even if technically advanced, fall outside the EEG framework since the system is designed for grid-connected generation. The EEG provides investment support, grid-connection priority for renewables, and mechanisms that have allowed broad citizen and cooperative ownership of small generation units. The 2023 EEG reform accelerates renewable expansion targets and simplifies some permitting and tender structures to scale up distributed renewables. At the same time, the German framework requires technical conformity with national grid codes and VDE technical rules for interconnection (Climate Change Laws of the World, 2023).

4.2.2 Tenant electricity schemes (Mieterstrommodell)

Mieterstrom (landlord-to-tenant electricity) schemes allow electricity produced at or near a residential building (e.g., rooftop PV) to be supplied directly to tenants without the project operator being subject to full retail supplier licensing, and are supported through specific subsidy mechanisms. The German federal government introduced promotion schemes and legal clarifications, but practical adoption has been constrained by administrative complexity, billing/EEG-levy handling and limited uptake of available support (BMWK, 2024). It is still framed within a grid-connected paradigm as one of the requirements is that the project remains connected to the public grid to qualify for support.

4.2.3 Integration of storage and local energy balancing

Germany enforces strict technical connection and safety standards. This includes VDE application rules such as VDE-AR-N 4105/4110/4120 for distributed generators and storage. Recent EEG reforms, including the Solarpaket I (2024), emphasize the integration of battery storage with distributed PV. The reform simplified permitting for rooftop systems, expanded incentives for coupling PV with batteries, and created exemptions for small-scale producers from certain levies.

Storage integration requires compliance with grid-support functionalities, protection settings, and sometimes additional grid-operator coordination. At scale, storage plus local balancing enables mini-grids to deliver ancillary services, manage local peaks, and support islanding capability. However, technical certification and grid code compliance are necessary, and recent VDE updates impose more stringent grid-support demands on distributed plants (VDE FNN, 2018).

4.2.4 Role of municipalities and community energy models

Municipal utilities (Stadtwerke) and energy cooperatives (Genossenschaften) are major actors in Germany's distributed energy scope. By 2016, more than 40% of renewable capacity in Germany was owned by citizens or energy cooperatives (Clean Energy Wire, 2018). The EEG's prior feed-in regime and decentralized support created a strong co-operative movement and municipal involvement in renewables, enabling local ownership and mini-grid-like arrangements at industrial parks, campuses and local districts. Municipal actors also often sponsor tenant-electricity pilots and local storage projects. However, the evolving legal status of customer installations is reshaping how municipalities and cooperatives can structure distribution activities (Moser, R., Xia-Bauer, C., Thema, J., & Vondung, 2021).

4.2.5 Policy barriers for stand-alone/off-grid mini- grids

Germany's legal framework historically allowed customer installations / closed distribution systems (Kundenanlagen/CDS) and private distribution networks for confined sites. This approach reflected Germany's market-oriented and grid-integrated electricity model, which prioritises non-discriminatory network access, consumer protection, and system reliability over decentralised autonomy.

However, recent EU and national case law, i.e ECJ judgment in late 2024 and implementing national court rulings in 2025, have challenged the compatibility of broad "customer installation" exemptions with EU law: The ECJ found that if a system effectively distributes electricity for sale to multiple customers, it must be treated as a regulated distribution network and not be exempted. The underlying rationale is that systems which effectively distribute electricity to multiple end users perform a function comparable to regulated distribution networks and should therefore be subject to equivalent obligations.

German courts and regulators are now re-interpreting the CDS/Kundenanlage category, tightening exemptions and increasing compliance obligations, which is a major policy barrier for projects that relied on lighter CDS rules. In practical terms, this raises uncertainty for any mini-grid that intends to supply multiple customers or behave like a mini-utility, and creates a tougher pathway for permanent, stand-alone mini-grids that are not clearly labelled as either private customer systems or full distribution operators. Additionally, stringent technical and certification requirements (VDE) can be costly for small community projects seeking islanding capability (Gleiss Lutz, 2024).

Despite Germany's strong grid coverage and reliable electricity supply, limited cases exist where off-grid or semi-autonomous systems could be both technically and economically justified. These include industrial or commercial sites requiring very high levels of supply security, research and demonstration projects testing advanced mini-grid control systems, military or critical infrastructure facilities, and geographically constrained locations such as islands, alpine regions, or remote facilities where full grid reinforcement would be disproportionate. In such contexts, off-grid operation is not intended to replace the public grid but to enhance resilience, flexibility, or innovation.

4.3 Europe Section Conclusion

Spain and Germany both exemplify mature European approaches to distributed renewable generation, but their regulatory strategies differ in emphasis. Spain's Royal Decree 244/2019 created a decisive break with past restrictions by removing the "sun tax" and enabling individual and collective self-consumption. It introduced a simplified surplus compensation scheme for small installations and set clear proximity rules for shared systems, thereby accelerating the spread of rooftop PV and energy communities. Spain's approach is therefore community-oriented, focusing on citizen participation and shared ownership models, albeit firmly within a grid-connected framework.

Germany's Renewable Energy Sources Act (EEG) followed a different trajectory. It pioneered feed-in tariffs and later evolved toward auctions and market premiums, embedding distributed renewables within a structured market framework. Complementary schemes such as the Mieterstrommodell (tenant electricity model) and the Solarpaket I (2024) reforms highlight Germany's effort to integrate prosumerism, rooftop solar, and storage within a broader market-based system. Germany's approach is therefore market-structured, emphasizing investor certainty, market participation, and the role of cooperatives and municipal utilities.

Together, Spain and Germany show that European distributed generation policies can either prioritize community empowerment (Spain) or market integration (Germany), but both remain firmly anchored in the logic of the interconnected grid.

4.3.1 Regulatory gaps in integrating autonomous off-grid communities

Despite their advances, both Spain and Germany exhibit a clear regulatory gap when it comes to autonomous off-grid communities. Spain's RD 244/2019 explicitly excludes isolated systems from the self-consumption regime, meaning that communities or businesses choosing to operate fully off-grid fall outside the legal framework for tariffs, surplus compensation, or consumer protections. Germany's EEG framework is equally grid-centric, offering support only to systems that inject power into the network. Off-grid projects are not recognized under energy law, and must instead rely on general building or safety codes, with no provisions for authorization, pricing, or consumer rights.

This creates uncertainty for groups seeking permanent energy autonomy, whether in rural Spain, German eco-villages, or island territories. Three main challenges stand out:

1. The absence of an authorization pathway for commercial or community-operated off-grid systems
2. The technical standards designed only for grid-connected systems, leaving off-grid mini-grids without tailored regulation
3. The lack of pricing and trading frameworks, meaning off-grid operators cannot legally supply multiple customers on a commercial basis.

Although recent policy discussions and draft reforms in Spain and Germany have focused on the idea of simplifying permitting and boosting support for renewables as neither addresses these off-grid regulatory blind spots. For Europe, where energy communities and prosumerism are increasingly central to the transition, creating a legal category for autonomous mini-grids would be a logical next step. This would provide clarity on authorization, consumer protection, and limited market participation, enabling innovation while ensuring that autonomous systems remain aligned with national energy policy goals.

5 Comparative Analysis: Africa vs Europe

5.1 Legal Recognition of mini-grids

In Africa, countries such as Nigeria and Tanzania have established explicit legal categories for mini-grids and off-grid systems. Nigeria's Mini-Grid Regulation (Nigerian Electricity Regulatory Commission, 2016; revised 2023) defines isolated and interconnected mini-grids, sets size thresholds, and introduces tariff and compensation rules (NERC, 2016; NERC, 2023). Tanzania's Small Power Producer Framework also formalises small-scale generation through standardised contracts, tariffs, and interconnection procedures (Government of the United Republic of Tanzania, 2008). These frameworks provide regulatory certainty for investors and align private activity with national electrification plans (ESMAP, 2022).

By contrast, in Europe, off-grid systems are rarely defined in law. Spain's Royal Decree 244/2019 regulates self-consumption only for installations connected to the public grid (Government of Spain, 2019). Germany's Renewable Energy Sources Act (EEG) focuses on feed-in remuneration and market participation for connected producers (BMWK, 2024). Fully autonomous systems operate outside the main legal framework, covered only by general electrical safety standards rather than energy regulation (Wurster and Hagemann, 2020).

5.2 Size-Based Thresholds & Licensing

African frameworks differentiate regulation according to system size. Nigeria exempts systems below 100 kW from licensing, requires simplified registration for systems up to 1 MW, and mandates full licensing above that threshold (NERC, 2023). Tanzania applies a similar scale through its Small Power Producer Rules, where Very Small Power Producers (VSPPs) under 100 kW benefit from simplified procedures and tariffs approved by EWURA (Energy and Water Utilities Regulatory Authority, 2009). This tiered approach encourages small-scale private investment and community participation.

In Europe, capacity thresholds exist but focus on administrative simplification for grid-connected prosumers rather than off-grid operators. Spain's Royal Decree 244/2019 exempts rooftop PV systems below 15 kW on urban land from connection permits and allows simplified surplus compensation for installations up to 100 kW (Government of Spain, 2019). Germany's EEG classifies installations by output for feed-in tariffs and market premiums but presupposes grid connection (BMWK, 2024). Off-grid systems, regardless of size, are not subject to specific licensing categories.

5.3 Integration with National Strategies

In Africa, off-grid systems form part of national electrification plans. Governments use least-cost geospatial planning tools, often developed with the World Bank's Energy Sector Management Assistance Programme (ESMAP), to identify optimal mixes of grid extension, mini-grids, and standalone systems (ESMAP, 2022). Nigeria's Rural Electrification Strategy and Implementation Plan and Tanzania's Rural Energy Master Plan both integrate off-grid options as pillars of universal access. These frameworks view mini-grids as permanent or semi-permanent infrastructure, designed for eventual grid integration or continued autonomy (World Bank, 2016).

In Europe, distributed generation supports energy transition goals rather than electrification. National plans under the EU Clean Energy for All Europeans Package prioritise renewable integration, prosumer participation, and energy communities (European Commission, 2019a). Off-grid mini-grids are rarely addressed. Their absence from mainstream planning reflects a structural assumption that all generation remains within a single, interconnected market (REScoop.eu, 2021).

5.4 Subsidies, Incentives, and Community Support

In Africa, most financial support comes from donor and development finance institutions (DFIs) through grants, results-based financing, and blended capital. The World Bank's Nigeria Electrification Project and the AfDB's Green Mini-Grid Market Development Programme are key examples (World Bank 2020 ; AfDB, 2019). Fiscal incentives such as import duty waivers and VAT exemptions on renewable equipment complement these programmes (GET.invest, 2023).

In Europe, distributed generation is incentivised through domestic market mechanisms. Spain's RD 244/2019 provides surplus compensation for small producers, while regional governments add direct grants and low-interest loans (Government of Spain, 2019). Germany's EEG offers feed-in tariffs and market premiums, and the Mieterstrommodell subsidises tenant electricity schemes (BMWK, 2017). The Solarpaket I (2024) simplified procedures for rooftop PV and battery storage (BMWK, 2024). These measures encourage participation but apply only to connected systems, not to isolated off-grid communities.

5.5 Role of National Utilities

In Africa, national and municipal utilities often act as partners or developers in off-grid projects. Nigeria's Rural Electrification Agency (REA) and Tanzania's TANESCO coordinate mini-grid development, facilitate private participation, and plan integration with national networks (REA, 2022; TANESCO, 2021). This hybrid approach links public and private investment to achieve universal access.

In Europe, utilities primarily manage the national grid and integrate distributed renewable generation. In Germany, Stadtwerke (municipal utilities) and in Spain, regional distribution companies, enable prosumer participation through connection agreements and community projects but do not develop or operate off-grid systems (Heinrich Böll Foundation, 2018). Their mandate remains firmly tied to grid operation and system balancing, reinforcing a centralised model of electricity governance.

6 Policy Gaps and Contradictions

This section explores the main misalignment and incompleteness in the policy frameworks developing distributed energy resources (DER) and mini-grids within the case study countries. While regulations are meant to create structure and certainty, the analysis shows significant gaps and contradictions that ultimately complicate investment, slow deployment, and lead to unintended outcomes in respect of energy access and decarbonisation objectives (Hirsch et al., 2018). A recurring gap is around having long-term bankable and adaptive regulatory contracts in place to de-risk investment in line with policy objectives (S.C, Bhattacharyya & Palit, 2016).

6.1 Missing or Ambiguous Definitions of mini-grids

A basic regulatory gap across both continents is the absence of clear, consistent legal definitions of mini-grids and distributed energy resources (DER).

In the African (Nigeria and Tanzania) contexts, the legal taxonomy tends to be binary, either a licensed utility vendor to the national grid or an "off-grid" operator with ambiguous legal status. This creates a critical gap for mini-grids specifically designed for future grid interconnection. Definitions for "isolated" and "interconnected" mini-grids are presented in Nigeria's Mini-Grid Regulations, yet the regulatory and practical process of transition from one state to the other is uncertain (NERC, 2017). Most importantly, no direction is provided as to the compensation mechanism or revenue model that would protect the mini-grid operator's investment once the national grid arrives (World Bank, 2017). Tanzania faces similar definitional challenges between community-owned models and commercially-owned models, each of which are treated differently in the regulations and affect the frameworks for financing.

In the case of Europe (Germany, Spain), the ambiguity refers to the legal identity of entities, such as a Citizen Energy Community (CEC), which was formally introduced to harmonize national laws but remains subject to varied interpretation during transposition (European Union, 2019) . In Germany, the issue of whether a mini-grid is a "closed distribution system" may complicate tax obligations, levies, and grid- fees, due to the coexistence of earlier national regulatory practices predating EU market definitions and the subsequent harmonised EU framework, creating regulatory ambiguity and uncertainty for developers (Lowitzsch, 2019). In Spain, the definition of "collective self-consumption," has been narrowly defined in legislation, which limits its application for innovative mini-grid models (e.g. mini-grids including storage and multi-building mini-grids in dense urban settings) (Frieden et al., 2020).

This definitional gap creates a regulatory no-man's-land. This directly contradicts policy goals, as it hinders the creation of scalable, investment-ready mini-grid models in Africa while stifling the innovation and citizen participation central to Europe's decarbonization strategy.

6.2 Overlaps between Local and National Rules

The local nature of distributed energy deployment frequently results in jurisdictional conflicts where local governance is not streamlined with national frameworks.

In Africa (Nigeria and Tanzania), national governments set electrification targets and frameworks for mini-grid permits, but control over land use, right-of-way, and local taxation resides with municipal or traditional authorities. This often means that a developer who secures a national permit may be stalled by a local government demanding separate fees or refusing necessary land access (Monyei et al., 2018). This structural overlap generates delays, increases soft costs, and deters investment, directly contradicting the national policy aim of rapid deployment.

In Europe, the jurisdictional overlap is layered across EU directives, national laws, and regional/local implementation. Germany, as a federal republic, exhibits this conflict where energy policy is shared by the federal government and the 16 states (Länder). Consequently, an EU directive, once transposed into national law, can face varying spatial planning rules, building codes, and grid connection requirements across the states . Spain experiences similar conflicts, where national energy laws clash with permitting and environmental requirements set by autonomous regional governments (Cansino et al., 2018).

There is a significant gap in establishing streamlined, one-stop-shop regulatory processes capable of harmonizing national policy objectives with local governance realities.

6.3 Regulatory Uncertainty for Off-Grid Communities in Europe

While European regulation largely focuses on grid-connected prosumers, a policy gap has emerged for communities that seek to become fully energy autonomous.

A crucial point of uncertainty is the lack of a clear "right to disconnect" from the central grid in most European regulations, which are built upon the assumption of a connected system. In both Germany and Spain, a community that successfully invests in storage, solar, and backup generation to achieve full off-grid independence may still be legally required to pay base tariffs for "standby" grid connection costs or be subject to system support levies (Frieden et al., 2020).

This constitutes a major contradiction: policies designed to incentivize decarbonization and self-consumption ultimately penalize communities that pursue the logical conclusion of full independence. This framework actively discourages the most resilient form of distributed generation and undermines long-term innovation in self-sufficient community energy, primarily serving to protect the incumbent utility and grid business model.

This situation reflects a broader tension within current energy policy frameworks. On the one hand, policies aim to incentivise decarbonisation and self-consumption; on the other, they seek to preserve system reliability, cost socialisation, and universal service obligations. As a result, regulatory frameworks may limit or discourage full disconnection from the grid, even where technical autonomy is feasible. While this approach is coherent with the governance of an integrated electricity system, it can create uncertainty for a limited set of communities pursuing autonomy for reasons such as resilience, experimentation, or site-specific constraints, rather than constituting an inherent contradiction in policy objectives.

6.4 Alignment Issues Between Electrification Targets and Investment Incentives

The most critical gap is the misalignment between ambitious policy targets and the on-the-ground financial incentives necessary to achieve them, threatening the predictability of revenue models.

In Africa, the "Grid Extension Threat" acts as a significant disincentive for private mini-grid investment in Nigeria and Tanzania. The national policy goal of universal access relies on both grid extension and mini-grid development, but these strategies are often uncoordinated. A private developer who successfully invests in and operates a mini-grid faces the substantial risk that the national utility will extend the main grid to the same service area, rendering the mini-grid obsolete. Crucially, current compensation frameworks for such events are often insufficient, failing to cover the initial investment (World Bank, 2017). This severe regulatory risk directly contradicts the policy objective of attracting necessary private capital for off-grid solutions (S.C, Bhattacharyya & Palit, 2016).

In Europe, the stability of support schemes is the primary issue. Spain's history is characterized by regulatory volatility (e.g., the "sun tax"), which created "regulatory whiplash" and eroded investor confidence, thereby jeopardizing the attainment of clear renewable capacity targets (Cansino et al., 2018). In Germany, while regulatory stability is generally higher, the transition from fixed Feed-in-Tariffs (FiTs) to competitive auctions has unintentionally disadvantaged smaller citizen energy communities (Bürgerenergie). This incentive mechanism contradicts the policy target for broad citizen participation by favoring commercial developers who can operate at a larger scale.

The frameworks frequently fail to provide a clear, predictable, and fair revenue model corresponding to the lifetime of the distributed energy asset.

7 Policy Recommendations

7.1 African Context: Accelerating Mini-Grid Deployment

7.1.1 Resolve investment uncertainty around grid arrival

The single most persistent barrier to private mini-grid investment in both Nigeria and Tanzania is the risk of asset stranding when the main grid arrives. In Nigeria, the 2023 NERC Mini-Grid Regulations acknowledge this problem but do not resolve it, compensation terms remain subject to negotiation at the point of grid arrival, precisely when developers are most exposed. NERC should amend the regulations to codify a mandatory, formula-based asset buyout mechanism with pre-agreed valuation methodologies, binding timelines, and a clear pathway for transitioning mini-grid operators to grid-connected status under long-term power purchase agreements. In Tanzania, EWURA should similarly strengthen the SPP framework's grid-arrival provisions, moving from general principles to enforceable protocols. Both countries should complement these reforms by publishing regularly updated geospatial grid-arrival forecasts with five- and ten-year extension horizons, giving developers the information they need to assess site-level stranding risk before committing capital. These reforms would do more to unlock investment than any new incentive programme, because they address the root cause of developer hesitation rather than compensating for it downstream.

7.1.2 Strengthen multi-stakeholder coordination and reduce administrative friction

In both countries, the coordination gap between national regulators, utilities, and local government authorities is an underappreciated but recurring bottleneck. In Tanzania, land access and right-of-way disputes between developers and local governments routinely delay project timelines, while the relationship between TANESCO and private operators remains dependent on bespoke negotiations rather than standardised procedures. EWURA should publicly release standardised interconnection protocols and PPA templates to reduce transaction costs and level the playing field for smaller developers. In Nigeria, formal coordination mechanisms between NERC, the REA, Distribution Companies, and state governments should be institutionalised to prevent overlapping investments and jurisdictional disputes. Both countries would also benefit from single-window licensing mechanisms that streamline approvals across ministries, with automatic fast-track approval for systems below a defined capacity threshold.

7.1.3 Develop sustainable financing beyond donor cycles

Results-based financing, as deployed under Nigeria's Electrification Project, has demonstrated real effectiveness but remains structurally dependent on donor funding. Both Nigeria and Tanzania should work with their central banks and regional development finance institutions to establish domestic, local-currency credit facilities for mini-grid developers, reducing foreign exchange exposure and enabling the sector to grow on commercially sustainable terms. Partial risk guarantee mechanisms should be expanded to cover political and regulatory risks, enabling commercial lenders to enter the market with greater confidence. Aggregation platforms that bundle smaller projects into investable portfolios can further reduce due diligence costs for financiers and improve access to capital for community-scale developers.

7.2 European Context: Enabling Distributed Energy and mini-grids

7.2.1 Officially recognize autonomous off-grid communities in national legislation

The most significant regulatory gap in both Spain and Germany is the absence of a coherent legal framework for fully autonomous off-grid installations. Spain's Royal Decree 244/2019 explicitly excludes isolated systems from its self-consumption regime, leaving standalone community energy installations without a clear legal status, defined technical standards, or access to public financing instruments. This gap is particularly consequential for the Canary and Balearic Islands, where autonomous mini-grids have clear strategic value for decarbonisation and energy security. The Spanish government should introduce a dedicated regulatory instrument, analogous in structure to RD 244/2019 but applicable to isolated systems, that provides legal certainty for standalone community energy installations and enables them to access the same financing and support mechanisms available to grid-connected systems.

In Germany, the European Court of Justice's 2024 reassessment of the Kundenanlage (customer installation) exemption has created acute uncertainty for community energy and industrial self-supply projects that were designed and financed under the previous interpretation (Gleiss Lutz, 2024). The BMWK should issue unambiguous guidance on the post-ruling regulatory position and consider amending the Energiewirtschaftsgesetz (EnWG) to establish a clear, proportionate regulatory category for closed distribution systems, one that serves community energy projects without subjecting them to full distribution system operator obligations.

7.2.2 Integrate off-grid systems into energy transition and resilience planning

Neither Spain nor Germany currently recognises autonomous mini-grids as a formal category within their National Energy and Climate Plans. Both countries should remedy this in their forthcoming NECP revisions, explicitly incorporating standalone renewable mini-grids as tools for decarbonisation, energy security, and local resilience, particularly for island territories, remote communities, and critical infrastructure requiring backup generation capacity. Recognising mini-grids in NECPs would also unlock access to EU structural and cohesion funds, which currently flow predominantly to grid-connected projects..

7.2.3 Enable fair, transparent market participation

Spain's municipal IBI property tax relief for solar installations is now offered by 67% of municipalities (Strategic Energy Europe, 2025), but inconsistent application creates a postcode lottery that is difficult for developers and communities to anticipate. The Ministry for Ecological Transition should establish a national minimum standard for municipal fiscal incentives to create a more equitable and predictable enabling environment. Spain should also clarify and simplify the administrative procedures governing Renewable Energy Communities, which continue to discourage uptake among smaller and less resourced community groups despite the strong underlying legal framework.

In Germany, while Solarpaket I (2024) made meaningful progress in simplifying the Mieterstrommodell and extending its reach, uptake in multi-unit housing remains constrained by administrative complexity at the point of implementation. The BMWK should establish a structured monitoring and evaluation process for Solarpaket I's prosumer provisions, with a commitment to introduce further simplification within two years if participation rates remain below projected levels. Both countries should also develop harmonised technical standards and proportionate network charging frameworks for autonomous systems seeking to connect or exchange energy with the central grid, ensuring that off-grid communities are not penalised for pursuing the logical conclusion of energy self-sufficiency.

8 Conclusion

This study conducted a case study analysis of regulatory frameworks for promoting distributed energy generation and mini-grids in Africa and Europe. The analysis has shown that mini-grid governance in Africa and Europe reflects fundamentally different policy priorities and energy system realities. While African regulatory frameworks are largely shaped by the urgent need to expand electricity access, European frameworks operate within advanced centralized power systems where mini-grids are viewed primarily as tools for flexibility and resilience rather than access provision.

The analysis demonstrates that legal recognition, licensing structures, integration into national strategies, and the role of public utilities are all shaped by these differing structural conditions. In African contexts, regulatory innovation often aims to enable decentralized electrification through clearer licensing pathways, tariff mechanisms, and defined mini-grid categories. In contrast, European regulatory systems tend to integrate mini-grids into broader electricity market rules, often without establishing a distinct regulatory category for autonomous systems.

Importantly, these differences are not simply geographic but systemic. They reflect contrasting development stages of energy infrastructure, market design traditions, and policy objectives. As a result, policy transfer between regions must be approached cautiously. Regulatory instruments effective in one context may not function similarly in another without adaptation to local institutional and infrastructural conditions.

Ultimately, the study highlights that mini-grid policy cannot be detached from broader energy governance frameworks. Whether deployed for electrification, resilience, or decarbonization, mini-grids remain embedded in national energy strategies and utility structures. Understanding these embedded relationships is essential for designing regulatory environments that are both enabling and context-sensitive.

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