

SWARM-E project

LEAVE NO ONE BEHIND: BOTTOM-UP ENERGY TRANSFORMATION OF LAST-MILE COMMUNITIES

**WP6 Regulatory Issues and Environmental Aspects
T6.1 Definition of Regulatory Environment**

POLICY PAPER

**Peer-to-Peer Solar Electricity Sharing in
Tanzania and Rwanda**

**An Enabling Policy and Regulatory Framework for
Community Energy Markets, SWARM Grids and Inclusive
Energy Access**



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Abbreviations

AfDB	African Development Bank
BESS	Battery Energy Storage System
EAC	East African Community
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Program
EWURA	Energy and Water Regulatory Authority
GSM	Global System for Mobile Communications
ICT	Information and Communication Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFC	International Finance Corporation
IoT	Internet of Things
IRENA	International Renewable Energy Agency
LoRaWAN	Long Range Wide Area Network
MECS	Modern Energy Cooking Services
NDCs	Nationally Determined Contributions
NIST	National Institute of Standards and Technology
P2P	Peer-to-Peer
PUE	Productive Use of Energy
PV	Photovoltaic
REA	Rural Energy Agency
REG	Rwanda Energy Group
RURA	Rwanda Utilities Regulatory Authority
SMEs	Small and Medium Enterprises
TANESCO	Tanzania Electricity Company
TAREA	Tanzania Renewable Energy Association
TBS	Tanzania Bureau of Standards
UNECA	United Nations Economic Commission for Africa
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value Added Tax
VPP	Virtual Power Plant
Wi-Fi	Wireless Fidelity

1.0 INTRODUCTION

1.1 Background

Universal access to affordable, reliable, sustainable and modern energy remains one of the greatest development challenges in East Africa. Although significant progress has been achieved during the past decade through national electrification programs, expansion of transmission networks, deployment of mini-grids and rapid growth of solar home systems, millions of households, businesses and public institutions continue to experience unreliable electricity supply or remain without electricity altogether [1] [8] [10].

Both Tanzania and Rwanda have made remarkable progress in expanding electricity access. Tanzania has implemented ambitious rural electrification programs through the Rural Energy Agency (REA), while Rwanda has adopted universal energy access as a central pillar of its National Strategy for Transformation. However, extending conventional electricity infrastructure to every settlement remains financially demanding due to dispersed populations, difficult terrain and high investment costs [18] [2] [31].

Recent advances in distributed renewable energy technologies, including solar photovoltaic systems, battery energy storage, smart meters, Internet of Things (IoT) devices, artificial intelligence and digital payment platforms have transformed the possibilities for decentralised electricity systems. Individual households and businesses equipped with solar generation and battery storage can now produce electricity that exceeds their own demand during certain periods of the day. Rather than allowing this surplus energy to remain unused, technological innovations make it possible for neighbouring consumers to purchase and utilise the excess electricity through secure digital platforms. [2] [3] [4] [17] [49].

This concept, commonly referred to as Peer-to-Peer (P2P) Electricity Sharing, represents a fundamental shift in electricity markets. Instead of relying exclusively on centralised utilities, consumers become prosumers, both producers and consumers of electricity, participating in local energy markets that improve energy utilisation, reduce costs and increase system resilience [11] [13] [2020].

The SWARM-E Project, funded through the Horizon Europe programme, is pioneering this concept in East Africa by demonstrating SWARM Grids in Tanzania and Rwanda. These systems interconnect multiple solar energy users, enabling automated electricity exchange through intelligent controllers while supporting productive uses of renewable energy such as agro-processing, refrigeration, clean cooking and small enterprises.

Despite the technological maturity of such systems, existing policy and regulatory frameworks in both countries were largely developed for conventional centralised electricity markets. Consequently, they provide limited guidance on community energy systems, digital electricity markets, local energy trading, consumer protection and technical standards for peer-to-peer electricity exchange. Without enabling policies, innovative business models such as SWARM Grids may face regulatory uncertainty that limits investment and large-scale deployment [19] [23] [31] [34].

This policy paper therefore provides evidence-based recommendations for developing an enabling legal, regulatory and institutional environment for peer-to-peer solar electricity sharing in Tanzania and Rwanda.

1.2 Purpose of the Policy Paper

The purpose of this policy paper is to support policy-makers, regulators, utilities, development partners and the private sector in establishing a modern regulatory framework that enables safe, efficient, inclusive and commercially viable peer-to-peer electricity sharing.

Specifically, the paper seeks to:

- (a) assess the existing policy and regulatory landscape in Tanzania and Rwanda;
- (b) identify legal and institutional gaps affecting peer-to-peer electricity sharing;
- (c) evaluate the socio-economic, environmental and technical benefits of SWARM Grids;
- (d) examine international experiences and lessons applicable to East Africa;
- (e) propose policy reforms that facilitate community energy markets;
- (f) recommend institutional arrangements for implementation and oversight;
- (g) outline strategies for stakeholder engagement and dissemination; and
- (h) provide a practical roadmap for scaling peer-to-peer electricity sharing.

1.3 Objectives

General Objective

To develop a comprehensive policy framework that enables peer-to-peer solar electricity sharing and supports the growth of community energy markets in Tanzania and Rwanda.

Specific Objectives

The policy paper aims to:

- (i) Examine the evolution of distributed renewable energy systems.
- (ii) Explain the principles of peer-to-peer electricity trading.
- (iii) Review existing policies, laws and regulations governing electricity markets.
- (iv) Identify policy, legal and institutional barriers.
- (v) Assess opportunities for integrating SWARM Grids into national electrification strategies.
- (vi) Recommend regulatory reforms.
- (vii) Propose standards for interoperability and safety.
- (viii) Promote investment in decentralised renewable energy.
- (ix) Enhance consumer protection.
- (x) Strengthen regional cooperation between Tanzania and Rwanda.

1.4 Scope

This policy paper focuses on decentralised electricity sharing using renewable energy technologies, particularly solar photovoltaic systems interconnected through intelligent energy management platforms.

The geographical focus is Tanzania and Rwanda, while drawing lessons from international experience in Europe, Asia and Australia. The paper considers legal, regulatory, institutional, technical, financial, environmental and social dimensions of peer-to-peer electricity sharing.

Although the primary emphasis is on off-grid and weak-grid rural communities, many recommendations are equally applicable to urban neighbourhoods, industrial parks, apartment complexes, universities, hospitals and commercial centres.

1.5 Why Peer-to-Peer Electricity Sharing Matters

Traditional electricity systems are based on a centralised model in which electricity flows from large power stations through transmission and distribution networks to passive consumers. While this model has served many countries for decades, it is increasingly challenged by the rapid growth of distributed renewable energy technologies [1] [8].

Peer-to-peer electricity sharing offers an alternative approach that transforms consumers into active market participants. Households and businesses equipped with rooftop solar systems and battery storage can share excess electricity with neighbouring users through digital platforms that automatically measure generation, consumption and financial transactions [11] [14] [15].

This model delivers several strategic advantages:

- (a) improved utilisation of renewable energy; [14] [17] [18].
- (b) reduced dependence on diesel generators;
- (c) enhanced energy security;
- (d) increased resilience during grid outages;
- (e) lower electricity costs for consumers;
- (f) reduced investment requirements for network expansion;
- (g) stimulation of rural entrepreneurship; and
- (h) acceleration of climate change mitigation.

For countries such as Tanzania and Rwanda, peer-to-peer electricity sharing also provides an opportunity to electrify remote communities without waiting for expensive grid extensions while simultaneously supporting productive energy uses that increase household incomes.

1.6 Alignment with National, Regional and Global Development Agendas

Peer-to-peer solar electricity sharing directly contributes to several national, regional and international development commitments.

(a) Tanzania

The proposed framework supports:

- (i) Tanzania Development Vision 2050;
- (ii) National Energy Policy 2015;
- (iii) Renewable Energy Strategy 2024-2034;
- (iv) National Energy Efficiency Strategy 2024-2034;
- (v) National Clean Cooking Strategy 2024-2034;
- (vi) National Electrification Programme 2013;
- (vii) Nationally Determined Contributions (NDCs) 2021.

(b) Rwanda

The framework contributes to:

- (i) Vision 2050;
- (ii) National Strategy for Transformation 2024;
- (iii) Energy Sector Strategic Plan 2024;
- (iv) National Electrification Plan 2024;
- (v) Green Growth and Climate Resilience Strategy 2023;
- (vi) Nationally Determined Contributions 2020.

(c) Regional Commitments

The recommendations align with:

- (i) East African Community Vision 2050;
- (ii) African Union Agenda 2063;
- (iii) African Single Electricity Market initiative 2021.

(d) Global Commitments

The proposed policy framework supports:

- (i) Sustainable Development Goal 7;
- (ii) Sustainable Development Goal 13;
- (iii) Paris Agreement 2015;
- (iv) Sendai Framework 2015;
- (v) Global Methane Pledge 2021;
- (vi) Sustainable Energy for All Initiative 2011.

1.7 Intended Audience

This policy paper has been prepared for:

- (a) Ministries responsible for energy;
- (b) electricity regulatory authorities;
- (c) rural electrification agencies;
- (d) national utilities;
- (e) standards organisations;
- (f) local government authorities;
- (g) development partners;
- (h) financial institutions;
- (i) renewable energy developers;

- (j) technology companies;
- (k) academic and research institutions;
- (l) civil society organisations; and
- (m) community energy cooperatives.

1.8 Methodology

The policy paper is based on a combination of:

- (a) review of national policies, laws and regulations in Tanzania and Rwanda;
- (b) analysis of international peer-to-peer electricity markets;
- (c) assessment of SWARM-E demonstration activities;
- (d) review of academic literature;
- (e) consultations with policy-makers and regulators;
- (f) stakeholder workshops;
- (g) technical analysis of distributed renewable energy systems; and
- (h) comparative policy analysis.

1.9 Structure of the Policy Paper

The policy paper is organised into ten substantive chapters covering the conceptual foundations of peer-to-peer electricity sharing, international experiences, policy and regulatory assessments, socio-economic and environmental benefits, proposed legal and institutional reforms, implementation arrangements, financing mechanisms, dissemination strategies and a roadmap for scaling community energy markets in Tanzania and Rwanda.

2.0 UNDERSTANDING PEER-TO-PEER SOLAR ELECTRICITY SHARING AND THE SWARM GRID CONCEPT

2.1 Introduction

The electricity sector is undergoing a profound transformation driven by technological innovation, digitalisation, decentralised renewable energy generation, and evolving consumer expectations. Traditionally, electricity has been generated by large centralised power plants and delivered to consumers through transmission and distribution networks. While this model has provided reliable electricity for many decades, it is increasingly challenged by rising electricity demand, climate change, high grid expansion costs, and the rapid adoption of distributed renewable energy technologies [2] [3] [17].

The emergence of affordable solar photovoltaic (PV) systems, battery energy storage systems (BESS), smart meters, cloud computing, artificial intelligence (AI), and Internet of Things (IoT) technologies has enabled consumers to become active participants in electricity markets. Instead of being passive consumers, households and businesses can now generate, store, consume, and trade electricity with one another.

Peer-to-peer (P2P) electricity sharing is one of the most innovative developments in modern electricity systems. It creates decentralised energy markets in which electricity can be exchanged directly between neighbouring consumers through secure digital platforms. In rural and peri-urban areas of Tanzania and Rwanda, this approach has the potential to significantly improve energy access, affordability, reliability, and economic productivity.

This chapter introduces the concepts, technologies, operational models, and business approaches underpinning peer-to-peer electricity sharing, with particular emphasis on the SWARM Grid concept being demonstrated under the SWARM-E Project.

2.2 Evolution of Electricity Systems

Electricity systems have evolved through four major phases:

2.2.1 Centralised Electricity Systems

The first generation of electricity systems relied on large centralised power stations using hydropower, coal, oil, gas, or nuclear energy. Electricity flowed in one direction from the generator to the consumer through extensive transmission and distribution networks [1] [4] [5].

Characteristics include:

- (a) Centralised generation;
- (b) One-way power flow;
- (c) Utility-owned infrastructure;
- (d) Passive consumers;
- (e) Limited consumer choice.

While effective in densely populated regions, centralised systems often struggle to economically serve remote rural communities.

2.2.2 Distributed Generation

The second phase introduced small-scale electricity generation closer to consumers. Distributed generation includes rooftop solar PV, small wind turbines, micro-hydropower, and biomass systems [3] [4] [17].

Advantages include:

- (a) Reduced transmission losses;
- (b) Improved energy security;
- (c) Increased renewable energy penetration;
- (d) Lower infrastructure costs;
- (e) Faster deployment.

2.2.3 Smart Grids

Smart grids integrate advanced communication technologies into electricity networks, enabling real-time monitoring, automated control, and efficient energy management [48] [43] [47].

Key features include:

- (a) Smart meters;
- (b) Two-way communication;
- (c) Demand response;
- (d) Automated fault detection;
- (e) Integration of distributed energy resources.

2.2.4 Peer-to-Peer Energy Networks

The latest evolution is the emergence of decentralised electricity markets where consumers interact directly with one another. These systems use digital platforms to facilitate electricity trading, allowing local communities to optimise renewable energy use while reducing dependence on centralised infrastructure. [11] [13] [14]

2.3 What is Peer-to-Peer Electricity Sharing?

Peer-to-peer electricity sharing is a decentralised market arrangement in which electricity producers and consumers exchange electricity directly through digital platforms without requiring all transactions to pass through a centralised utility [11] [13] [14].

Participants include:

- (a) households;
- (b) farms;
- (c) schools;
- (d) health facilities;
- (e) commercial enterprises;
- (f) industries; and
- (g) community organisations.

Each participant can act as:

- (a) Producer
- (b) Consumer
- (c) Prosumer (both producer and consumer)

Electricity sharing may occur:

- (a) Within a village;
- (b) Between neighbouring households;
- (c) Across a community mini-grid;
- (d) Within an apartment complex;
- (e) Inside industrial parks;
- (f) Between public institutions.

Unlike conventional electricity markets, electricity transactions are managed automatically through intelligent software platforms that continuously monitor energy generation, storage, demand, and pricing.

2.4 Defining the SWARM Grid Concept

A SWARM Grid is an intelligent, decentralised electricity network composed of interconnected solar energy systems that cooperate to optimise electricity generation, storage, and consumption.

Instead of operating independently, individual solar home systems communicate through smart controllers that determine where electricity should flow based on demand, battery state of charge, system availability, and predefined operational rules. A SWARM Grid functions similarly to a colony of bees, where many independent units collaborate to achieve a common objective. In the same way, interconnected solar systems operate collectively to maximise energy efficiency and reliability.

Core Components

A SWARM Grid typically includes:

- (a) Stand-alone solar photovoltaic systems
- (b) Wind turbines
- (c) Mini hydro

A single technology or a hybrid can be used.

Each system should consist of:

- (d) Battery energy storage systems;
- (e) SWARM Controller;
- (f) Smart energy meters;
- (g) Communication network;
- (h) Digital payment platform;
- (i) Mobile application;
- (j) Cloud-based energy management system.

2.5 Key Principles of Peer-to-Peer Electricity Sharing

Decentralization

Electricity generation occurs close to consumers, reducing dependence on large centralised infrastructure.

Local Energy Markets

Communities establish localised electricity markets where energy is exchanged within the neighbourhood or sold to the national grid.

Consumer Empowerment



Consumers gain greater control over:

- (a) electricity generation;
- (b) energy consumption;
- (c) electricity costs;
- (d) investment decisions.

Digital Transactions

Digital platforms automate electricity trading and record every transaction accurately and transparently.

Renewable Energy Optimisation

Neighbouring consumers use excess solar energy that would otherwise be wasted.

2.6 Technology Architecture

A complete peer-to-peer electricity sharing system consists of six technology layers.

Layer 1: Electricity Generation

Generation sources include:

- (a) Solar photovoltaic systems;
- (b) Small wind turbines;
- (c) Micro-hydropower;
- (d) Biomass systems.

Solar PV is expected to dominate due to declining equipment costs and abundant solar resources in East Africa.

Layer 2: Battery Storage

Battery storage balances generation and demand.

Functions include:

- (a) storing daytime solar energy;
- (b) supplying electricity during nighttime;
- (c) supporting power quality;
- (d) improving system reliability.

Layer 3: Smart Controllers

The SWARM Controller acts as the "brain" of the network.

It continuously monitors:

- (a) power generation;
- (b) battery condition;
- (c) electricity demand;
- (d) electricity flows;
- (e) system health.

Based on predefined algorithms, it automatically directs electricity to where it is most needed.

Layer 4: Communication Network

Communication technologies may include:

- (a) Wi-Fi;



- (b) GSM/4G/5G;
- (c) LoRaWAN;
- (d) Bluetooth;
- (e) Zigbee;
- (f) Ethernet.

Reliable communication is essential for secure energy transactions.

Layer 5: Digital Energy Platform

The software platform performs:

- (a) energy accounting;
- (b) billing;
- (c) pricing;
- (d) settlement;
- (e) forecasting;
- (f) reporting.

Artificial intelligence can further optimise electricity allocation.

Layer 6: Mobile Applications

Consumers can use mobile applications to:

- (a) monitor electricity generation;
- (b) view battery status;
- (c) purchase electricity;
- (d) sell surplus electricity;
- (e) review transaction history;
- (f) receive maintenance alerts.

2.7 Electricity Trading Process

A typical transaction follows these steps: [16]

- (a) Household A generates surplus solar electricity.
- (b) The SWARM Controller detects excess generation.
- (c) Neighbouring households request electricity.
- (d) The controller identifies the optimal recipient.
- (e) Electricity is transferred automatically.
- (f) Smart meters record the transaction.
- (g) The digital platform calculates payment.
- (h) Payment is processed through electronic payment systems.
- (i) Transaction records are securely stored.

This process typically occurs within seconds without requiring manual intervention.

2.8 Business Models

Several business models can support peer-to-peer electricity sharing [12] [14] [15].

Community-Owned Cooperative

Residents jointly invest in the energy infrastructure and share profits according to agreed rules.

Private Operator Model

A private company owns and operates the SWARM Grid while consumers purchase electricity through service agreements.

Utility Partnership Model

The national utility collaborates with local communities, integrating SWARM Grids into broader electrification strategies.

Franchise Model

Local entrepreneurs operate standardised SWARM systems under licensing agreements.

Energy-as-a-Service

Consumers pay only for electricity consumed without owning generation equipment.

2.9 Productive Uses of Electricity

Peer-to-peer electricity sharing can stimulate local economic development by powering: [54] [55].

- (a) irrigation systems;
- (b) milling machines;
- (c) grain processing;
- (d) refrigeration;
- (e) milk cooling;
- (f) welding workshops;
- (g) carpentry;
- (h) ICT centres;
- (i) electric motorcycle charging;
- (j) electric vehicle charging;
- (k) clean cooking;
- (l) water pumping;
- (m) fish farming;
- (n) cold storage.

These productive uses increase income generation and improve the financial sustainability of community energy systems.

2.10 Benefits of the SWARM Grid Approach

Technical Benefits: [2] [4] [10] [18].

- (a) Higher utilisation of solar, wind and hydro generation;
- (b) Reduced battery cycling;
- (c) Improved power reliability;
- (d) Enhanced system resilience;
- (e) Lower technical losses.

Economic Benefits:

- (a) Lower electricity costs;
- (b) Additional income for prosumers (prosumer = combination of producer and consumer);

- (c) Reduced diesel fuel consumption;
- (d) New business opportunities;
- (e) Job creation.

Social Benefits:

- (a) Increased energy access;
- (b) Improved education outcomes;
- (c) Better healthcare services;
- (d) Women's economic empowerment;
- (e) Youth entrepreneurship.

Environmental Benefits:

- (a) Reduced greenhouse gas emissions;
- (b) Increased renewable energy adoption;
- (c) Lower air pollution;
- (d) Reduced deforestation where electricity replaces biomass.

2.11 Challenges and Considerations

Successful deployment requires addressing: [16]

Technical Challenges

- (a) Interoperability between equipment from different manufacturers;
- (b) Battery degradation management;
- (c) Cybersecurity risks;
- (d) Communication network reliability.

Regulatory Challenges

- (a) Absence of legal recognition for peer-to-peer electricity trading;
- (b) Licensing requirements;
- (c) Tariff setting;
- (d) Consumer protection.

Financial Challenges

- (a) High initial investment costs;
- (b) Limited access to finance;
- (c) Foreign exchange risks;
- (d) Revenue uncertainty.

Social Challenges

- (a) Consumer awareness;
- (b) Digital literacy;
- (c) Trust in automated systems;
- (d) Equitable access for vulnerable households.

2.12 Relevance to Tanzania and Rwanda

The SWARM Grid concept is particularly suited to Tanzania and Rwanda because both countries have: [18] [50]

- (a) rapidly expanding solar PV markets;
- (b) ambitious rural electrification programmes;

- (c) strong mobile money ecosystems;
- (d) increasing digital connectivity;
- (e) supportive renewable energy policies;
- (f) significant demand for productive use of energy in agriculture and small enterprises.

Pilot implementations under the SWARM-E Project will provide valuable evidence on technical performance, consumer acceptance, regulatory requirements, and business viability, informing future policy reforms and investment decisions.

3.0 INTERNATIONAL BEST PRACTICES IN PEER-TO-PEER SOLAR ELECTRICITY SHARING

3.1 Introduction

The global transition towards clean, decentralised, and digital energy systems has accelerated the adoption of peer-to-peer (P2P) electricity sharing. Countries around the world are experimenting with innovative regulatory frameworks that empower consumers to become active participants in electricity markets. These initiatives demonstrate that distributed renewable energy systems can improve energy access, optimise renewable energy utilisation, enhance grid resilience, and stimulate local economic development [2] [3] [13] [14].

Although peer-to-peer electricity markets are still emerging, several countries have established regulatory sandboxes, community energy programmes, and digital energy trading platforms that offer valuable lessons for Tanzania and Rwanda. Their experiences show that successful implementation depends not only on technological innovation but also on enabling policies, transparent regulations, consumer protection, digital infrastructure, and institutional collaboration.

This chapter reviews international experiences from Europe, Asia-Pacific, and Africa, identifying best practices that can inform the development of policy and regulatory frameworks for SWARM Grids and community energy markets in East Africa.

3.2 Global Trends in Peer-to-Peer Electricity Markets

Several global trends are driving the emergence of P2P electricity systems:

3.2.1 Rapid Decline in Solar PV Costs

The cost of solar photovoltaic technology has declined dramatically over the past decade, making distributed generation affordable for households, businesses, and public institutions. As installation costs continue to decrease, increasing numbers of consumers are becoming electricity producers [2] [3].

3.2.2 Growth of Battery Energy Storage

Advances in lithium-ion battery technology have enabled households and businesses to store surplus electricity for later use or trading, increasing the flexibility and value of distributed renewable energy systems [17] [3].

3.2.3 Digital Transformation

The widespread adoption of smart meters, cloud computing, artificial intelligence (AI), blockchain technologies, Internet of Things (IoT) devices, and mobile payment platforms has made automated electricity trading technically feasible and commercially attractive [16] [49].

3.2.4 Energy Democratisation

Consumers increasingly expect greater participation in energy decision-making. Community-owned energy projects, energy cooperatives, and local energy markets are emerging as alternatives to traditional utility-dominated systems [11] [14].

3.2.5 Climate Commitments

Countries are adopting ambitious renewable energy targets under the Paris Agreement, creating opportunities for decentralised renewable energy systems to contribute to national climate goals [7].

3.3 Germany: Community Energy and Prosumers

Germany is widely recognised as a global leader in decentralised renewable energy development. The country's energy transition (Energiewende) has encouraged millions of households, farmers, municipalities, and cooperatives to invest in renewable energy systems [13] [14].

(a) Key Features

- (i) Strong legal recognition of renewable energy producers.
- (ii) Community ownership of renewable energy projects.
- (iii) Simplified grid connection procedures.
- (iv) Net metering and feed-in mechanisms.
- (v) Active citizen participation in electricity markets.

(b) Lessons for Tanzania and Rwanda

- (i) Legally recognise prosumers.
- (ii) Encourage community ownership of renewable energy infrastructure.
- (iii) Simplify licensing for small renewable energy systems.
- (iv) Develop transparent compensation mechanisms for surplus electricity.

3.4 The Netherlands: Local Energy Cooperatives

The Netherlands has promoted local energy communities through supportive legislation and digital innovation. Many neighbourhoods operate renewable energy cooperatives where residents jointly invest in solar systems and share electricity among participating members [14] [12].

(a) Best Practices

- (i) Energy cooperatives recognised under national law.
- (ii) Smart metering infrastructure.
- (iii) Transparent energy accounting.
- (iv) Community financing mechanisms.
- (v) Consumer participation in governance.

(b) Lessons

- (i) Develop legal frameworks for community energy organisations.
- (ii) Promote cooperative ownership models.
- (iii) Encourage local investment in renewable energy.

3.5 Australia: Virtual Power Plants

Australia has one of the world's highest penetrations of rooftop solar PV systems. To improve grid stability, utilities aggregate thousands of household batteries into Virtual Power Plants (VPPs). These distributed systems operate collectively, providing electricity services similar to conventional power stations [3] [17].

(a) Advantages

- (i) Improved grid reliability.
- (ii) Increased renewable energy utilisation.
- (iii) Reduced peak demand.
- (iv) Additional income for consumers.
- (v) Lower electricity prices.

(b) Lessons

- (i) Promote battery aggregation.
- (ii) Encourage intelligent energy management systems.
- (iii) Develop regulations for distributed energy resources.

3.6 United Kingdom: Regulatory Sandboxes

The United Kingdom introduced regulatory innovation programmes allowing new energy business models to be tested under temporary regulatory exemptions. These "regulatory sandboxes" enable innovators to demonstrate new technologies while regulators evaluate their impacts before introducing permanent legislation [13] [14].

(a) Best Practices

- (i) Controlled pilot projects.
- (ii) Close regulatory supervision.
- (iii) Consumer protection.
- (iv) Data collection.
- (v) Evidence-based policy development.

(b) Lessons

- (i) Establish regulatory sandboxes for SWARM Grids.
- (ii) Permit pilot peer-to-peer electricity markets.
- (iii) Use pilot results to inform permanent regulations.

3.7 Japan: Smart Communities

Japan has developed numerous smart community projects integrating:

- (a) rooftop solar;
- (b) battery storage;
- (c) electric vehicles;
- (d) smart appliances;
- (e) demand response.

These systems optimise electricity consumption while improving resilience against natural disasters [17] [14].

Lessons

- (a) Integrate multiple distributed energy technologies.

- (b) Promote energy resilience.
- (c) Encourage digital energy management.

3.8 South Korea

Digital Energy Markets

South Korea has invested heavily in: [16] [49]

- (a) smart grids;
- (b) artificial intelligence;
- (c) blockchain;
- (d) digital energy platforms.

Consumers participate in electricity markets through advanced digital infrastructure [16] [49].

Lessons

- (a) Invest in digital energy platforms.
- (b) Develop cybersecurity standards.
- (c) Promote artificial intelligence for energy optimisation.

3.9 Singapore

Intelligent Electricity Markets

Singapore has introduced advanced electricity market reforms emphasising: [13] [14]

- (a) digital metering;
- (b) demand response;
- (c) consumer choice;
- (d) electricity market transparency.

Its experience demonstrates how advanced digital technologies can improve electricity market efficiency even within densely populated urban environments. [13] [14].

Lessons

- (a) Develop transparent electricity market rules.
- (b) Strengthen digital infrastructure.
- (c) Enhance consumer information systems.

3.10 Emerging African Experiences

Although peer-to-peer electricity trading remains relatively new in Africa, several countries have introduced innovative decentralised energy programmes.

(a) Kenya

Kenya has experienced rapid growth in solar home systems supported by mobile money platforms [4] [18].

Key lessons include:

- (i) Digital payment integration.
- (ii) Consumer financing.
- (iii) Private sector innovation.
- (iv) Strong renewable energy entrepreneurship.

(b) Nigeria



Several pilot projects have tested blockchain-enabled electricity trading within mini-grids [13] [14].

Lessons include:

- (i) Importance of regulatory flexibility.
- (ii) Consumer education.
- (iii) Technical standardisation.

(c) South Africa

Community energy initiatives and municipal renewable energy programmes are expanding, particularly in response to electricity shortages [8] [18].

Lessons include:

- (i) Local government involvement.
- (ii) Municipal renewable energy planning.
- (iii) Distributed generation regulations.

3.11 Comparative Analysis

Table 1: Comparison of electricity business models

Country	Regulatory Strength	Key Innovation	Main Lesson
Germany	High	Community energy	Recognize prosumers
Netherlands	High	Energy cooperatives	Community ownership
Australia	High	Virtual Power Plants	Battery aggregation
United Kingdom	High	Regulatory sandbox	Pilot before regulation
Japan	High	Smart communities	Integrated technologies
South Korea	High	AI and blockchain	Digital energy markets
Singapore	High	Smart electricity markets	Digital governance
Kenya	Moderate	Mobile payments	Financial inclusion
Nigeria	Emerging	Blockchain pilots	Regulatory flexibility
South Africa	Moderate	Municipal energy	Local government participation

3.12 Success Factors

Analysis of international experience identifies several common success factors.

3.12.1 Enabling Legislation

Successful countries have explicitly recognised:

- (a) distributed generation;
- (b) prosumers;
- (c) community energy;
- (d) local electricity markets.

3.12.2 Independent Regulation

Strong regulators provide:

- (a) licensing;
- (b) technical oversight;
- (c) tariff approval;
- (d) consumer protection.

3.12.3 Smart Infrastructure

Deployment of:

- (a) smart meters;
- (b) communication systems;
- (c) cloud platforms;
- (d) digital payment systems.

3.12.4 Consumer Participation

Consumers actively participate in:

- (a) planning;
- (b) ownership;
- (c) governance;
- (d) investment.

3.12.5 Digital Innovation

Artificial intelligence, blockchain, IoT, and cloud computing improve:

- (a) market transparency;
- (b) system efficiency;
- (c) operational reliability.

3.13 Common Challenges

Despite their success, countries have encountered several challenges.

(a) Technical

- (i) interoperability;
- (ii) communication reliability;
- (iii) cybersecurity;
- (iv) battery degradation.

(b) Regulatory

- (i) outdated electricity laws;
- (ii) licensing complexity;
- (iii) tariff design;
- (iv) taxation.

(c) Financial

- (i) high upfront investment;
- (ii) limited financing;
- (iii) uncertain revenue streams.

(d) Social

- (i) consumer awareness;
- (ii) digital literacy;
- (iii) trust in automated trading.

3.14 Implications for Tanzania and Rwanda

International experience demonstrates that Tanzania and Rwanda need not replicate existing electricity market models. Instead, both countries can adopt a "leapfrog" approach by designing modern regulatory frameworks specifically suited to decentralised renewable energy systems. [13] [14] [17].

Key priorities include:

(a) Legal Recognition of Prosumers

National electricity laws should define and recognise consumers who generate, consume, and sell renewable electricity [11] [14].

(b) Community Energy Frameworks

Regulations should enable communities, cooperatives, and local enterprises to own and operate SWARM Grids [12] [14].

(c) Regulatory Sandboxes

Energy regulators should establish controlled environments where innovative business models can be tested before nationwide implementation [13] [14].

(d) Technical Standards

National standards bodies should develop standards for smart controllers, communication protocols, metering accuracy, cybersecurity, and interoperability [48].

(e) Consumer Protection

Rules governing pricing transparency, dispute resolution, data privacy, and service quality should accompany market liberalisation [16].

(f) Digital Integration

The widespread use of mobile money in East Africa provides a strong foundation for automated electricity payments and settlement [13] [14].

3.15 Recommendations for Adapting International Best Practices

To accelerate deployment of peer-to-peer solar electricity sharing, Tanzania and Rwanda should: [13] [14] [39] [40].

- (a) Establish legal recognition of community energy systems and prosumers.
- (b) Create simplified licensing categories for community-based SWARM Grids.
- (c) Introduce regulatory sandboxes under national energy regulators.
- (d) Promote local energy cooperatives and public-private partnerships.
- (e) Develop national standards for interoperability, smart metering, and cybersecurity.
- (f) Encourage investment through fiscal incentives and access to green finance.
- (g) Integrate mobile money and digital payment systems into electricity trading platforms.

- (h) Support research, innovation, and local manufacturing of smart energy technologies.
- (i) Promote regional harmonisation through the East African Community to facilitate knowledge sharing and future cross-border energy cooperation.

4.0 THE SWARM-E PROJECT: DEMONSTRATING PEER-TO-PEER SOLAR ELECTRICITY SHARING IN TANZANIA AND RWANDA

4.1 Introduction

The transition towards decentralised renewable energy systems requires more than technological innovation. It requires practical demonstrations that validate technical performance, business viability, consumer acceptance, and regulatory readiness. While peer-to-peer (P2P) electricity trading has been implemented in several developed countries, there remains limited evidence on its application within Sub-Saharan Africa, particularly in rural and peri-urban settings where decentralised energy systems can have the greatest impact.

The SWARM-E Project addresses this gap by demonstrating innovative SWARM Grids in Tanzania and Rwanda. The project provides an opportunity to evaluate how interconnected solar photovoltaic systems, battery storage, intelligent energy controllers, and digital energy trading platforms can improve energy access, increase renewable energy utilisation, stimulate productive uses of electricity, and strengthen community resilience.

Importantly, SWARM-E is not only a technology demonstration project; it is also a policy innovation initiative. By generating evidence from real-world pilot implementations, the project supports governments, regulators, utilities, and development partners in developing enabling policy and regulatory frameworks for decentralised community energy markets.

4.2 Project Background

Despite significant investments in rural electrification, many communities across East Africa continue to experience: [4] [18] [50].

- (a) limited access to reliable electricity;
- (b) high electricity costs;
- (c) underutilised solar photovoltaic systems;
- (d) dependence on diesel generators;
- (e) insufficient electricity for productive economic activities.

Many households with standalone solar home systems generate surplus electricity during daylight hours. However, because these systems typically operate independently, excess energy cannot be shared with neighbouring consumers. Consequently, valuable renewable energy remains unused while nearby households continue to experience electricity shortages.

SWARM-E addresses this challenge by interconnecting individual solar systems into intelligent community energy networks that enable electricity sharing between participants.

The project recognises that decentralised renewable energy systems should evolve beyond individual household electrification toward collaborative community energy ecosystems capable of supporting social and economic development.

4.3 Project Vision

The vision of SWARM-E is: To establish intelligent, community-based renewable energy systems that enable affordable, reliable, sustainable, and inclusive electricity access through peer-to-peer energy sharing.

The project seeks to demonstrate that decentralised electricity systems can become active local energy markets rather than isolated household installations.

4.4 Project Goal

The overall goal of the SWARM-E Project is to demonstrate technically feasible, economically viable, socially inclusive, and environmentally sustainable peer-to-peer solar electricity sharing systems that can be replicated throughout East Africa and other developing regions.

4.5 Specific Objectives

The project aims to:

- (a) Demonstrate SWARM Grid technology under real operating conditions.
- (b) Validate peer-to-peer electricity sharing among households and small businesses.
- (c) Increase utilisation of locally generated renewable electricity.
- (d) Improve electricity reliability through interconnected distributed energy systems.
- (e) Promote productive uses of renewable energy.
- (f) Strengthen local entrepreneurship and employment.
- (g) Generate evidence for policy and regulatory reforms.
- (h) Develop scalable business models for decentralised electricity markets.
- (i) Build institutional and technical capacity among stakeholders.
- (j) Contribute to climate change mitigation through increased renewable energy use.

4.6 Project Implementation Countries

The SWARM-E Project is implemented in Rwanda and Tanzania.

These countries were selected because they:

- (a) have rapidly growing renewable energy sectors;
- (b) have ambitious rural electrification programmes;
- (c) possess strong mobile money ecosystems;
- (d) demonstrate political commitment to clean energy;
- (e) have increasing demand for productive energy use;
- (f) provide diverse rural electrification contexts suitable for technology demonstration.

The experiences gained are expected to inform broader regional adoption within the East African Community (EAC).

4.7 Project Consortium

SWARM-E is implemented through a multidisciplinary consortium comprising:

- (a) universities;
- (b) research institutions;
- (c) renewable energy associations;
- (d) technology developers;

- (e) private companies;
- (f) non-governmental organisations;
- (g) policy experts.

Each partner contributes expertise in areas such as:

- (a) renewable energy engineering;
- (b) artificial intelligence;
- (c) smart energy systems;
- (d) battery technologies;
- (e) hydrogen integration;
- (f) policy analysis;
- (g) energy regulations governance;
- (h) socio-economic research;
- (i) community engagement.

The diversity of the consortium ensures that technical innovation is complemented by policy, economic, environmental, and social considerations.

4.8 Technical Architecture of the SWARM Grid

The SWARM Grid integrates multiple technologies into a coordinated energy management system.

4.8.1 Solar Photovoltaic Generation

Each participating household or institution operates a rooftop solar PV system that generates renewable electricity.

Electricity generated may be:

- (a) consumed immediately;
- (b) stored in batteries;
- (c) shared with neighbouring participants.

4.8.2 Battery Energy Storage Systems

Battery systems:

- (a) store surplus solar energy;
- (b) stabilise electricity supply;
- (c) improve reliability;
- (d) reduce dependence on backup generators;
- (e) support electricity trading.

The intelligent management of battery charging and discharging increases battery lifetime while maximising energy availability.

4.8.3 SWARM Controller

The SWARM Controller serves as the central intelligence of the community energy network.

Its functions include:

- (a) monitoring electricity generation;
- (b) monitoring battery status;



- (c) monitoring household demand;
- (d) optimising electricity allocation;
- (e) facilitating electricity trading;
- (f) preventing overload;
- (g) maintaining system stability;
- (h) recording operational data.

The controller continuously determines the most efficient distribution of available renewable electricity.

4.8.4 Smart Metering

Each participant is equipped with smart meters capable of measuring:

- (a) electricity generation;
- (b) electricity consumption;
- (c) electricity imports;
- (d) electricity exports;
- (e) battery charging;
- (f) battery discharging.

These measurements provide the basis for transparent billing and energy accounting.

4.8.5 Digital Communication Platform

The SWARM Grid uses secure communication systems that enable real-time information exchange between:

- (a) smart meters;
- (b) controllers;
- (c) mobile applications;
- (d) cloud servers.

This digital infrastructure enables automated operation with minimal manual intervention.

4.9 Peer-to-Peer Energy Trading Process

The SWARM Grid facilitates automated electricity transactions through the following sequence: [16]

- (a) Solar PV systems generate electricity.
- (b) Households first satisfy their own demand.
- (c) Surplus electricity is identified by the SWARM Controller.
- (d) Neighbouring households requiring electricity submit demand requests automatically.
- (e) The controller allocates electricity according to predefined operational algorithms.
- (f) Smart meters record all energy flows.
- (g) Digital payment systems process financial transactions.
- (h) Energy accounting records are securely stored for auditing and consumer verification.

The entire process occurs in real time, ensuring efficient utilisation of locally generated renewable energy.

4.10 Productive Uses of Electricity

A key innovation of SWARM-E is its emphasis on productive uses of energy (PUE). Rather than limiting electricity to lighting and phone charging, the project demonstrates how reliable community electricity can support income-generating activities [54] [55].

Potential productive uses include:

(a) Agriculture

- (i) irrigation pumping;
- (ii) grain milling;
- (iii) maize shelling;
- (iv) rice processing;
- (v) milk cooling;
- (vi) seaweed processing;
- (vii) Agricultural produce preservation (cooling);
- (viii) greenhouse farming.

(b) Water Supply

- (i) community water pumping;
- (ii) water purification;
- (iii) water treatment systems.

(c) Small Enterprises

- (i) welding workshops;
- (ii) carpentry;
- (iii) tailoring;
- (iv) salons;
- (v) printing services.

(d) Food Processing

- (i) refrigeration;
- (ii) cold storage;
- (iii) fruit drying;
- (iv) food preservation.

(e) Digital Economy

- (i) ICT centres;
- (ii) internet cafés;
- (iii) digital learning;
- (iv) mobile money services.

(f) Clean Cooking

- (i) electric pressure cookers;
- (ii) induction cooking;
- (iii) institutional kitchens.

Reliable electricity for these applications can increase incomes, create jobs, and improve community livelihoods.

4.11 Expected Socio-Economic Impacts

The project is expected to generate significant benefits [10] [18] [50].

(a) Economic Benefits

- (i) increased household incomes;
- (ii) lower electricity expenditures;
- (iii) reduced diesel fuel costs;
- (iv) growth of local enterprises;
- (v) new employment opportunities.

(b) Social Benefits

- (i) improved education services;
- (ii) enhanced healthcare;
- (iii) increased women's participation in economic activities;
- (iv) youth entrepreneurship;
- (v) improved quality of life.

(c) Environmental Benefits

- (i) reduced greenhouse gas emissions;
- (ii) increased renewable energy utilisation;
- (iii) reduced deforestation;
- (iv) lower air pollution;
- (v) improved resource efficiency.

4.12 Policy Innovation

One of the project's most significant contributions lies in generating evidence for policy reform.

The demonstration enables governments to evaluate:

- (a) legal requirements for peer-to-peer electricity trading;
- (b) licensing approaches;
- (c) tariff methodologies;
- (d) consumer protection mechanisms;
- (e) technical standards;
- (f) taxation issues;
- (g) digital payment regulation;
- (h) cybersecurity requirements.

Evidence generated through pilot implementation reduces uncertainty for regulators and supports evidence-based policy making.

4.13 Capacity Building

The project places strong emphasis on developing local capacity.

- (a) Training activities include:
 - (i) installation and maintenance of SWARM Grids;
 - (ii) operation of smart controllers;
 - (iii) renewable energy entrepreneurship;
 - (iv) digital energy management;
 - (v) productive use of electricity;
 - (vi) policy analysis;
 - (vii) regulatory development;
 - (viii) standards development.
- (b) Capacity building targets:
 - (i) engineers;
 - (ii) technicians;
 - (iii) local authorities;
 - (iv) regulators;
 - (v) universities;
 - (vi) entrepreneurs;
 - (vii) women's groups;
 - (viii) youth organisations.

4.14 Alignment with National Development Priorities

The SWARM-E Project directly contributes to national priorities in both Tanzania and Rwanda by supporting:[6] [7] [9] [19] [32] [33]

- (a) universal electricity access;
- (b) renewable energy deployment;
- (c) digital transformation;
- (d) climate resilience;
- (e) rural industrialisation;
- (f) agricultural modernisation;
- (g) youth employment;
- (h) women's economic empowerment;

- (i) sustainable economic growth.

The project complements existing national electrification programmes by demonstrating innovative approaches for communities where conventional grid expansion may be technically or economically challenging.

4.15 Opportunities for Scaling Up

If successfully demonstrated, SWARM Grids could be expanded to:

- (a) rural villages;
- (b) fishing communities;
- (c) agricultural cooperatives;
- (d) schools;
- (e) health centres;
- (f) universities;
- (g) refugee settlements;
- (h) industrial parks;
- (i) tourism facilities;
- (j) Island communities;
- (k)
- (l) urban residential communities.

Future integration with national electricity networks could enable hybrid systems, where community energy markets complement rather than compete with centralised utilities.

4.16 Risks and Mitigation Measures

Table 2: Risks and Mitigation of SWARM-E Grid

Risk	Potential Impact	Proposed Mitigation
Regulatory uncertainty	Delayed commercialization	Establish a regulatory sandbox and develop interim guidelines
Cybersecurity threats	Unauthorised access to systems	Adopt cybersecurity standards, encryption, and regular security audits
Consumer resistance	Low participation	Conduct community awareness campaigns and user training
High initial investment	Slow deployment	Facilitate concessional finance, grants, and blended financing
Technology interoperability	Equipment incompatibility	Develop national interoperability standards
Battery degradation	Reduced system performance	Implement battery management systems and maintenance protocols
Revenue uncertainty	Weak business sustainability	Pilot different tariff structures and business models

5.0 REVIEW OF THE EXISTING POLICY, LEGAL AND REGULATORY FRAMEWORKS IN TANZANIA AND RWANDA

5.1 Introduction

The successful deployment of peer-to-peer (P2P) solar electricity sharing depends not only on technological innovation but also on enabling policy, legal, and regulatory frameworks. Electricity is a regulated public service, and any new business model involving generation, distribution, supply, or sale of electricity must operate within an established legal framework that ensures public safety, consumer protection, fair competition, and power system reliability [19] [31] [34].

Tanzania and Rwanda have made considerable progress in reforming their electricity sectors over the past two decades. Both countries have adopted policies promoting renewable energy, rural electrification, private sector participation, and universal electricity access. They have also enacted legislation governing electricity generation, transmission, distribution, and supply.

However, most existing laws and regulations were developed when electricity systems were predominantly centralised and utility-based. Consequently, they do not explicitly recognise prosumers, community energy markets, or peer-to-peer electricity trading. This chapter reviews the policy, legal, regulatory, and institutional environments in Tanzania and Rwanda, identifying areas that support decentralised renewable energy and the gaps that hinder the deployment of SWARM Grids.

5.2 Part 1: Tanzania

5.2.1 National Energy Policy

The National Energy Policy provides the overarching direction for energy development in Tanzania. Its objectives include: [19]

- (a) ensuring reliable energy supply;
- (b) promoting renewable energy;
- (c) increasing electricity access;
- (d) encouraging private sector investment;
- (e) improving energy security;
- (f) supporting sustainable economic development.

5.2.1.1 Relevance to Peer-to-Peer Electricity Sharing

The policy strongly promotes decentralised renewable energy and private sector participation. However, it does not explicitly address:

- (i) peer-to-peer electricity trading;
- (ii) community electricity markets;
- (iii) energy sharing among households;
- (iv) prosumer rights and responsibilities;
- (v) digital electricity marketplaces;
- (vi) community-owned electricity networks.

5.2.1.2 Policy Gap



Although decentralised generation is encouraged, the policy assumes that electricity is supplied either through:

- (i) TANESCO;
- (ii) licensed mini-grid operators; or
- (iii) licensed independent power producers.

There is no policy recognition of **household-to-household electricity trading**.

5.2.2 Electricity Act

The Electricity Act establishes the legal framework governing: (URT, 2021a)

- (a) electricity generation;
- (b) transmission;
- (c) distribution;
- (d) supply;
- (e) licensing;
- (f) regulation.

The Act empowers the national electricity regulator to:

- (a) issue licences;
- (b) establish technical standards;
- (c) approve tariffs;
- (d) protect consumers.

5.2.2.1 Strengths

The Act:

- (a) allows private participation;
- (b) provides licensing mechanisms;
- (c) supports mini-grid development;
- (d) promotes consumer protection.

5.2.2.2 Limitations

The Act does not define:

- (a) prosumer;
- (b) peer-to-peer electricity;
- (c) community energy;
- (d) virtual power plant;
- (e) local electricity market;
- (f) electricity aggregation.

Consequently, households cannot legally sell electricity directly to neighbouring consumers under existing provisions.

5.2.3 Renewable Energy Strategy

The Renewable Energy Strategy promotes: [20]

- (a) solar energy;
- (b) wind power;
- (c) biomass;
- (d) geothermal;
- (e) small hydropower.

The strategy recognises decentralised renewable energy as an important component of rural electrification.

5.2.3.1 Positive Elements

- (i) promotion of off-grid systems;
- (ii) private investment;
- (iii) local manufacturing;
- (iv) productive use of energy.

5.2.3.2 Missing Elements

The strategy does not discuss:

- (i) electricity sharing;
- (ii) neighbourhood energy trading;
- (iii) community batteries;
- (iv) distributed energy markets;
- (v) digital electricity platforms.

5.2.4 National Energy Efficiency Strategy

The Energy Efficiency Strategy seeks to reduce national energy consumption through efficient technologies [22]

Although improved utilisation of renewable energy aligns with energy efficiency objectives, the strategy does not explicitly recognise peer-to-peer electricity sharing as an efficiency measure.

5.2.5 National Clean Cooking Strategy

The Clean Cooking Strategy encourages transition from biomass to modern cooking technologies [21] [54] [55]

Reliable community electricity supplied through SWARM Grids could significantly accelerate:

- (a) electric pressure cooker adoption;
- (b) induction cooking;
- (c) institutional cooking.

However, the strategy does not yet recognise community electricity markets as an enabler of clean cooking.

5.2.6 Rural Electrification Framework

The Rural Energy Agency (REA) has successfully expanded rural electrification through: [27]

- (a) grid extension;
- (b) mini-grids;
- (c) solar home systems.

The framework supports decentralised energy but focuses primarily on infrastructure deployment rather than community electricity trading.

Opportunity

REA could become an important facilitator of:

- (a) community energy cooperatives;

- (b) SWARM Grid pilots;
- (c) productive use programmes.

5.2.7 Mini-grid Regulations

Tanzania has established one of Africa's most progressive mini-grid regulatory frameworks. The regulations address: [24] [25] [26]

- (a) licensing;
- (b) tariffs;
- (c) service quality;
- (d) technical standards.

However, they primarily regulate electricity supplied by licensed operators to customers.

Gaps

They do not provide mechanisms for:

- (a) consumer-to-consumer electricity sales;
- (b) distributed ownership;
- (c) multiple electricity sellers within one mini-grid;
- (d) local electricity exchanges.

5.2.8 Grid Code

The national Grid Code establishes technical requirements for connecting electricity generation to the national grid.

Current provisions mainly address:

- (a) utilities;
- (b) independent power producers;
- (c) large generators.

Distributed household electricity sharing falls outside the intended scope.

5.2.9 Technical Standards

The Tanzania Bureau of Standards (TBS) has developed standards covering: [28]

- (a) solar modules;
- (b) batteries;
- (c) inverters;
- (d) cables;
- (e) electrical installations.

However, standards remain limited regarding:

- (a) smart controllers;
- (b) interoperability;
- (c) peer-to-peer communication;
- (d) cybersecurity;
- (e) blockchain-based energy transactions;
- (f) intelligent battery management.

5.2.9 Consumer Protection

Existing consumer protection regulations focus primarily on utility-customer relationships.

Future peer-to-peer electricity markets will require additional provisions covering:

- (a) transparent pricing;
- (b) billing verification;
- (c) digital dispute resolution;
- (d) data privacy;
- (e) cyber protection;
- (f) energy transaction records.

5.3 Part II: Rwanda

5.3.1 National Energy Policy

Rwanda has adopted an ambitious energy policy emphasising: [31]

- (a) universal access;
- (b) renewable energy;
- (c) private investment;
- (d) productive energy use.

The policy strongly supports decentralised renewable energy.

Gap

There is no explicit recognition of:

- (a) energy communities;
- (b) electricity sharing;
- (c) peer-to-peer trading;
- (d) community energy cooperatives.

5.3.2 Electricity Law

The Electricity Law establishes: [34] [35]

- (a) licensing;
- (b) electricity market regulation;
- (c) technical oversight;
- (d) consumer protection.

5.3.2.1 Strengths

The law encourages:

- (i) private investment;
- (ii) renewable energy;
- (iii) competition.

5.3.2.2 Limitations

The law assumes electricity is supplied through licensed entities rather than decentralised community energy markets.

Definitions of prosumers and local energy trading are absent.

5.3.3 National Electrification Plan

Rwanda's electrification strategy combines: [36] [38]

- (a) grid extension;
- (b) off-grid systems;
- (c) mini-grids.

The plan has significantly expanded electricity access. However, future revisions should consider:

- (a) interconnected solar home systems;
- (b) community batteries;
- (c) neighbourhood electricity trading.

5.3.4 Renewable Energy Policies

Rwanda promotes: [31] [32]

- (a) solar PV;
- (b) mini-hydropower;
- (c) methane gas;
- (d) peat;
- (e) biomass.

Distributed renewable energy receives strong policy support. Nevertheless, community electricity markets remain largely unaddressed.

5.3.5 Licensing Framework

Current licensing arrangements focus on: [35]

- (a) generators;
- (b) distributors;
- (c) suppliers;
- (d) mini-grid operators.

There is no simplified licensing category for:

- (a) community energy systems;
- (b) SWARM Grids;
- (c) neighbourhood electricity exchanges.

5.3.6 Technical Standards

Rwanda Standards Board has adopted standards for renewable energy technologies [37].

Future standards should include:

- (a) smart metering;
- (b) communication protocols;
- (c) interoperability;
- (d) cybersecurity;
- (e) distributed energy management.

5.4 Comparative Analysis

Table 3: Comparison of Policy and Regulatory Frameworks

Area	Tanzania	Rwanda	Assessment
Renewable Energy Policy	Strong	Strong	Supportive
Rural Electrification	Strong	Strong	Supportive
Mini-grid Regulation	Advanced	Advanced	Supportive
Prosumers	Absent	Absent	Major Gap
Peer-to-Peer Trading	Absent	Absent	Major Gap
Community Energy	Limited	Limited	Major Gap
Smart Grid Regulation	Emerging	Emerging	Needs Development
Cybersecurity Standards	Limited	Limited	Needs Improvement
Community Batteries	Not addressed	Not addressed	Major Gap
Digital Energy Markets	Not regulated	Not regulated	Major Gap

5.5 Institutional Landscape

Several institutions will play critical roles in enabling peer-to-peer electricity sharing.

Tanzania

Table 4: Potential Institutions to Enable Peer-to-Peer Electricity Sharing in Tanzania

Institution	Proposed Role
Ministry of Energy	Policy leadership
EWURA	Licensing, tariffs, regulation
REA	Rural deployment and financing
TANESCO	Grid integration and technical coordination
TBS	Technical standards
NEMC	Environmental compliance
Local Government Authorities	Community mobilization
Universities	Research and innovation

Rwanda

Table 5: Potential Institutions to Enable Peer-to-Peer Electricity Sharing in Tanzania

Institution	Proposed Role
Ministry of Infrastructure	National policy
Rwanda Utilities Regulatory Authority (RURA)	Regulation and licensing
Rwanda Energy Group (REG)	Grid integration
Rwanda Standards Board	Technical standards
District Governments	Local implementation
Universities	Research and capacity building

5.6 Key Policy and Regulatory Gaps

The review identifies ten critical gaps common to both countries:

Gap 1: No Legal Recognition of Prosumers

Households generating surplus electricity have no defined legal status as market participants.

Gap 2: No Legal Basis for Peer-to-Peer Trading

Current laws prohibit or fail to recognise direct electricity sales between consumers.

Gap 3: Absence of Community Energy Frameworks

Energy cooperatives and community-owned electricity markets lack legal recognition.

Gap 4: Inadequate Licensing Models

Existing licensing systems are designed for utilities and mini-grid operators rather than decentralised community systems.

Gap 5: Missing Technical Standards

There are no comprehensive standards for:

- (a) SWARM Controllers;
- (b) smart meters;
- (c) interoperability;
- (d) communication protocols;
- (e) cybersecurity.

Gap 6: No Tariff Methodology

Neither country has rules governing:

- (a) local electricity pricing;
- (b) settlement mechanisms;
- (c) dynamic tariffs.

Gap 7: Consumer Protection Gaps

Digital electricity markets require additional protections concerning:

- (a) privacy;
- (b) dispute resolution;
- (c) data ownership;
- (d) billing transparency.

Gap 8: Limited Fiscal Incentives

Tax and investment incentives are not specifically designed to encourage peer-to-peer energy systems.

Gap 9: Institutional Capacity



Regulators, utilities, and standards bodies require new technical expertise in decentralised digital energy systems.

Gap 10: Regional Harmonisation

There is no East African framework for peer-to-peer electricity sharing, limiting future cross-border collaboration and standardisation.

5.7 Strategic Opportunities

Despite these gaps, Tanzania and Rwanda possess several strengths that position them well for adopting peer-to-peer electricity sharing:

- (a) strong political commitment to universal energy access;
- (b) growing renewable energy markets;
- (c) supportive mini-grid experience;
- (d) extensive mobile money ecosystems;
- (e) expanding digital connectivity;
- (f) active research institutions;
- (g) increasing private sector participation;
- (h) strong international partnerships.

These strengths provide a solid foundation for introducing modern community energy markets.

5.8 Priority Regulatory Actions

To enable peer-to-peer solar electricity sharing, the Governments of Tanzania and Rwanda should prioritise:

- (a) Introducing legal definitions for prosumers, community energy systems, and peer-to-peer electricity trading.
- (b) Establishing regulatory sandboxes to pilot SWARM Grids under controlled conditions.
- (c) Developing technical standards for smart controllers, advanced metering, communication protocols, and cybersecurity.
- (d) Creating simplified licensing and registration frameworks for community energy operators.
- (e) Designing transparent tariff and settlement methodologies for local electricity markets.
- (f) Strengthening consumer protection for digital energy transactions.
- (g) Coordinating regional policy development through the East African Community (EAC) to promote harmonised standards and facilitate future regional scaling.

6.0 COMPREHENSIVE GAP ANALYSIS AND POLICY REFORM NEEDS FOR PEER-TO-PEER SOLAR ELECTRICITY SHARING IN TANZANIA AND RWANDA

6.1 Introduction

The policy and regulatory review presented in Chapter Five demonstrates that both Tanzania and Rwanda have made substantial progress in promoting renewable energy, rural electrification, and private sector participation in the electricity sector. However, these frameworks were designed primarily to regulate centralised electricity systems and conventional mini-grids. They do not adequately address the emergence of decentralised, digitally interconnected community energy systems such as SWARM Grids [11] [13] [14] [19] [31] [34].

Peer-to-peer (P2P) solar electricity sharing fundamentally changes the structure of electricity markets. It transforms households, businesses, institutions, and communities into active participants capable of generating, consuming, storing, and selling electricity. This transition requires a regulatory environment that recognises new market actors, supports digital energy platforms, protects consumers, ensures cybersecurity, and promotes innovation while maintaining system reliability and public safety.

This chapter presents a comprehensive gap analysis, identifying barriers across the legal, regulatory, institutional, technical, financial, fiscal, environmental, and social dimensions. It concludes with a policy reform agenda to guide governments, regulators, and development partners.

6.2 Analytical Framework

The gap analysis is structured around nine dimensions:

- (a) Policy gaps
- (b) Legal gaps
- (c) Regulatory gaps
- (d) Institutional gaps
- (e) Technical gaps
- (f) Financial and investment gaps
- (g) Fiscal and taxation gaps
- (h) Social and capacity gaps
- (i) Regional integration gaps

For each dimension, the chapter identifies the current situation, implications for P2P electricity sharing, and recommended reforms.

6.3 Policy Gaps

6.3.1 Absence of Vision for Community Energy: Current Situation

National energy policies in both countries prioritise universal electricity access, renewable energy deployment, and private investment. However, they do not articulate a vision for community-owned or peer-to-peer electricity markets [19] [31]. (URT, 2015).

(a) Implications



Without a clear policy direction:

- (i) investors face uncertainty;
- (ii) regulators lack guidance;
- (iii) utilities have no framework for collaboration;
- (iv) communities have limited incentives to organise energy cooperatives.

(b) Recommended Reform

Future energy policies should include a dedicated chapter on Community Energy and Peer-to-Peer Electricity Markets, covering:

- (i) energy communities;
- (ii) prosumers;
- (iii) distributed generation;
- (iv) community storage;
- (v) local electricity markets;
- (vi) digital energy platforms.

6.3.2 Limited Recognition of Digital Energy Markets

Electricity policies continue to treat electricity as a commodity supplied primarily by utilities or licensed operators. They do not recognise digital platforms that facilitate decentralised energy trading [11] [13] [14].

Policy Recommendation

Governments should formally recognise digital electricity marketplaces as legitimate components of national electricity systems and establish guiding principles for their development.

6.4 Legal Gaps

6.4.1 No Legal Definition of a Prosumer

(a) Current Situation

Electricity legislation distinguishes between generators, distributors, suppliers, and consumers. It does not define a prosumer.

(b) Implications

Households with rooftop solar systems cannot participate fully in electricity markets.

(c) Proposed Legal Definition

Prosumer: *A natural or legal person who generates electricity primarily for self-consumption and is authorised to store, share, or sell surplus electricity through approved electricity networks or digital energy platforms.*

6.4.2 No Legal Basis for Peer-to-Peer Electricity Trading

Electricity laws do not recognise direct transactions between consumers [23] [34] [11] [13].

(a) Consequences

- (i) electricity trading remains legally uncertain;
- (ii) commercial models cannot scale;
- (iii) investment risks remain high.

(b) Recommendation

Introduce a new legal category:

Peer-to-Peer Electricity Trading: *The exchange of electricity between authorised electricity users through approved digital platforms or community energy systems under the supervision of the national electricity regulator.*

6.4.3 Lack of Legal Recognition of Energy Communities

Community-owned renewable energy systems have no formal legal identity in electricity legislation [12] [14] [39] [40] [41] [42].

Recommendation

Recognise Energy Communities as legal entities eligible to:

- (a) generate electricity;
- (b) distribute electricity within approved service areas;
- (c) own community batteries;
- (d) participate in electricity markets;
- (e) receive government incentives.

6.5 Regulatory Gaps

6.5.1 Licensing Framework

(a) Current Situation

Licensing systems are designed for:

- (i) utilities;
- (ii) independent power producers;
- (iii) mini-grid operators.

Community SWARM Grids do not fit existing licensing categories.

(b) Recommendation

Introduce three new licensing categories:

Category A

Registered Community Energy Systems

Small non-commercial systems operating below a defined capacity threshold.

Category B

Licensed Community Energy Cooperatives

Community organisations authorised to trade electricity among members.

Category C

Digital Electricity Platform Operators

Companies providing energy trading platforms without owning generation assets.

6.5.2 Regulatory Sandbox

(a) Gap

Neither country has permanent regulatory mechanisms for testing innovative electricity business models.

(b) Recommendation

Energy regulators should establish Peer-to-Peer Electricity Regulatory Sandboxes allowing:

- (i) temporary regulatory exemptions;
- (ii) monitored pilot projects;
- (iii) structured data collection;
- (iv) evaluation before nationwide rollout.

6.6 Technical Gaps

6.6.1 Smart Metering

Current standards focus on conventional electricity metering. Future systems require:

- (a) bidirectional measurement;
- (b) remote communication;
- (c) real-time settlement;
- (d) tamper detection.

6.6.2 Interoperability

SWARM Grids will involve equipment from multiple manufacturers. Without interoperability standards [48]

- (a) competition decreases;
- (b) costs increase;
- (c) innovation slows.

Recommendation

Develop national interoperability standards covering:

- (a) controllers;
- (b) inverters;
- (c) batteries;
- (d) communication protocols;
- (e) software interfaces.

6.6.3 Cybersecurity

Digital energy systems introduce new cyber risks. Potential threats include: [16] [48]

- (a) unauthorised electricity transactions;
- (b) manipulation of billing;
- (c) malware attacks;
- (d) identity theft;
- (e) denial-of-service attacks.

Recommendation

Develop national cybersecurity requirements specifically for decentralised energy systems, including:

- (a) encryption of communications;
- (b) secure authentication;
- (c) regular software updates;
- (d) vulnerability testing;
- (e) incident reporting procedures.

6.7 Market Design Gaps

6.7.1 Pricing Mechanisms

There is no methodology for determining electricity prices within local energy markets [11] [12] [14] [15].

Possible pricing models include:

- (a) fixed community tariffs;
- (b) dynamic pricing based on supply and demand;
- (c) auction-based pricing;
- (d) regulated price caps.

Recommendation

Allow communities flexibility to adopt transparent pricing models subject to regulatory oversight.

6.7.2 Settlement Systems

Electricity transactions require secure settlement. Regulations should specify: [16]

- (a) payment timelines;
- (b) transaction verification;
- (c) audit requirements;
- (d) dispute resolution.

6.8 Consumer Protection Gaps

Future electricity markets require expanded consumer rights. Recommended protections include: [16]

(a) Transparent Pricing

Consumers should receive clear information regarding:

- (i) electricity prices;
- (ii) transaction fees;
- (iii) taxes.

(b) Data Privacy

Energy consumption data should be protected through data governance legislation.

(c) Dispute Resolution

Fast and affordable mechanisms should resolve disputes regarding:

- (i) billing;
- (ii) electricity quality;
- (iii) system performance.

(d) Consumer Education

Governments should support public awareness campaigns explaining:

- (i) peer-to-peer electricity;
- (ii) consumer rights;
- (iii) digital security;
- (iv) energy efficiency.

6.9 Institutional Gaps

(a) Current Situation

Many public institutions possess expertise in conventional electricity regulation but limited experience with digital decentralised electricity markets.

(b) Capacity Building Needs

Training should target:

- (a) regulators;
- (b) utilities;
- (c) standards organisations;
- (d) local governments;
- (e) financial institutions;
- (f) judiciary;
- (g) universities.

6.10 Financial and Investment Gaps

(a) Current barriers include

- (i) high capital costs;
- (ii) limited concessional finance;
- (iii) insufficient guarantees;
- (iv) foreign exchange risks;
- (v) limited private investment.

(b) Recommended Financing Instruments

- (i) green bonds;

- (ii) blended finance;
- (iii) concessional loans;
- (iv) carbon finance;
- (v) revolving funds;
- (vi) community investment funds;
- (vii) results-based financing.

6.11 Fiscal and Taxation Gaps

Current taxation systems were not designed for decentralised energy markets.

Issues requiring review include:

- (i) VAT treatment of electricity transactions;
- (ii) import duties on smart controllers;
- (iii) taxation of community cooperatives;
- (iv) depreciation allowances;
- (v) incentives for battery storage.

Recommendation

Governments should establish targeted fiscal incentives for:

- (i) locally manufactured smart energy equipment;
- (ii) community batteries;
- (iii) advanced metering infrastructure;
- (iv) productive use equipment.

6.12 Environmental and Social Gaps

Future policy should address:

- (i) battery recycling;
- (ii) electronic waste management;
- (iii) environmental safeguards;
- (iv) gender equality;
- (v) youth participation;
- (vi) inclusion of vulnerable households.

SWARM Grids should incorporate circular economy principles by promoting battery reuse, recycling, and environmentally sound disposal.

6.13 Regional Integration Gaps

Tanzania and Rwanda are members of the East African Community (EAC), yet no regional framework currently exists for peer-to-peer electricity sharing. [39] [40]

Areas requiring harmonisation include:

- (a) technical standards;
- (b) cybersecurity requirements;
- (c) smart metering specifications;
- (d) licensing principles;
- (e) data governance;
- (f) interoperability standards.

Regional harmonisation would facilitate technology transfer, investment, and future expansion of decentralised energy markets across East Africa.

6.14 Priority Policy Reform Agenda

The following reforms are recommended over the period 2027–2035 [19] [20] [23] [31] [34] [39] [40].

Table 6: Proposed policy instruments for the reform

Reform Area	Lead Institution	Timeframe
Amend Electricity Acts	Ministries responsible for Energy	Short term
Recognize Prosumers	Parliament and Regulators	Short term
Establish Regulatory Sandboxes	EWURA / RURA	Short term
Develop Community Energy Regulations	Regulators	Medium term
Publish Technical Standards	TBS / Rwanda Standards Board	Medium term
Develop Cybersecurity Framework	ICT Authorities & Regulators	Medium term
Introduce Fiscal Incentives	Ministries of Finance	Medium term
Harmonise Regional Standards	East African Community	Long term
Mainstream SWARM Grids into National Electrification Plans	Ministries of Energy	Long term

6.15 Proposed Institutional Coordination Framework

Effective implementation requires coordinated action among multiple stakeholders.

(a) Policy Leadership

- (i) Ministries responsible for Energy

(b) Regulation

- (i) EWURA (Tanzania)
- (ii) RURA (Rwanda)

(c) Rural Deployment

- (i) REA
- (ii) Rwanda Energy Group (Off-grid programmes)

(d) Standards

- (i) TBS
- (ii) Rwanda Standards Board

(e) Research

- (i) Universities
- (ii) Research institutes

(f) Private Sector

- (i) Technology providers
- (ii) Energy service companies
- (iii) Financial institutions

(g) Civil Society

- (i) Renewable energy associations (including TAREA)
- (ii) Community organizations
- (iii) Consumer associations

7.0 SOCIO-ECONOMIC, ENVIRONMENTAL, AND ENERGY SYSTEM BENEFITS OF PEER-TO-PEER SOLAR ELECTRICITY SHARING

7.1 Introduction

Energy is more than a basic utility. It is a catalyst for economic transformation, social development, environmental sustainability, and technological innovation. The availability of reliable, affordable, and clean electricity determines the ability of households to improve their livelihoods, businesses to grow, schools to provide quality education, health facilities to deliver life-saving services, and governments to achieve national development goals.

Traditional rural electrification programmes have largely focused on connecting households to electricity. While increasing electricity access remains essential, the next stage of the energy transition requires maximising the value of every kilowatt-hour generated. Peer-to-peer (P2P) solar electricity sharing addresses this challenge by enabling surplus renewable electricity to be exchanged within communities, improving energy utilisation, reducing costs, and supporting productive economic activities.

This chapter examines the broad benefits of SWARM Grids and peer-to-peer solar electricity sharing for Tanzania and Rwanda. It analyses impacts on economic development, employment, agriculture, gender equality, education, health, climate change mitigation, energy security, and national electricity systems. It also presents an indicative cost-benefit assessment and scenarios for scaling the technology.

7.2 Economic Benefits

7.2.1 Improved Utilisation of Renewable Energy

Standalone solar home systems frequently generate more electricity than is immediately consumed, particularly during daylight hours. Without the ability to share or sell this surplus, valuable renewable energy is curtailed or wasted [2] [3] [4] [17]. Peer-to-peer electricity sharing allows excess generation to be used by neighbouring consumers, increasing the overall utilisation of installed solar PV capacity.

Expected Outcomes

- (a) Higher capacity utilisation of solar PV systems.
- (b) Increased return on investment for system owners.
- (c) Reduced energy wastage.
- (d) Improved financial viability of distributed renewable energy projects.

7.2.2 Reduced Household Energy Costs

By purchasing locally generated renewable electricity, households can reduce dependence on expensive diesel generators, kerosene, candles, and disposable batteries [18] [50].

Benefits include:

- (a) lower monthly energy expenditure;
- (b) reduced transport costs associated with fuel purchases;
- (c) lower maintenance costs compared with diesel generators;

- (d) more predictable energy prices.

7.2.3 Additional Income for Prosumers

Households and businesses generating surplus electricity can earn additional income by selling excess energy to neighbouring consumers. Potential uses of this income include: [11] [15]

- (a) repayment of solar system loans;
- (b) investment in productive assets;
- (c) education expenses;
- (d) health care;
- (e) expansion of renewable energy systems.

This creates a new income stream while improving the affordability of solar investments.

7.2.4 Growth of Local Enterprises

Reliable electricity enables the establishment and expansion of small and medium-sized enterprises (SMEs). Examples include: [10] [18].

- (a) welding workshops;
- (b) carpentry;
- (c) tailoring;
- (d) grain milling;
- (e) food processing;
- (f) refrigeration services;
- (g) internet cafés;
- (h) digital service centres.

The increased availability of electricity stimulates local economic activity and broadens the rural tax base.

7.3 Productive Use of Energy (PUE)

7.3.1 Agriculture

Agriculture remains the primary source of income for many rural households in Tanzania and Rwanda. Reliable electricity can transform agricultural productivity [18] [51].

Applications include:

- (a) solar-powered irrigation;
- (b) milk cooling;
- (c) crop drying;
- (d) grain milling;
- (e) maize shelling;
- (f) rice processing;
- (g) greenhouse ventilation;
- (h) livestock watering.

Expected Benefits

- (a) increased crop yields;
- (b) reduced post-harvest losses;
- (c) higher farm incomes;

- (d) improved food security.

7.3.2 Fisheries

Electricity supports: [18]

- (a) ice production;
- (b) cold storage;
- (c) fish processing;
- (d) refrigeration during transport.

This improves product quality and reduces spoilage.

7.3.3 Tourism

Community energy systems can provide reliable electricity for: [18]

- (a) eco-lodges;
- (b) campsites;
- (c) cultural tourism centres;
- (d) restaurants;
- (e) electric vehicle charging.

Reliable renewable electricity enhances visitor experiences while reducing operational costs.

7.4 Employment Creation

The deployment and operation of SWARM Grids create employment opportunities throughout the value chain [10] [18].

(a) Direct Jobs

- (i) engineers;
- (ii) electricians;
- (iii) installers;
- (iv) technicians;
- (v) software developers;
- (vi) maintenance personnel.

(b) Indirect Jobs

- (i) equipment suppliers;
- (ii) transport providers;
- (iii) financial services;
- (iv) retailers;
- (v) construction workers.

(c) Induced Jobs

Income generated through the project stimulates additional employment in local economies.

Youth employment opportunities are particularly significant due to the digital nature of peer-to-peer energy systems.

7.5 Social Benefits

7.5.1 Improved Education

Reliable electricity enables: [18] [50]

- (a) evening study;
- (b) digital learning;
- (c) internet connectivity;
- (d) operation of school laboratories;
- (e) computer training.

Schools connected to SWARM Grids can extend learning hours and improve educational outcomes.

7.5.2 Improved Healthcare

Health facilities require reliable electricity for: [18] [50]

- (a) vaccine refrigeration;
- (b) laboratory equipment;
- (c) lighting;
- (d) sterilization;
- (e) emergency services;
- (f) communications.

Peer-to-peer electricity sharing enhances reliability by allowing neighbouring facilities to support one another during equipment failures or localised shortages.

7.5.3 Improved Water Supply

Reliable electricity enables: [18]

- (a) water pumping;
- (b) purification;
- (c) treatment;
- (d) storage;
- (e) distribution.

Improved access to safe water contributes to better public health and reduced time spent collecting water.

7.6 Gender Equality and Social Inclusion

Women and girls are disproportionately affected by energy poverty [6] [9] [10]

Peer-to-peer electricity sharing can contribute to gender equality by:

- (a) reducing time spent collecting fuelwood;
- (b) enabling electric cooking;
- (c) supporting women-owned enterprises;
- (d) improving access to education;
- (e) increasing household safety through improved lighting.

Women should be actively involved in:

- (a) community energy governance;
- (b) technical training;
- (c) entrepreneurship;

- (d) decision-making.

Youth and persons with disabilities should also be included in project planning and implementation.

7.7 Environmental Benefits

7.7.1 Greenhouse Gas Emission Reductions

Replacing diesel generators and fossil fuel-based electricity with renewable solar energy reduces greenhouse gas emissions. Benefits include:

- (a) lower carbon dioxide emissions;
- (b) reduced methane emissions associated with biomass use;
- (c) improved air quality.

Peer-to-peer sharing increases renewable energy utilisation, thereby maximising these environmental benefits.

7.7.2 Reduced Deforestation

Reliable electricity supports: [5]

- (a) electric cooking;
- (b) electric agro-processing;
- (c) renewable-powered enterprises.

Reduced dependence on fuelwood and charcoal contributes to forest conservation.

7.7.3 Reduced Air Pollution

Replacing diesel generators and biomass combustion improves indoor and outdoor air quality. This contributes to:

- (a) reduced respiratory illness;
- (b) lower healthcare costs;
- (c) improved worker productivity.

7.8 Climate Change Resilience

Climate change is increasing the frequency of floods, droughts, and extreme weather events [5] [7].

Distributed community energy systems enhance resilience because:

- (a) electricity generation is geographically dispersed;
- (b) communities are less dependent on a single power source;
- (c) battery storage provides backup during outages;
- (d) local energy resources remain available during emergencies.

7.9 Energy System Benefits

7.9.1 Reduced Distribution Losses

Electricity consumed close to where it is generated minimises transmission and distribution losses. This increases overall system efficiency and reduces infrastructure investment requirements.

7.9.2 Improved Grid Reliability

SWARM Grids improve reliability by: [17] [18]

- (a) balancing local demand and supply;
- (b) reducing peak demand;
- (c) providing localised backup;
- (d) supporting voltage stability.

Future integration with national electricity networks could allow community energy systems to contribute ancillary services such as demand response and frequency support.

7.9.3 Deferred Network Investments

By satisfying part of local electricity demand through distributed generation, governments and utilities may defer costly investments in transmission and distribution infrastructure [18].

Savings can be redirected toward electrifying additional communities or upgrading critical infrastructure.

7.10 Financial Sector Benefits

Peer-to-peer electricity markets create new opportunities for financial institutions through:

- (a) green loans;
- (b) microfinance;
- (c) leasing;
- (d) insurance products;
- (e) carbon finance;
- (f) results-based financing.

The predictable cash flows generated by energy trading can improve the creditworthiness of community energy projects.

7.11 Benefits for National Governments

Governments benefit through: [6] [9] [10] [50]

- (a) accelerated progress toward universal energy access;
- (b) reduced public expenditure on grid extension;
- (c) increased tax revenues from growing rural enterprises;
- (d) improved energy security;
- (e) enhanced climate performance;
- (f) attraction of green investment.

Peer-to-peer energy markets also support national commitments under the Paris Agreement and the Sustainable Development Goals.

7.12 Indicative Cost–Benefit Assessment

The table below presents a qualitative comparison of expected costs and benefits associated with SWARM Grid deployment.

Table 7: Cost Assessment of SWARM Grid Deployment

Aspect	Initial Cost	Long-Term Benefit
Solar PV systems	High	High
Battery storage	High	High
Smart controllers	Medium	High
Smart meters	Medium	High
Digital platform	Medium	High
Community training	Low	High
Regulatory development	Low	Very High
Productive use equipment	Medium	Very High

Overall, while capital investments are significant, the long-term economic, environmental, and social benefits substantially outweigh initial costs, particularly when systems are deployed at scale.

7.13 Potential Risks and Mitigation

While benefits are substantial, successful implementation requires proactive risk management [16] [18] [29].

Table 8: Risks and Mitigation Assessment for SWARM E Grid Deployment

Risk	Potential Impact	Mitigation
Unequal participation	Exclusion of vulnerable households	Inclusive financing and targeted subsidies
Technology failure	Reduced consumer confidence	Quality assurance, standards, and maintenance
Cybersecurity incidents	Financial and operational losses	Secure communication protocols and regular audits
Market concentration	Reduced competition	Transparent licensing and oversight
Battery waste	Environmental pollution	Battery recycling and extended producer responsibility

8.0 PROPOSED POLICY AND REGULATORY FRAMEWORK FOR PEER-TO-PEER SOLAR ELECTRICITY SHARING IN TANZANIA AND RWANDA

8.1 Introduction

This chapter proposes a comprehensive policy and regulatory framework for Tanzania and Rwanda. It is based on six guiding principles: [11] [13] 14] [19] [31] [34].

- (a) Innovation – encourage new technologies and business models.
- (b) Consumer Protection – safeguard the rights and interests of electricity users.
- (c) Competition – create a level playing field for market participants.
- (d) Reliability and Safety – maintain technical integrity and operational resilience.
- (e) Inclusiveness – ensure participation by women, youth, low-income households, and vulnerable groups.
- (f) Sustainability – support national development, climate action, and long-term financial viability.

The framework is designed to complement, rather than replace, existing electricity laws and regulations.

8.2 Vision

To establish inclusive, secure, efficient, and sustainable community electricity markets that enable citizens, businesses, and institutions to generate, store, share, and trade renewable electricity while supporting national economic development and universal energy access.

8.3 Policy Objectives

The proposed framework seeks to:

- (a) establish a legal basis for peer-to-peer electricity sharing;
- (b) recognise prosumers and community energy systems;
- (c) facilitate investment in decentralised renewable energy;
- (d) encourage innovation through regulatory sandboxes;
- (e) ensure consumer protection and market transparency;
- (f) promote productive uses of renewable electricity;
- (g) strengthen cybersecurity and data governance;
- (h) harmonise standards within the East African Community.

8.4 Guiding Principles

The following principles should underpin all future legislation and regulations [11] [14] [16] [29]

Principle 1: Technology Neutrality

Regulations should permit various renewable energy technologies, including solar PV, wind, micro-hydropower, biomass, and future innovations, provided they meet technical and safety standards.

Principle 2: Consumer-Centred Markets

Consumers should have the right to:

- (a) generate electricity;
- (b) store electricity;

- (c) consume electricity;
- (d) share electricity;
- (e) sell surplus electricity through approved platforms.

Principle 3: Fair Competition

The regulatory framework should encourage competition among technology providers and service companies while preventing anti-competitive practices.

Principle 4: Safety and Reliability

All systems must comply with national electrical safety standards and technical codes.

Principle 5: Environmental Sustainability

Peer-to-peer electricity systems should contribute to reduced greenhouse gas emissions, efficient resource use, and environmentally sound management of batteries and electronic waste.

8.5 Proposed Legal Definitions

To eliminate ambiguity, electricity legislation should introduce the following definitions [11] [14] [16] [29].

Prosumer

A natural or legal person who generates electricity primarily for self-consumption and is authorised to store, share, or sell surplus electricity under approved regulatory arrangements.

Peer-to-Peer Electricity Trading

The exchange of electricity between authorised participants through an approved community energy system or digital platform under the supervision of the national electricity regulator.

Community Energy System

A locally governed electricity system owned or managed by a community, cooperative, association, or other legal entity that generates, stores, distributes, and trades renewable electricity for the benefit of its members.

SWARM Grid

An intelligent decentralised electricity network that interconnects distributed renewable energy systems using smart controllers, communication technologies, and digital energy management platforms to optimise local generation, storage, consumption, and peer-to-peer electricity trading.

Digital Energy Platform

A software platform that facilitates the measurement, accounting, settlement, and management of electricity transactions between authorised participants.

8.6 Proposed Market Structure

The proposed market structure introduces new participants while preserving the roles of existing institutions.

Table 9: Proposed Market Structure for SWARM-E Grid

Market Participant	Primary Role
Ministry responsible for Energy	National policy and strategic oversight
Electricity Regulator	Licensing, tariff approval, consumer protection, market oversight
National Utility	Grid integration, network coordination, system planning
Community Energy Cooperative	Local generation, distribution, and governance
Prosumers	Generation, self-consumption, sale of surplus electricity
Consumers	Purchase and use of electricity
Digital Platform Operator	Facilitation of transactions and settlement
Financial Institutions	Financing and payment services
Standards Bodies	Technical standards and certification
Local Governments	Community mobilization and local oversight

8.7 Licensing Framework

A risk-based licensing approach is recommended to reduce barriers while ensuring appropriate oversight.

Category A – Registered Community Energy Systems

Eligibility: Small community systems below a prescribed installed capacity.

Requirements:

- (a) Simple registration.
- (b) Compliance with technical standards.
- (c) Basic safety inspection.

Advantages:

- (a) Reduced administrative burden.
- (b) Faster deployment in rural areas.

Category B – Community Energy Cooperatives

Eligibility: Cooperatives and community organisations trading electricity among members.

Requirements:

- (a) Cooperative registration.
- (b) Approved governance structure.
- (c) Consumer protection procedures.
- (d) Annual reporting.

Category C – Commercial Peer-to-Peer Operators

Eligibility: Companies operating larger decentralised energy markets.

Requirements:

- (a) Full licence.

- (b) Financial capability.
- (c) Cybersecurity compliance.
- (d) Independent audits.
- (e) Data protection measures.

Category D – Digital Energy Platform Providers

Eligibility: Organisations providing software for electricity trading.

Requirements:

- (a) Cybersecurity certification.
- (b) Data privacy compliance.
- (c) Interoperability with approved metering systems.
- (d) Disaster recovery and business continuity plans.

8.8 Regulatory Sandbox Framework

Energy regulators should establish Peer-to-Peer Electricity Regulatory Sandboxes to allow controlled testing of innovative business models [13] [14].

Objectives

- (a) Evaluate technical performance.
- (b) Assess consumer acceptance.
- (c) Test tariff models.
- (d) Review cybersecurity measures.
- (e) Inform permanent regulation.

Typical Features

- (a) Defined geographic area.
- (b) Time-bound authorisation (e.g., 24–36 months).
- (c) Regular reporting requirements.
- (d) Independent monitoring and evaluation.
- (e) Consumer safeguards and exit arrangements.

Evidence from sandbox projects should guide future amendments to legislation and regulations.

8.9 Tariff and Pricing Principles

Tariff regulation should balance affordability, investment incentives, and market transparency [11] [12] [14] [15].

(a) Recommended Principles

- (i) Cost reflectivity.
- (ii) Transparency.
- (iii) Non-discrimination.
- (iv) Simplicity.
- (v) Consumer choice.
- (vi) Regulatory oversight.

(b) Pricing Options

- (i) Fixed community tariff.
- (ii) Time-of-use tariff.

- (iii) Dynamic pricing based on supply and demand.
- (iv) Capacity-based tariff for shared infrastructure.
- (v) Social tariffs for low-income households.

Regulators should approve methodologies while allowing communities flexibility to select pricing structures appropriate to local conditions.

8.10 Settlement and Payment Systems

The regulatory framework should define procedures for: [12] [14] [15]

- (i) electricity metering;
- (ii) transaction verification;
- (iii) billing;
- (iv) payment processing;
- (v) reconciliation;
- (vi) auditing.

Given the widespread adoption of mobile money in both countries, integration with digital payment systems should be encouraged to simplify transactions and improve financial inclusion.

8.11 Technical Standards Framework

National standards bodies should develop or adopt standards covering:

- (a) Generation Equipment**
 - (i) Solar PV modules.
 - (ii) Inverters.
 - (iii) Battery systems.
- (b) Smart Infrastructure**
 - (i) Smart meters.
 - (ii) SWARM Controllers.
 - (iii) Communication devices.
 - (iv) Gateway equipment.
- (c) Interoperability**
 - (i) Data exchange protocols.
 - (ii) Equipment compatibility.
 - (iii) Software interfaces.
- (d) Safety**
 - (i) Electrical installations.
 - (ii) Fire protection.
 - (iii) Earthing.
 - (iv) Isolation and protection devices.
- (e) Cybersecurity**
 - (i) Encryption.
 - (ii) User authentication.
 - (iii) Secure software updates.
 - (iv) Incident reporting.
- (f) Battery Management**
 - (i) State-of-charge monitoring.
 - (ii) Thermal management.
 - (iii) Recycling and end-of-life handling.

Where appropriate, standards should align with internationally recognised frameworks such as IEC standards while reflecting local operating conditions [44] [45] [46].

8.12 Consumer Protection Framework

Consumers should enjoy clear rights and responsibilities [16] [29].

(a) Rights

- (i) Access to transparent pricing.
- (ii) Accurate billing.
- (iii) Data privacy.
- (iv) Quality electricity supply.
- (v) Fair dispute resolution.
- (vi) Freedom to join or leave community energy schemes, subject to agreed contractual terms.

(b) Responsibilities

- (i) Comply with technical requirements.
- (ii) Prevent tampering with equipment.
- (iii) Make timely payments.
- (iv) Use electricity safely.
- (v) Report faults and cybersecurity incidents.

8.13 Data Governance and Cybersecurity

Digital energy markets generate large volumes of operational and consumer data [16] [48] [49].

The framework should address:

- (a) ownership of energy data;
- (b) consent for data sharing;
- (c) secure storage of transaction records;
- (d) cybersecurity risk management;
- (e) protection against fraud and unauthorised access;
- (f) incident response procedures.

Energy regulators should collaborate with national ICT and cybersecurity authorities to develop sector-specific guidance.

8.14 Environmental and Social Safeguards

All peer-to-peer electricity systems should comply with environmental and social requirements, including: [29] [30] [33].

- (a) environmentally sound battery disposal and recycling;
- (b) electronic waste management;
- (c) occupational health and safety;
- (d) gender equality;
- (e) community participation;
- (f) protection of vulnerable groups.

Projects should include environmental and social management plans proportionate to their scale and potential impacts.

8.15 Institutional Roles and Responsibilities

Table 10: Proposed Institutional Roles in Developing SWARM-E Grid

Institution	Key Responsibilities
Ministry responsible for Energy	Policy development, legislative reform, national coordination
Energy Regulator	Licensing, tariff regulation, market oversight, consumer protection, sandbox management
National Utility	Grid planning, technical coordination, interoperability, connection standards
Rural Electrification Agency/Programme	Rural deployment, financial support, capacity building
Standards Bodies	Development and enforcement of technical standards
Local Governments	Community engagement, local coordination, conflict resolution
Universities and Research Institutions	Research, innovation, testing, monitoring and evaluation
Financial Institutions	Green finance, concessional lending, guarantees
Civil Society and Industry Associations	Public awareness, advocacy, training, stakeholder coordination

8.16 Governance Framework for Community Energy Systems

Each community energy system should establish a governance structure comprising:

General Assembly

The highest decision-making body representing all members.

Management Committee

Responsible for strategic oversight and accountability.

Technical Committee

Oversees operation, maintenance, and technical compliance.

Finance Committee

Monitors financial management, tariffs, and audits.

Consumer Protection Committee

Handles complaints, community engagement, and awareness.

Transparent governance will build trust and support long-term sustainability.

8.17 Monitoring and Compliance

Regulators should monitor compliance using indicators such as:[19] [23] [31] [34]

- system reliability;
- safety incidents;
- electricity traded;
- consumer complaints;
- tariff compliance;
- cybersecurity incidents;
- renewable energy utilisation;
- environmental compliance.

Periodic reporting requirements should be proportionate to the size and complexity of each licensed entity.

8.18 Proposed Legislative Amendments

To operationalise the proposed framework, Tanzania and Rwanda should consider amendments to: [19] [23] [24] [31] [34]

- (a) Electricity Acts/Laws.
- (b) Energy Policies.
- (c) Renewable Energy Strategies.
- (d) Mini-grid Regulations.
- (e) Licensing Regulations.
- (f) Technical Codes.
- (g) Consumer Protection Regulations.
- (h) Data Protection Legislation (where relevant to the energy sector).

These amendments should introduce the legal concepts of prosumers, community energy systems, peer-to-peer electricity trading, digital energy platforms, and regulatory sandboxes.

8.19 Implementation Principles

The proposed framework should be implemented through a phased approach: [13] [14] [39] [40]

Phase I

- (a) Establish regulatory sandboxes.
- (b) Develop interim guidelines.
- (c) Conduct pilot projects.

Phase II

- (a) Amend legislation.
- (b) Develop technical standards.
- (c) Expand pilot programmes.

Phase III

- (a) National rollout.
- (b) Integration into electrification programmes.
- (c) Regional harmonisation within the East African Community.

9.0 IMPLEMENTATION ROADMAP, FINANCING STRATEGY, CAPACITY BUILDING, AND DISSEMINATION PLAN FOR PEER-TO-PEER SOLAR ELECTRICITY SHARING

9.1 Introduction

The successful transition from policy recommendations to practical implementation requires a structured roadmap supported by appropriate financing mechanisms, institutional coordination, technical capacity, stakeholder engagement, and continuous monitoring.

Peer-to-peer (P2P) solar electricity sharing and SWARM Grids represent a new generation of energy systems that combine renewable energy technologies, digital platforms, community participation, and innovative business models. Therefore, their successful deployment requires coordinated action from governments, regulators, utilities, development partners, private sector actors, research institutions, communities, and financial institutions.

This chapter presents an implementation roadmap for Tanzania and Rwanda. It defines priority actions, responsible institutions, financing approaches, capacity-building requirements, and dissemination strategies necessary to move from demonstration projects to large-scale adoption.

9.2 Implementation Vision

By 2035, Tanzania and Rwanda will have established enabling policy, regulatory, technical, and financial environments where communities, businesses, and institutions can generate, store, share, and trade renewable electricity through secure, inclusive, and sustainable peer-to-peer energy markets.

9.3 Implementation Objectives

The roadmap aims to:

- (a) Establish enabling policy and regulatory frameworks.
- (b) Scale SWARM Grid demonstration projects.
- (c) Develop technical standards and certification systems.
- (d) Mobilise investment for decentralised energy markets.
- (e) Build institutional and human capacity.
- (f) Promote inclusive participation.
- (g) Integrate peer-to-peer electricity sharing into national energy planning.
- (h) Strengthen regional cooperation.

9.4 Implementation Phases

The implementation roadmap is divided into three phases:

Phase I: Foundation and Demonstration (2024–2028)

Phase II: Regulatory Development and Expansion (2029–2031)

Phase III: Commercial Scale-Up and Regional Integration (2032–2035)

9.5 Phase I: Foundation and Demonstration (2024–2028)

Objective

To establish the foundation for peer-to-peer electricity sharing through pilot projects, regulatory experimentation, stakeholder engagement, and evidence generation.

9.5.1 Establish National Coordination Mechanisms

Governments should establish national task forces comprising:

- (a) Ministry of Energy;
- (b) electricity regulators;
- (c) utilities;
- (d) rural electrification agencies;
- (e) standards bodies;
- (f) ICT authorities;
- (g) financial institutions;
- (h) renewable energy associations;
- (i) research institutions.

Expected Output

National P2P Energy Coordination Platforms established in Tanzania and Rwanda.

9.5.2 Establish Regulatory Sandboxes

Energy regulators should create controlled environments where SWARM Grid projects can operate under temporary regulatory arrangements [13] [14].

Activities include:

- (a) defining sandbox rules;
- (b) selecting pilot communities;
- (c) monitoring performance;
- (d) collecting regulatory evidence.

Lead Institutions

Tanzania:

- (a) Ministry of Energy
- (b) EWURA
- (c) REA

Rwanda:

- (a) Ministry of Infrastructure
- (b) RURA
- (c) Rwanda Energy Group

9.5.3 Expand SWARM-E Demonstrations

Pilot projects should demonstrate:

- (a) household electricity sharing;
- (b) community batteries;
- (c) productive use applications;
- (d) digital payment systems;
- (e) energy management platforms.

Priority locations may include:

- (a) rural communities;

- (b) agricultural areas;
- (c) health facilities;
- (d) schools;
- (e) small enterprises.

9.5.4 Develop Interim Guidelines

Before permanent regulations are adopted, regulators should issue interim guidelines covering:

- (a) project registration;
- (b) safety requirements;
- (c) metering;
- (d) consumer protection;
- (e) reporting obligations.

9.6 Phase II: Regulatory Development and Expansion (2029–2031)

Objective

To transition from pilot demonstrations toward structured market development.

9.6.1 Legislative and Regulatory Reform

Actions:

- (a) amend electricity laws;
- (b) introduce prosumer definitions;
- (c) recognise energy communities;
- (d) establish P2P trading provisions;
- (e) introduce new licensing categories.

Expected Result

A legally recognised framework for community energy markets.

9.6.2 Development of Technical Standards

Standards organisations should develop requirements for:

Solar Equipment

- (a) PV modules;
- (b) inverters;
- (c) batteries.

Smart Energy Equipment

- (a) SWARM Controllers;
- (b) smart meters;
- (c) communication systems.

Digital Systems

- (a) cybersecurity;
- (b) data management;
- (c) interoperability.

9.6.3 Establish Certification Systems

Create certification programmes for:

- (a) SWARM Grid installers;
- (b) technicians;
- (c) energy auditors;

- (d) community energy managers.

Training institutions and universities should participate in curriculum development.

9.6.4 Integration with National Electrification Programmes

SWARM Grids should become recognised options within:

- (a) rural electrification plans;
- (b) mini-grid programmes;
- (c) productive use initiatives;
- (d) climate adaptation programmes.

9.7 Phase III: Commercial Scale-Up and Regional Integration (2032–2035)

Objective

To achieve widespread deployment and establish mature decentralised electricity markets.

9.7.1 National Deployment

Actions:

- (a) replicate successful models;
- (b) attract private investors;
- (c) expand community energy cooperatives;
- (d) integrate digital energy platforms.

9.7.2 Utility Integration

National utilities should develop mechanisms for cooperation with SWARM Grids through:

- (a) grid support services;
- (b) demand response;
- (c) renewable energy balancing;
- (d) future virtual power plant models.

9.7.3 Regional Harmonisation

Through the East African Community, countries should collaborate on:

- (a) technical standards;
- (b) cybersecurity frameworks;
- (c) equipment certification;
- (d) knowledge exchange.

9.8 Financing Strategy

Scaling peer-to-peer electricity sharing requires innovative financing approaches because traditional energy financing models may not adequately support decentralised community systems.

9.8.1 Financing Requirements

Investment requirements include:

- (a) solar PV systems;



- (b) smart controllers;
- (c) meters;
- (d) communication infrastructure;
- (e) digital platforms;
- (f) training;
- (g) community mobilization.

9.8.2 Financing Sources

9.8.2.1 Government Funding

Governments can support:

- (a) pilot projects;
- (b) regulatory development;
- (c) standards development;
- (d) rural deployment programmes.

Possible sources:

- (a) energy sector budgets;
- (b) rural electrification funds;
- (c) climate funds.

9.8.2.2 Development Partners

Potential support areas:[52] [53]

- (a) grants;
- (b) technical assistance;
- (c) capacity building;
- (d) demonstration projects.

Partners may include:

- (a) European Union;
- (b) World Bank;
- (c) African Development Bank;
- (d) UN agencies;
- (e) bilateral cooperation agencies.

9.8.2.3 Private Sector Investment

Private companies can invest through:

- (a) Energy Service Company (ESCO) models;
- (b) leasing arrangements;
- (c) pay-as-you-go systems;
- (d) electricity-as-a-service models.

9.8.2.4 Green Finance

Potential instruments:

- (a) green bonds;
- (b) climate finance;
- (c) carbon credits;
- (d) sustainability-linked loans.

9.8.2.5 Community Financing



Communities can participate through:

- (a) cooperatives;
- (b) membership contributions;
- (c) community shares;
- (d) savings groups.

9.9 Recommended Business Models

Model 1: Community Cooperative Model

Community owns and manages the SWARM Grid.

Advantages:

- (a) local ownership;
- (b) community empowerment;
- (c) income retention.

Model 2: Private Energy Service Company Model

A private company invests, operates, and maintains the system.

Consumers pay for electricity services.

Advantages:

- (a) professional management;
- (b) easier scaling.

Model 3: Public–Private Partnership Model

Government provides enabling support while private companies provide technology and operation.

Advantages:

- (a) shared risk;
- (b) faster deployment.

Model 4: Utility Partnership Model

Utilities integrate community energy systems into national electricity planning.

Advantages:

- (a) improved grid coordination;
- (b) long-term sustainability.

9.10 Capacity Building Strategy

Successful implementation requires new skills across the energy sector.

9.10.1 Regulatory Capacity

Training for regulators on:

- (a) decentralised electricity markets;
- (b) digital energy platforms;
- (c) tariff design;
- (d) cybersecurity;
- (e) consumer protection.

9.10.2 Technical Capacity

Training for engineers and technicians on:

- (a) SWARM Grid installation;
- (b) battery systems;



- (c) smart controllers;
- (d) troubleshooting;
- (e) data management.

9.10.3 Community Capacity

Communities should receive training on:

- (a) energy management;
- (b) governance;
- (c) financial management;
- (d) maintenance;
- (e) consumer rights.

9.10.4 Academic and Research Capacity

Universities should develop:

- (a) renewable energy courses;
- (b) smart grid research programmes;
- (c) innovation laboratories.

9.11 Gender and Youth Inclusion Strategy

Implementation should ensure meaningful participation of women and youth [13] [14].

Actions include:

- (a) women-focused renewable energy training;
- (b) youth entrepreneurship programmes;
- (c) support for women-owned energy businesses;
- (d) inclusion of women in community energy governance.

9.12 Monitoring and Evaluation Framework

A comprehensive monitoring system should track progress [50].

Key Indicators

Policy Indicators

- (a) Number of regulations developed.
- (b) Number of institutions trained.
- (c) Number of standards adopted.

Technical Indicators

- (a) Number of SWARM Grids installed.
- (b) Installed renewable energy capacity.
- (c) Battery storage capacity.
- (d) Electricity traded.

Economic Indicators

- (a) Number of enterprises supported.
- (b) Jobs created.
- (c) Household income improvements.

Social Indicators

- (a) Number of beneficiaries.

- (b) Women and youth participation.
- (c) Consumer satisfaction.

Environmental Indicators

- (a) CO₂ emissions avoided.
- (b) Diesel/kerosene fuel displaced.
- (c) Biomass reduction.

9.13 Dissemination and Stakeholder Engagement Strategy

Effective dissemination is essential for policy adoption, investment mobilisation, and public acceptance. The dissemination strategy should operate at five levels.

9.13.1 Policy and Decision-Maker Engagement

Target audiences:

- (i) Ministers;
- (ii) Members of Parliament;
- (iii) Regulators;
- (iv) Utilities;
- (v) Local government authorities.

Methods:

- (i) policy dialogues;
- (ii) regulatory workshops;
- (iii) parliamentary presentations;
- (iv) executive meetings.

9.13.2 Technical Dissemination

Target audiences:

- (i) engineers;
- (ii) universities;
- (iii) technology companies;
- (iv) installers.

Methods:

- (i) technical workshops;
- (ii) training manuals;
- (iii) standards forums;
- (iv) conferences;
- (v) research publications.

9.13.3 Community Awareness

Target audiences:

- (i) households;
- (ii) farmers;
- (iii) entrepreneurs;
- (iv) community leaders.

Methods:

- (i) demonstration days;



- (ii) village meetings;
- (iii) radio programmes;
- (iv) local language materials;
- (v) videos.

9.13.4 Private Sector and Investor Engagement

Methods:

- (i) investment forums;
- (ii) business roundtables;
- (iii) technology exhibitions;
- (iv) project investment briefs.

9.13.5 Regional and International Dissemination

Platforms:

- (i) East African Community forums;
- (ii) Africa Energy Forum;
- (iii) international renewable energy conferences;
- (iv) climate finance events;
- (v) academic conferences.

9.14 Knowledge Products

The following materials should be developed:

- (i) Full policy paper.
- (ii) Executive policy brief (10 pages).
- (iii) Decision-maker briefing note (3 pages).
- (iv) Regulatory guideline.
- (v) Technical standards handbook.
- (vi) Community energy handbook.
- (vii) Investor prospectus.
- (viii) Training materials.
- (ix) Project documentary video.
- (x) Online knowledge platform.

9.15 Risk Management

Table 11: Risks and Mitigation in Realising Peer-to-Peer Electricity Sharing

Risk	Mitigation
Slow regulatory reform	Early engagement with policy-makers
Limited financing	Develop blended finance mechanisms
Low community acceptance	Awareness and participation programmes
Technical challenges	Standards and certification
Cybersecurity risks	Strong digital security framework
Lack of skilled personnel	Training and academic partnerships

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

The transformation of electricity systems from centralised, utility-driven models toward decentralised, intelligent, and community-oriented energy systems represents one of the most important developments in the global energy transition. Tanzania and Rwanda, with their strong commitment to renewable energy, universal electricity access, digital transformation, and climate action, are well positioned to benefit from this transition [11] [13] [14] [19] [31] [34].

Peer-to-peer (P2P) solar electricity sharing, enabled through innovative approaches such as **SWARM Grids**, provides an opportunity to redefine the role of electricity consumers. Instead of being passive recipients of electricity, households, businesses, institutions, and communities can become active participants in energy generation, storage, sharing, and trading.

This policy paper has demonstrated that P2P electricity sharing can contribute significantly to:

- (a) accelerated renewable energy deployment;
- (b) improved electricity access;
- (c) increased utilisation of solar energy resources;
- (d) rural economic transformation;
- (e) productive use of electricity;
- (f) job creation;
- (g) climate change mitigation;
- (h) improved energy resilience.

However, achieving these benefits requires deliberate policy, legal, regulatory, technical, and institutional reforms.

10.2 Overall Conclusion

Tanzania and Rwanda have established strong foundations for renewable energy development through national energy policies, rural electrification programmes, mini-grid frameworks, and private sector participation. These achievements provide a favourable environment for introducing next-generation decentralised energy systems. However, existing electricity sector frameworks remain largely designed around traditional electricity models where:

- (a) utilities generate and supply electricity;
- (b) consumers only purchase electricity;
- (c) electricity flows mainly in one direction;
- (d) transactions are controlled through centralised systems.

The emergence of SWARM Grids requires a new paradigm where:

- (a) consumers can become producers;
- (b) electricity can flow in multiple directions;
- (c) communities can manage local energy resources;
- (d) digital platforms can facilitate energy exchange;
- (e) renewable electricity can become a locally traded resource.

Therefore, Tanzania and Rwanda should proactively develop enabling frameworks for peer-to-peer electricity sharing rather than waiting for technological adoption to outpace regulation.

10.3 Key Findings of the Policy Paper

Finding 1: Existing Policies Support Renewable Energy but Do Not Recognise Peer-to-Peer Electricity Markets

Both countries have supportive renewable energy policies, but there are no explicit provisions recognising:

- (a) prosumers;
- (b) community energy systems;
- (c) electricity sharing;
- (d) digital energy platforms.

Policy implication: Existing frameworks require targeted modernisation.

Finding 2: Legal and Regulatory Reform Is the Most Critical Enabler

Technology alone cannot create functioning peer-to-peer electricity markets.

A supportive legal environment is required to define:

- (a) who can generate electricity;
- (b) who can trade electricity;
- (c) how transactions are regulated;
- (d) how consumers are protected.

Policy implication: Electricity legislation should be updated to recognise new energy market participants.

Finding 3: Regulatory Sandboxes Provide the Best Starting Point

Because peer-to-peer electricity sharing is a new concept, immediate full-scale regulation may be premature.

Regulatory sandboxes provide an effective mechanism to:

- (a) test technology;
- (b) evaluate consumer behaviour;
- (c) develop evidence-based regulations;
- (d) reduce investment risks.

Policy implication: Tanzania and Rwanda should establish P2P electricity regulatory sandboxes as an immediate priority.

Finding 4: Technical Standards Are Essential for Safety and Market Development

The success of SWARM Grids depends on reliable and interoperable technologies.

Standards are required for:

- (a) smart meters;
- (b) controllers;
- (c) batteries;
- (d) communication systems;
- (e) cybersecurity;

- (f) data management.

Policy implication: National standards institutions should develop appropriate technical frameworks.

Finding 5: Peer-to-Peer Electricity Sharing Creates Broad Development

Benefits

Beyond electricity access, SWARM Grids can support:

- (a) agriculture;
- (b) healthcare;
- (c) education;
- (d) water supply;
- (e) small businesses;
- (f) digital services;
- (g) clean cooking.

Policy implication: P2P electricity sharing should be integrated into national development strategies rather than treated only as an electricity-sector intervention.

10.4 Strategic Recommendations for Tanzania

Recommendation 1:

Establish a National Peer-to-Peer Energy Policy Framework

The Ministry responsible for Energy should develop guidelines recognising:

- (a) prosumers;
- (b) community energy systems;
- (c) digital electricity markets;
- (d) local energy trading.

Recommendation 2:

Amend Electricity Legislation

The Electricity Act should introduce:

- (a) definitions for prosumers;
- (b) community energy entities;
- (c) P2P electricity transactions;
- (d) digital energy platforms.

Recommendation 3:

Establish EWURA Regulatory Sandbox Programme

EWURA should develop a framework allowing controlled implementation of SWARM Grid pilots.

Recommendation 4:**Integrate SWARM Grids into Rural Electrification Planning**

REA should consider SWARM Grids as complementary solutions alongside:

- (a) grid extension;
- (b) mini-grids;
- (c) solar home systems.

Recommendation 5:**Develop National Technical Standards**

Tanzania Bureau of Standards should develop standards for:

- (a) smart energy controllers;
- (b) advanced metering;
- (c) interoperability;
- (d) cybersecurity.

Recommendation 6:**Promote Local Capacity Development**

Tanzania should establish training programmes for:

- (a) engineers;
- (b) technicians;
- (c) entrepreneurs;
- (d) regulators;
- (e) communities.

10.5 Strategic Recommendations for Rwanda

Recommendation 1: Recognise Community Energy Systems in Electricity Regulation

Rwanda should introduce legal recognition of:

- (a) energy communities;
- (b) prosumers;
- (c) local electricity markets.

Recommendation 2:**Establish RURA P2P Energy Innovation Framework**

RURA should develop mechanisms for:

- (a) pilot authorization;
- (b) monitoring;
- (c) consumer protection;
- (d) transition toward permanent regulations.

Recommendation 3:**Establish RURA Regulatory Sandbox Programme**

RURA should develop a framework allowing controlled implementation of SWARM Grid pilots.

Recommendation 4:

Integrate P2P Electricity Sharing into Electrification Strategies

Peer-to-peer systems should complement:

- (a) off-grid solutions;
- (b) mini-grids;
- (c) grid expansion programmes.

Recommendation 5:

Develop Digital Energy Governance Framework

Rwanda should establish rules for:

- (a) electricity data management;
- (b) cybersecurity;
- (c) digital transactions;
- (d) platform operators.

Recommendation 6:

Strengthen Regional Knowledge Leadership

Rwanda can become a regional demonstration centre for:

- (a) digital energy innovation;
- (b) smart community electricity systems;
- (c) renewable energy entrepreneurship.

10.6 Joint Recommendations for Tanzania and Rwanda

Both countries should collaborate on:

(a) East African Peer-to-Peer Energy Initiative

Establish a regional platform for:

- (i) knowledge exchange;
- (ii) research;
- (iii) standards harmonisation;
- (iv) investment promotion.

(b) Development of Regional Technical Standards

Promote harmonised standards for:

- (i) smart meters;
- (ii) batteries;
- (iii) controllers;
- (iv) cybersecurity.

(c) Joint Research and Innovation Programmes

Universities and research institutions should collaborate on:

- (i) smart grids;
- (ii) artificial intelligence applications;
- (iii) energy storage;
- (iv) digital energy markets.

(d) Regional Capacity Building

Develop joint training programmes for:

- (i) regulators;
- (ii) engineers;



- (iii) policymakers;
- (iv) technicians.

10.7 Recommendations for Development Partners

Development partners should support:

(a) Policy and Regulatory Reform

Through:

- (i) technical assistance;
- (ii) regulatory capacity building;
- (iii) policy research.

(b) Demonstration Projects

Through:

- (i) grants;
- (ii) blended finance;
- (iii) innovation funds.

(c) Private Sector Development

Through:

- (i) investment guarantees;
- (ii) business acceleration programmes;
- (iii) entrepreneurship support.

(d) Knowledge Sharing

Through:

- (i) regional conferences;
- (ii) publications;
- (iii) online platforms.

10.8 Recommendations for Private Sector

Private sector actors should:

- (a) invest in SWARM Grid technologies;
- (b) develop affordable business models;
- (c) establish local manufacturing capacity;
- (d) support technician training;
- (e) participate in regulatory discussions.

Technology providers should prioritise:

- (a) open standards;
- (b) interoperability;
- (c) cybersecurity;
- (d) long-term maintenance.

10.9 Recommendations for Civil Society and Industry Associations

Organisations such as renewable energy associations should:

- (a) advocate for enabling policies;
- (b) support stakeholder dialogue;

- (c) provide market information;
- (d) promote consumer awareness;
- (e) facilitate collaboration between communities and policymakers.

Industry associations can serve as bridges between:

- (a) government;
- (b) private sector;
- (c) communities;
- (d) research institutions.

10.10 Proposed High-Level Action Plan

Table 12: Proposed High Level Action Plan

Action	Responsible Institution	Priority
Establish P2P Energy Task Force	Ministries of Energy	Immediate
Launch Regulatory Sandbox	EWURA/RURA	Immediate
Implement SWARM-E Pilot Projects	Partners and Communities	Immediate
Develop Interim Guidelines	Regulators	Short term
Amend Electricity Regulations	Governments	Medium term
Develop Technical Standards	Standards Bodies	Medium term
Mobilise Green Finance	Governments and Partners	Medium term
Scale Community Energy Markets	Public and Private Sector	Long term
Harmonise Regional Frameworks	EAC Member States	Long term

10.11 Final Policy Message

Peer-to-peer solar electricity sharing represents a fundamental opportunity for Tanzania and Rwanda to move beyond traditional electrification approaches and create modern, inclusive, and resilient electricity systems.

The future electricity system will not only consist of large power plants and transmission networks. It will increasingly include:

- (a) households generating solar electricity;
- (b) communities managing local energy resources;
- (c) businesses trading renewable electricity;
- (d) digital platforms optimising energy flows;
- (e) intelligent systems supporting national grids.

By establishing appropriate policies, regulations, standards, and investment frameworks today, Tanzania and Rwanda can become leaders in Africa's transition toward decentralised renewable energy markets.

The introduction of SWARM Grids should therefore be viewed not simply as a technological innovation, but as a strategic development opportunity that supports:

- (a) energy security;
- (b) economic transformation;

- (c) climate resilience;
- (d) digital innovation;
- (e) inclusive growth.

A coordinated commitment from governments, regulators, utilities, communities, development partners, and the private sector will enable peer-to-peer electricity sharing to become a practical pathway toward a sustainable energy future.

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