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Policy Enablers for Renewable Energy Self-Consumption in Decentralised Energy Systems

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Abstract

Renewable energy self-consumption is increasingly relevant to Saudi Arabia not only as a sustainability measure under Saudi Vision 2030 but also as a mechanism that may support electricity system resilience, demand management, energy diversification, and investment. This study examines how the Saudi regulatory system converts the formal recognition of renewable energy self-consumption into operational enablement. Drawing on regulatory governance theory, the study adopts an embedded qualitative single-case design combining semi-structured interviews with 15 experts and qualitative content analysis of official Saudi regulatory and policy documents. Interview and documentary evidence were analysed thematically using NVivo 12. The analysis identifies five interconnected dimensions of regulatory enablement: legal operational clarity, institutional coordination, adaptive regulatory capacity, commercial enablement, and architecture-specific technical compatibility. The findings indicate that relevant regulation exists, but the experts perceived continuing implementation concerns relating to licensing and connection pathways, surplus electricity settlement, institutional coordination, commercial predictability, and the treatment of storage and newer distributed energy arrangements. The official framework distinguishes distribution-connected, transmission-connected, and off-grid systems and permits storage under specified conditions; however, the practical accessibility of these arrangements remains an important concern. The study contributes by distinguishing formal regulatory recognition from operational regulatory enablement and by proposing a framework connecting rule design, institutional coordination, technological adaptability, commercial viability, and system architecture. Because the evidence is qualitative and context-specific, the findings identify regulatory governance conditions requiring further technical and economic evaluation rather than establishing the relative magnitude of all barriers to adoption.



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1. Introduction

The transition to low-carbon energy systems has increased interest in decentralised electricity generation [1]. Renewable energy self-consumption is an important component of this transition. Self-consumption is defined in this study as the production of electricity

by households, firms, or public institutions from renewable energy sources and its consumption primarily at the premises where it is generated. Users may remain connected to the electricity grid and obtain additional electricity from a central supplier when on-site generation is insufficient. Renewable prosumer models require clear legal recognition, grid access, and fair rules for the electricity generated by consumers [2]. They also require clear rules specifying who may generate electricity, how systems are connected to the grid and metered, and how surplus electricity is treated.

This study approaches renewable energy self-consumption through a regulatory governance perspective. Regulatory governance concerns not only the existence of formal rules but also the allocation of authority, institutional coordination, implementation procedures, and the capacity of regulation to respond to technological and market developments [3,4]. Formal legal recognition may therefore be insufficient when procedures remain unclear, institutional responsibilities are fragmented, or implementation is difficult in practice [3].

Saudi Arabia provides an important setting in which to examine these issues. Renewable energy development is closely associated with the country's Vision 2030, economic diversification, and long-term sustainability plans [5,6]. Self-consumption is also increasingly relevant to current electricity system resilience, demand management, and energy security objectives. By allowing part of electricity demand to be met at the point of use, self-consumption may diversify supply and reduce some dependence on centralised generation. These potential benefits depend, however, on load patterns, storage, system controls, network conditions, and appropriate regulation [7,8].

Saudi Arabia has introduced formal regulatory frameworks governing small-scale solar PV systems and renewable energy generation for self-consumption [9,10]. The central problem is therefore not the complete absence of regulation. Rather, it is whether existing rules provide sufficiently clear, coordinated, adaptable, and practically accessible implementation pathways. A regulatory provision may formally exist while its scope remains ambiguous, its operational detail remains incomplete, or its implementation remains difficult for users and investors.

This regulatory issue is also evident in the overall Gulf region. Low electricity prices, fossil fuel subsidies, regulated electricity markets, and incomplete policy frameworks are obstacles to renewable energy development in the GCC states [11,12]. For residential PV adoption in Saudi Arabia, effective billing arrangements and supportive policies are necessary [13]. Previous Saudi studies have examined rooftop solar potential in Riyadh, distributed PV deployment, building-integrated photovoltaics, residential billing arrangements, and the broader green energy transition [13–18]. These studies provide valuable evidence concerning technical, economic, tariff, and policy barriers. However, they generally examine these issues separately and give less attention to how legal clarity, administrative implementation, institutional coordination, technological adaptability, and commercial viability interact within one regulatory governance system.

The commercial dimension is relevant because regulatory uncertainty may increase project development costs, delay investment decisions, and weaken the predictability of savings or revenues. The practical viability of self-consumption therefore depends not only on tariffs and direct incentives but also on predictable licensing, grid connection, metering, compensation, and institutional procedures.

This study seeks to examine the regulatory and legislative conditions in Saudi Arabia that enable or constrain renewable energy self-consumption in a decentralised energy system. Legal clarity, institutional coordination, licensing, grid connection, surplus electricity treatment, technological adaptability, commercial conditions, and policy incentives are the principal areas examined. Using a regulatory governance perspective, the study

investigates how these conditions interact in the practical implementation of renewable energy self-consumption. The following research questions guide the study:

1. How much do current regulations and laws in Saudi Arabia facilitate or obstruct the implementation of RE self-consumption systems?
2. How responsive are the existing Saudi energy policies to technological changes like smart inverters, energy storage and digital energy platforms?
3. What are the gaps in terms of institutional and legal coordination for implementing renewable energy self-consumption systems in Saudi Arabia?
4. What policy and regulatory measures could be put in place to stimulate households, industries and investors towards renewable energy self-consumption technologies?

This study contributes to renewable energy governance research by examining self-consumption in Saudi Arabia as an integrated legal and institutional problem rather than as a collection of separate technical, economic, or tariff barriers. It advances previous research by analysing how regulatory clarity, licensing, grid connection, surplus electricity treatment, institutional coordination, technological adaptability, commercial viability, and policy incentives interact in practical implementation. By comparing expert accounts with official regulatory and policy documents, the study distinguishes between formal regulatory provisions and the conditions experienced during implementation. It therefore extends the application of regulatory governance theory to renewable energy self-consumption and identifies areas in which policymakers can strengthen procedural clarity, institutional coordination, regulatory adaptability, and implementation support.

2. Literature Review

2.1. International Approaches to Self-Consumption Regulation

Self-consumption of renewable energy is not just a technical issue. From a regulatory governance perspective, it also depends on how authority is allocated, institutions coordinate, rules are implemented, and regulatory systems adapt to technological and market change [19]. In decentralised electricity systems, these governance conditions determine whether consumers can participate effectively in electricity production and consumption [3,20]. Inês et al. [21] demonstrate the need for legal recognition, grid access, and equitable treatment of electricity generated by renewable energy prosumers. Accordingly, a self-consumption regulatory framework should clarify who may generate electricity, how users connect to the electricity grid, and how electricity produced in excess of on-site demand is treated [22]. The issues of self-consumption also involve broader regulatory concerns, including network charges, consumer protection, settlement rules, and the role of energy communities [23]. Self-consumption therefore cannot be addressed through a single tariff instrument and instead requires a coherent legal, institutional, market, and operational structure. A framework may exist formally while remaining ambiguous, incomplete, or difficult to implement in practice.

There is also international evidence that the structure of self-consumption varies depending on market design and national legal traditions. Moreno et al. [2] compare the rules of Portugal, Spain, and France and demonstrate that each country treats individual and collective self-consumption differently, applies different proximity requirements, uses different methods for energy sharing and allocation, and treats surplus electricity differently. The legal distinction between electricity “sharing” and “trading” also affects ownership, contractual relationships, and the rights of participants in collective schemes [24]. Barabino et al. [25] demonstrate that regulation, business models, and technical design must be aligned for energy communities to operate effectively. Taken together, these studies indicate that financial incentives alone are insufficient. Effective self-consumption also requires predictable compensation, workable ownership and service arrangements, manageable

transaction costs, and clear grid procedures. These international approaches provide a basis for assessing whether the Saudi framework converts formal recognition into practical regulatory enablement.

2.2. Centralised and Decentralised Governance Models

Decentralisation in electricity systems involves more than a transition to smaller generation units. Dokk Smith et al. [20] distinguish political, administrative, and economic dimensions of electricity sector decentralisation. This is crucial because some countries have installed distributed energy technologies but have maintained highly concentrated decision-making, licensing, and market control. Even if policy statements are supportive, regulations designed for a centralised electricity system can inhibit decentralised energy [3]. Governance therefore shapes whether households, firms, and public institutions can participate actively as electricity producers and consumers. Technological decentralisation does not necessarily produce institutional decentralisation or broader legal rights for prosumers.

The experience of developing and emerging energy systems has demonstrated that governance arrangements influence the effectiveness of decentralised renewable energy projects. Projects in Nepal and Indonesia were constrained by top-down control, weak coordination, and limited local implementation [26]. This is important for Saudi Arabia because national renewable energy targets alone do not ensure that self-consumption is workable in practice. Implementation also requires clear user-facing rules, defined institutional roles, and coordination between central policy objectives and project-level procedures. Islam and Ali [16] similarly emphasise policy integration and cross-sectoral coordination in Saudi Arabia's transition under Vision 2030. Compared with European models that recognise collective self-consumption and energy communities, a strongly centralised model may support individual on-site installations while remaining less accommodating of energy sharing, aggregation, and other network-embedded arrangements [2,21]. The governance challenge is therefore how Saudi Arabia can enable broader prosumer participation while maintaining system coordination, safety, consumer protection, and accountability.

2.3. Regulatory Flexibility, Grid Integration, and Digitalization

Self-consumption depends on grid rules because distributed systems interface directly with the electricity network. Shi et al. [8] demonstrate the need for standards governing interconnection, protection, voltage control, and microgrid operation in distributed energy-resource integration. This is important because self-consumption can affect power flows, metering, safety, and distribution network planning. Smart inverters can support the integration of PV and battery systems, voltage regulation, and network hosting capacity [7]. However, these benefits depend on appropriate technical settings and coordination rules. Within regulatory governance theory, regulatory flexibility refers to adaptive regulatory capacity: the ability to update interconnection, metering, inverter-function, storage, and data-management requirements as technologies and operating models evolve. It must also account for differences among grid-connected, storage-supported, and off-grid systems.

Technological change can be supported through regulatory experimentation while wider legal reforms are developed. According to Aydın and Yardımcı [27], regulatory sandboxes, pilot projects, and related instruments allow regulators to test new technologies, business models, and regulatory arrangements under controlled conditions. The European Commission [28] also considers regulatory sandboxes mechanisms for regulatory learning in relation to tariffs, supplier obligations, data management, metering, and market design. Saudi Arabia has already established relevant formal rules. The 2019 small-scale solar PV framework addressed distribution system connection, bidirectional metering, certified contractors, and net-billing arrangements [9]. The 2023 self-consumption framework

covers grid-connected and off-grid systems, consumer protection, billing, safe construction, installation, operation, and storage [10], Sections 1, 8.10, and 11.3–11.4). Net billing does not apply to off-grid systems, while storage is permitted under specified capacity and operating conditions. The issue is therefore not regulatory absence, but whether the existing rules are sufficiently clear, adaptable, and consistently implementable across different system architectures.

2.4. Incentives and Implementation Mechanisms

While incentives are important, the literature indicates that they are most effective when they are credible, stable, and linked to implementation [29]. Hashemizadeh et al. [30] demonstrate that sustained government support and coherent policy design can accelerate renewable energy development. For self-consumption, however, support must extend beyond a general policy commitment. Users require predictable tariffs and compensation, accessible connection procedures, and confidence that regulatory conditions will remain sufficiently stable for investment decisions [31]. This is particularly true for Saudi Arabia, where the economic benefit of self-consumption depends strongly on tariff and billing design. Qadir et al. [32] show that residential solar outcomes vary across combinations of capital incentives, production-based support, net metering, and net billing. High solar potential alone therefore does not ensure adoption.

Saudi-focused studies reinforce the relationship between incentives and implementation. Hassan and El-Amin [13] compare residential PV billing options and show that tariff and compensation design materially affect payback outcomes. International experience similarly indicates that distributed PV growth depends on combinations of policy instruments, declining costs, and stakeholder participation rather than isolated incentives [33]. Al-Hanoot et al. [15] identify technical and economic constraints affecting distributed PV in Saudi buildings, including rooftop design, dust, high temperatures, maintenance, electricity tariffs, and regulatory conditions [14]. These studies indicate that incentives should not be considered as stand-alone financial instruments. Commercial viability also depends on predictable compensation, ownership and service arrangements, development and connection costs, risk allocation, and the expected recovery of investment [25,31]. The Saudi framework permits contractor ownership and operation under a service agreement, subject to licensing and the same-premises requirement, and assigns preliminary assessments of costs, revenues, savings, and expected returns to the eligible consumer ([10], Clause 5.2 and Annex 3, Section 2.2). In the Saudi context, incentives need to be linked to grid access, billing and compensation rules, installation procedures, commercially workable arrangements, and long-term regulatory certainty.

2.5. Synthesis and Research Gap

The literature indicates that five interrelated conditions shape renewable energy self-consumption. Firstly, there should be clarity and stability regarding legal eligibility, grid access, metering, and the treatment and settlement of surplus electricity [21]. Second, Dokk Smith et al. [20] demonstrate that decentralised energy requires governance structures that define institutional responsibilities and enable meaningful participation by local users, rather than merely introducing distributed technologies within centralised systems. Third, regulatory flexibility is essential for modern self-consumption, as new technologies such as smart inverters, batteries, meters, and digital platforms require adaptable technical and market regulations [8]. Fourth, commercially workable tariffs, compensation arrangements, and investment conditions are necessary for adoption [13,32]. Fifth, regulatory requirements must reflect the different operational characteristics of grid-connected, storage-supported, and off-grid systems [10]. These conditions are directly relevant to

Saudi Arabia because they connect renewable energy policy with electricity regulation, building technology, institutional coordination, and practical implementation.

A number of Saudi studies have been conducted that have contributed to understanding these issues; however, they do not fully integrate the legal, institutional, commercial, and governance dimensions examined in this study. The billing policy of residential PV systems is examined by Hassan and El-Amin [13]. The status, challenges, and prospects of distributed PV systems in buildings in Saudi Arabia have also been analysed [15]. Al-Sharafi et al. [34] evaluate lessons from rooftop photovoltaic policies in Saudi Arabia. Islam and Ali [16] explore the broader approach to the green energy transition in Saudi Arabia. The studies offer valuable insights into technology, economics, tariff design, policy development, and national transition planning. However, they generally examine these dimensions separately and do not sufficiently explain how legal clarity, administrative implementation, institutional coordination, technological adaptability, commercial viability, and system architecture interact within a single regulatory governance framework. This work explores the issue by looking at the role of regulatory design, institutional coordination, licensing, grid connection, the treatment of surplus electricity, technological adaptability, commercial conditions, and policy incentives in facilitating or hindering renewable energy self-consumption in Saudi Arabia's decentralised energy system. It also compares formal regulatory provisions with expert accounts of implementation to distinguish formal regulatory recognition from operational regulatory enablement.

From a theoretical perspective, the central question is therefore not whether regulation is present, but how different regulatory governance conditions combine to make formal rules practically usable. Existing studies identify legal clarity, institutional coordination, regulatory adaptability, commercial incentives, and technical compatibility as important factors, but these factors are frequently treated as separate barriers or policy requirements. This study examines whether they operate instead as interdependent dimensions of operational regulatory enablement. It proposes that formal regulatory recognition becomes effective only when rules are translated into clear procedures, coordinated institutional responsibilities, adaptable regulatory processes, commercially predictable arrangements, and requirements suited to different technical architectures. The Saudi case is used to refine regulatory governance theory by explaining the mechanisms through which formal rules may exist while implementation remains constrained.

3. Methodology

3.1. Research Design and Justification

This study examines the regulatory and legislative dimensions of renewable energy self-consumption in Saudi Arabia through a qualitative, theory-informed single-case study design. The bounded case is the Saudi regulatory and institutional framework governing renewable energy self-consumption, and the unit of analysis is how that framework is designed, interpreted, and implemented. The legal, policy, licensing, grid-integration, and institutional perspectives examined are embedded within the same national case rather than treated as separate cases. This design is appropriate because the research focuses on legal rules, policy arrangements, institutional coordination, and implementation barriers, all of which require attention to how regulation is interpreted, applied, and experienced in practice. Renewable energy self-consumption is therefore not only a technical and economic issue but also a question of governance. A qualitative case study approach is well suited to analysing these legal and institutional arrangements [35,36].

The study retains a descriptive-analytical orientation within the single-case design. It describes the current regulatory framework and analyses its strengths, limitations, and implications for renewable energy self-consumption. This orientation supports a contextual

assessment of how formal rules operate in practice and how institutional arrangements respond to policy and technological change [4]. Regulatory governance theory guides interpretation, while interviews and documentary materials provide complementary evidence concerning the same national case. This permits comparison of formal provisions with practitioner accounts of their operation across administrative, legal, and technical settings.

3.2. Participant Selection and Sample

Participants were recruited first through purposive sampling and subsequently through snowball sampling. Purposive sampling was used to recruit experts with direct experience in the regulation, development, implementation, or coordination of renewable energy in Saudi Arabia [37]. Eligibility was based on relevant professional experience in energy law, policy, regulation, grid integration, licensing, or energy-sector governance. Snowball sampling was then used to identify additional specialists through professional referrals in these specialised fields [38]. This strategy sought analytically relevant and varied professional perspectives rather than statistical representativeness.

The final sample comprised 15 experts. Their different fields were included to capture perspectives on legal interpretation, policy development, institutional coordination, licensing, grid integration, and practical implementation. Sample adequacy was assessed through information power, considering the focused aim, the specificity and diversity of participant expertise, the theoretical framework, and the depth required for the analysis [39]. The sample was therefore intended to provide depth across the principal regulatory fields rather than numerical representation of all stakeholder groups. Table 1 summarises participants' institutional backgrounds, professional roles, areas of expertise, years of relevant experience, and involvement in renewable energy self-consumption.

Table 1. Participants with expert knowledge in their area of specialisation.

No.	Code	Area of Expertise	Description	Institutional Background and Professional Role	Relevant Experience and Involvement in Renewable Energy Self-Consumption
1	LR1	Energy Law	Specialist in legislation governing the energy sector and related utilities.	Legal specialist working at an entity associated with the energy sector, providing legal analysis and advice on electricity and renewable energy regulation.	Examining and reviewing the legal requirements governing the production of renewable energy for self-consumption.
2	LE2	Environmental Law	Expert in legal frameworks for sustainability and environmental licensing.	Specialist in environmental law.	Examining the environmental requirements and regulatory frameworks required for renewable energy systems.
3	LM3	Energy Market Regulation	Focuses on regulating producer–consumer relationships and grid integration.	Regulatory specialist working in the energy market.	Experience in pricing and consumption policies.
4	LI4	Administrative Law for Infrastructure	Specialist in the regulation of infrastructure projects and energy tenders.	Administrative law specialist focusing on infrastructure projects, administrative procedures, and procurement related to the energy sector.	Experience in infrastructure requirements, procedural matters, and coordination concerning renewable energy projects.
5	LP5	Legislative Policy in the Energy Sector	Expert in linking legislation with policymaking in the energy sector.	Specialist in legislative policy and in the analysis and development of policies governing the energy sector in Saudi Arabia.	Experience in proposing and reviewing policies related to renewable energy production, defining regulatory responsibilities, and implementing self-consumption rules.

Table 1. Cont.

No.	Code	Area of Expertise	Description	Institutional Background and Professional Role	Relevant Experience and Involvement in Renewable Energy Self-Consumption
6	SP1	Sustainability Policies	Focuses on aligning policies with sustainable development goals.	Engaged in the study of sustainability policies and strategic planning at a research institution.	Proposing and reviewing energy policies and renewable energy initiatives in line with sustainability priorities, energy-efficiency objectives, and national development goals.
7	ST2	Energy Transition Policies	Studies transitional frameworks for the shift to renewable energy.	Energy transition policy specialist working in policy development, research, or strategic planning.	Examining the transition to renewable energy self-consumption, including storage and development.
8	SE3	Innovation Enablement Policies	Examines policy instruments that support innovation adoption.	Innovation policy specialist involved in supporting the adoption of energy and digital technologies.	Experience in assessing policies that support energy innovation, storage, and digital monitoring systems related to renewable energy consumption.
9	SI4	Administrative Regulation and Institutional Integration	Studies institutional coordination among relevant organisations and agencies.	Administrative regulation specialist involved in institutional coordination and the implementation of government policies.	Experience in coordination and organizational structuring across administrative bodies, including energy authorities, regulatory bodies, energy service providers, municipalities, and entities involved in approving renewable energy projects.
10	SM5	Centralisation and Decentralisation in Administration	Specialist in institutional role and authority distribution.	Specialist in public administration and institutional governance.	Experience in examining the distribution of responsibilities among national authorities, regulatory bodies, service providers, and local administrative bodies in approving and overseeing self-consumption systems.
11	SX6	Implementation Policies	Involved in policy formulation and implementation in the energy sector.	Energy policy implementation specialist working at a government entity associated with the energy sector.	Experience with policy proposals involving the translation of renewable energy policies into implementation procedures, stakeholder coordination, and the monitoring of implementation challenges.
12	TG1	Grid Integration Regulation	Specialist in energy distribution within public grids, billing, interconnection, pricing policies, and accounting principles.	Technical and regulatory specialist working in electricity distribution, grid connection, metering, billing, or pricing.	Experience in technical connection studies, bidirectional metering, billing arrangements, and grid-capacity assessment, with a background in connecting renewable energy systems to distribution networks.
13	TF2	Regulatory Flexibility	Expert in assessing the adaptability of regulatory frameworks to innovation.	Regulatory assessment specialist working in policy evaluation, regulatory development, or energy-sector research.	Experience in assessing the capacity of existing regulatory systems to respond to technological developments.
14	TL3	Licensing and Permit Regulation	Works in procedures related to system licensing and permitting.	Licensing and permits specialist working at an electricity sector regulatory body, specifically within a licensing department.	Experience in processing licences, technical approvals, and permits.
15	TC4	Institutional Regulatory Coordination	Specialist in coordination among relevant regulatory authorities.	Specialist in institutional coordination.	Experience in coordinating regulatory approvals, clarifying overlapping jurisdictions, and addressing delays or inconsistencies in licensing procedures.

3.3. Data Collection

Data were collected through semi-structured interviews with experts. This method was suitable because it enabled the researcher to examine participants' perceptions of regulation, policy, practice, institutional coordination, and the challenges of renewable energy self-consumption in Saudi Arabia. To ensure consistency across interviews, a common interview guide was used, while follow-up questions allowed participants' meanings to be clarified [35]. The guide focused on three areas: the current regulatory framework, barriers to the adoption of sustainable technologies, and areas for policy improvement.

Interviews were either face-to-face or conducted via a secure online communication system, depending on participants' availability. The interviews lasted approximately 10–30 min. Participation was voluntary, and informed consent was obtained before each interview. Participants preferred written documentation rather than audio recording. Responses were documented during the interviews under the corresponding questions in the guide, and follow-up questions clarified unclear points. The resulting written interview transcripts were anonymised and imported into NVivo 12 for analysis. These procedures supported the completeness and accuracy of the written records while preserving confidentiality. Data collection ended when later interviews no longer generated substantively new issues.

3.4. Documentary Sources and Selection

Written evidence directly pertaining to renewable energy self-consumption in Saudi Arabia was obtained from documentary sources. The review was targeted rather than systematic, and sources were classified by evidential function. The documentary corpus comprised official Saudi regulatory instruments governing small-scale solar photovoltaic systems and renewable energy self-consumption [9,10]. These instruments were selected because of their issuing authority, direct relevance, and specification of rules and procedures. They were treated as primary evidence of the regulatory framework. No separate official policy document was included in the documentary corpus; policy context was identified through academic literature criteria were used to select peer-reviewed journal articles. First, each included article had to have been peer-reviewed and published from 2010 onwards. Second, it had to address regulation, governance, policy incentives, implementation barriers, or distributed renewable energy adoption. Third, it had to focus on Saudi Arabia or the Gulf region, or provide an international comparison concerning self-consumption. The selected studies addressed collective prosumer regulation in Europe [21], renewable energy barriers in the Gulf [11,40], Saudi rooftop solar policy and incentives [11,13,17], Saudi green energy transition policy [16], and distributed photovoltaic deployment in Saudi buildings [15]. Academic studies were treated as contextual and comparative evidence. This distinction enabled formal provisions to be compared with expert accounts while keeping regulatory and academic evidence separate.

3.5. Analytical Procedure

Thematic analysis was used to analyse the written interview transcripts because it supported the identification, organisation, and interpretation of recurring patterns in relation to the research questions [41]. The anonymised transcripts were imported into NVivo 12, organised, and read repeatedly for familiarisation. Initial codes identified recurring issues, including regulatory clarity, licensing, grid connection, treatment of surplus electricity, policy incentives, technological adaptation, and institutional coordination. The research questions and regulatory governance lens guided interpretation while allowing issues to emerge.

After initial coding, related codes were grouped into higher-level analytical categories. Candidate themes were reviewed, defined, and refined against the coded material and research questions. Table 2 presents the coding pathway from example coded issues to initial codes, analytical categories, and final themes. The themes were distinguished by primary focus: legal operational clarity concerned the clarity and operability of current rules; adaptive regulatory capacity concerned responsiveness to technological and market change; commercial enablement concerned commercial and implementation support; institutional coordination concerned legal coherence and institutional mandates; and architecture-specific technical compatibility concerned the regulatory treatment of technologies, grid interfaces, and system architectures. Issues crossing categories were assigned according to their principal focus while their relationships with other themes were retained.

Table 2. Provides an overview of the code, category, and theme development of the data collected in interviews and documentaries.

Data Source	Example Coded Issue	Initial Code	Category	Final Theme
Interview data	Unclear rules for small-scale renewable generation	Regulatory ambiguity	Legal clarity	Legal operational clarity
Interview data	Difficult or unclear permit pathways	Licensing barriers	Administrative procedures	Legal operational clarity
Interview data	No fair treatment for excess electricity	Surplus compensation gap	Market and billing rules	Legal operational clarity
Document data	Limited operational detail in self-consumption frameworks	Incomplete operational framework	Regulatory design	Institutional coordination
Interview data	Policies do not keep pace with storage and smart systems	Low regulatory adaptability	Regulatory flexibility	Institutional coordination
Document data	Existing frameworks remain oriented towards conventional models	Traditional regulatory model	Innovation responsiveness	Institutional coordination
Interview data	Need for net metering, tax support, and simpler procedures	Incentive deficiency	Adoption support mechanisms	Adaptive regulatory capacity
Document data	Limited direct support for small-scale users	Limited implementation tools	Economic and legal support	Adaptive regulatory capacity
Interview data	Overlapping roles across ministries and regulators	Overlapping mandates	Institutional fragmentation	Commercial enablement
Interview data	No clearly designated lead body for implementation	Institutional uncertainty	Governance structure	Commercial enablement
Document data	Policy functions dispersed across multiple bodies	Fragmented policy structure	Institutional coordination	Commercial enablement
Interview data	Hybrid and off-grid uptake constrained by storage cost and grid rules	Technical-regulatory constraint	System viability conditions	Architecture-specific technical compatibility
Document data	Interconnection and billing rules shape operational feasibility	Grid dependence	Operational viability	Architecture-specific technical compatibility

Interview transcripts were analysed thematically, while official regulatory instruments and selected academic studies were examined through directed content analysis [42]. Interview-derived codes provided the starting framework for examining documentary sources. Official instruments directly identified formal provisions, whereas academic studies provided contextual and comparative interpretation. Documentary evidence was used to confirm, contextualise, or contrast expert accounts without treating the source categories as equivalent. The final thematic structure resulted from an iterative process of coding, comparison, review, and refinement.

The analysis was informed by regulatory governance theory and used the interview data to examine how its concepts are reflected in the Saudi context. Comparing the

interview findings with documentary evidence helped refine the interpretation of the results and highlighted the distinction between formal regulatory recognition and operational regulatory enablement.

4. Data Analysis and Findings

Analysis of the interview data and documentary data produced five themes: legal operational clarity, institutional coordination, adaptive regulatory capacity, commercial enablement and architecture-specific technical compatibility. Both datasets were used in an iterative process of coding, comparison and refinement of these themes. Interviews were used to obtain expert opinions of the regulatory environment as it is experienced, and documentary evidence was gathered as formal and published evidence of the regulatory environment, its design, policy development, and implementation conditions. The codes and categories have been condensed to themes as summarised in Table 2.

4.1. Legal Operational Clarity

The first theme examines whether the existing regulatory framework provides the operational conditions necessary for renewable energy self-consumption in Saudi Arabia. From the interview data, participants acknowledged that formal regulatory provisions exist but described continuing difficulties at the point of use. The main issues cited were unclear licensing pathways, insufficient procedural guidance for small-scale users, uncertainty regarding compensation for surplus electricity, and difficulty navigating grid-connection requirements. As one participant explained, “The rules remain unclear, particularly the licensing pathway and the arrangements for compensating surplus electricity.” These findings indicate an operational readiness problem arising from regulatory ambiguity and implementation difficulty rather than from a complete regulatory absence. The theme therefore concerns whether formally recognised rules can be translated into clear, predictable, and usable procedures for households, firms, and public institutions. This distinction captures the gap between formal regulatory recognition and operational regulatory enablement that guides the study’s analysis.

Official regulatory instruments confirm that self-consumption is formally recognised. The Small-Scale Solar PV Regulatory Framework establishes connection and net-billing arrangements for solar PV systems within its scope [9]. The later framework applies to specified grid-connected and off-grid renewable energy systems and defines its permitted use cases ([10], Clauses 3.1–3.5 and Annex 4). It requires study authorisation and licensing and directs service providers to establish publicly available connection processes defining responsibilities, required documents, timelines, technical criteria, and agreements ([10], Clauses 4.4–4.5 and 6.1–6.4). It also contains metering and net-billing rules, including the treatment of spill energy exported to the grid ([10], Clauses 7.1–7.5 and 8.1–8.10). These provisions demonstrate regulatory presence; the interview evidence concerns clarity and implementation in practice. Academic studies similarly identify tariff, regulatory, and economic constraints affecting rooftop and distributed PV deployment [15,17]. The evidence indicates partial regulatory readiness: formal recognition and procedures exist, but participants considered their application insufficiently clear and predictable for wider use.

Theoretically, this finding refines the conventional understanding of regulatory clarity. Clarity cannot be assessed solely by determining whether a rule, licence, or connection procedure formally exists. Inês et al. [21] emphasise the importance of legal recognition and grid access, while Woodman and Baker [3] show that regulatory frameworks designed around centralised systems may constrain decentralised participation. The interview evidence extends these arguments by indicating that regulatory clarity has an operational dimension: users must be able to identify the applicable pathway, responsible institution,

and required sequence of actions. Legal recognition without this procedural usability produces formal inclusion but incomplete practical enablement.

4.2. Adaptive Regulatory Capacity

The second theme concerns adaptive regulatory capacity concerns. Participants indicated that regulation remains oriented towards traditional electricity governance rather than emerging decentralised technologies. They identified limited responsiveness to storage, smart inverters, digital monitoring, and distributed energy management. An edited representative quotation captures this assessment: “Existing policies are not sufficiently responsive to energy storage and emerging smart energy systems” (TF2; SE3). This finding was coded as low regulatory adaptability and concerns policy-updating capacity rather than the architecture-specific requirements examined. This is evident in Table 3. The arrangements in place were perceived as conventional, with weak adaptation and not linked to innovation processes by participants from policy, legal, and regulatory domains.

Table 3. Expert judgment of the adoption and flexibility of regulatory policy.

Regulatory Policy Element	Regulatory Objective	Current Level of Realisation	Experts
Core objective	Promote decentralisation and improve energy security and sustainability through self-consumption energy production	Reflected in Vision 2030, but without a fully operational regulatory framework for self-consumption	LP5, SP1, SM5
Target groups	Support individuals and institutions generating renewable energy for self-consumption	No comprehensive regulatory coverage for intended user groups	LP5, SI4, SX6
Regulatory flexibility	Enable rapid adaptation to technological innovation	Current policies remain conventional and inflexible	TF2, SE3
Adaptability to innovation	Align policies with technological developments in energy systems	Weak institutional linkage between regulation and innovation	SE3, TF2, LP5
Supportive regulatory frameworks	Establish clear policies governing technical enablement of self-consumption	No fully developed and operational policy framework is in place	LP5, SI4, SX6
Infrastructure readiness	Ensure infrastructure can support independent and distributed energy production	Existing support remains limited and insufficiently defined	LI4, SP1
Policy development	Base policy development on evidence and specialised expertise	Implementation remains limited and weakly institutionalised	SE3, SX6, LP5
Adopted regulatory model	Use adaptive models rather than rigid traditional approaches	Policy practice remains largely based on traditional regulatory models	TF2, SE3, ST2

This is corroborated by the documentary evidence. Furthermore, Saudi policy studies revealed that there is still a need to further align rooftop PV policies with good international practices, particularly when it comes to user-facing policies and incentives [34]. A more comprehensive analysis of the transition reveals the need for more policy coherence and institutional responsiveness in Saudi Arabia’s green energy transition [16]. The evidence suggests there is, therefore, still not a high degree of policy flexibility, and the regulatory environment is not yet as adaptive as the innovations it supports.

This finding extends previous research by showing that adaptive regulatory capacity involves not only updating regulations but also ensuring that regulatory frameworks can respond effectively to emerging technologies. Shi et al. [8] highlight the need for evolving technical standards, while Aydın and Yardımcı [27] emphasise the role of regulatory experimentation in supporting innovation. The interview findings suggest that adaptability also depends on how regulatory institutions translate technological change into practical implementation.

4.3. Commercial Enablement

The third theme concerns commercial enablement. Participants did not describe a complete absence of support; rather, they considered existing incentives fragmented and insufficiently predictable for households, institutions, and investors. Their concerns centred on compensation for surplus electricity, administrative assistance, and clear implementation pathways for smaller users. As one participant stated, “Clearer incentives, fairer compensation arrangements, and simpler administrative procedures are needed to encourage adoption.” This theme concerns the commercial and administrative conditions influencing adoption, rather than the general operability of rules examined in Theme 1.

The official framework establishes mandatory net billing, records exported spill energy as a financial balance, permits that balance to be carried forward, and provides for payment of accrued credit when a connection agreement ends ([10], Clauses 8.1–8.7). However, Annex 2 lists the spill energy tariff as “to be determined by SERA,” while Annex 3 assigns preliminary cost, savings, and return-on-investment assessments to the eligible consumer ([10], Annex 2, Section 2; Annex 3, Section 2.2). These provisions demonstrate formal support mechanisms but also help explain participants’ concerns about predictability. Academic studies similarly show that tariff and compensation design affect residential PV economics and rooftop solar attractiveness [13,17]. Overall, support mechanisms exist, but participants considered their commercial and administrative operation insufficiently clear and attractive for smaller users.

This finding extends previous research by showing that commercial enablement depends on both appropriate financial arrangements and clear implementation conditions. Recent studies indicate that tariff design, remuneration of surplus electricity, policy constraints, and grid connection limits influence the economic viability and practical deployment of rooftop PV systems [43,44]. The interview findings similarly suggest that unclear compensation and administrative procedures may reduce investment predictability even where formal support mechanisms exist.

4.4. Institutional Coordination

The fourth theme concerns the institutional coordination’s ability to evolve in line with the evolving needs of renewable energy self-consumption. Participants identified overlapping institutional mandates, uncertainty regarding implementation responsibility, and weak coordination across regulation, licensing, connection, and administration. As one participant explained, “Institutional responsibilities overlap, and it is not always clear which authority is responsible for implementation.” This theme concerns legal coherence and institutional coordination, rather than the user-facing procedural clarity examined in Theme 4.1 or the policy-updating capacity examined in Theme 2.

The official framework assigns formal responsibilities. SERA is the final reference for interpreting the framework and issues required authorisations and licences, while service providers receive and assess grid connection applications and must establish processes defining roles, documents, timelines, technical criteria, and agreements ([10], Clauses 4.1 and 6.1–6.4). The documents therefore do not support a claim that no authority is designated. Instead, the interviews indicate perceived coordination and implementation difficulties across assigned responsibilities. Academic studies provide broader context by identifying continuing needs for policy integration in Saudi Arabia and the GCC [11,16]. The legislative adaptation gap is therefore structural: it concerns whether legal mandates and institutional relationships operate coherently as self-consumption evolves, rather than a complete absence of governing rules.

This finding shows that institutional coordination depends not only on formally defined responsibilities but also on effective cooperation among the institutions involved [45].

Recent research similarly emphasises the need for coordination across institutions and sectors in decentralised energy systems [46,47]. The interview findings indicate that separate mandates may still produce a fragmented implementation pathway.

4.5. Architecture-Specific Technical Compatibility

The final theme concerns the architecture-specific technical compatibility. Participants identified storage costs, maintenance requirements, grid dependence, and infrastructure needs, but linked these factors to requirements governing interconnection, metering, billing, system approval, and operation. As one participant stated, “High storage costs and unclear grid rules continue to constrain the implementation of hybrid and off-grid systems.” This theme examines the interface between technical configurations and architecture-specific regulation.

The official framework distinguishes relevant system models. Off-grid systems are recognised as an allowed use case and must use feeding voltages consistent with the Grid Code and Distribution Code ([10], Clause 11.3 and Annex 4). Storage-supported systems are permitted where storage is combined with renewable generation, remains within the connected capacity limit, serves on-premises self-consumption, and, for grid-connected systems, is supported by documentation specified by the service provider ([10], Clauses 11.4.1–11.4.2). Grid-connected systems with bidirectional exchange are subject to metering and net-billing requirements, while connection requires application review, technical assessment, inspection, and operational notification ([10], Clauses 7.1–7.5, 8.1–8.10, and Annex 3). Academic evidence likewise identifies interacting technical, economic, and regulatory challenges for distributed PV in Saudi buildings [15]. The findings suggest that technical feasibility depends partly on clear rules tailored to off-grid, storage-supported, and grid-connected configurations; they do not imply that regulation alone determines viability.

Across the five themes, the evidence suggests that regulatory and institutional conditions are important constraints on the practical expansion of renewable energy self-consumption in Saudi Arabia. The findings do not establish that these constraints are more important than all technical or economic factors. Rather, they show how operational clarity, policy flexibility, commercial support, institutional coordination, and architecture-specific technical rules interact in implementation.

This finding shows that technical and regulatory requirements vary across system architectures. Recent studies similarly indicate that grid-connected, storage-based, and other distributed energy configurations require different integration and operational arrangements [48,49]. The interview findings confirm that regulation should reflect these technical differences.

5. Discussion

The findings suggest that regulatory and institutional conditions are important constraints on self-consumption of renewable energy in Saudi Arabia, but the qualitative design does not establish that they are the single greatest barrier or that technical and economic factors are secondary. This directly helps to address RQ1. Islam and Ali [16] indicate that the green transition in Saudi Arabia has become an integral part of Vision 2030 and the country’s sustainability initiatives. The present results indicate, however, that this strategic move has not yet been translated consistently into clear user-facing arrangements for licensing, grid access, surplus electricity treatment, and implementation. The central issue is therefore not regulatory absence, but the gap between formal regulatory recognition and operational regulatory enablement. A framework may acknowledge self-consumption while remaining difficult to use predictably in practice.

The results also answer RQ2. Participants perceived existing policy processes as insufficiently responsive to storage systems, smart inverters, digital monitoring, and distributed energy management. This indicates limited adaptive regulatory capacity rather than simply a temporary delay in rulemaking. Inês et al. [21] demonstrate that self-consumption frameworks are more effective if regulation allows for evolving prosumer roles and participation arrangements, while Al-Sharafi et al. [34] identify the need to align Saudi rooftop PV policy more closely with relevant international practice. Compared with European approaches that increasingly recognise collective and network-embedded prosumers, the Saudi framework remains centred mainly on individual users within a centrally governed electricity system. Centralised governance is not inherently incompatible with self-consumption, but it requires mechanisms for updating rules, testing emerging arrangements, and coordinating decentralised participation. This supports Dokk Smith et al.'s [20] distinction between technological decentralisation and political or administrative decentralisation.

With respect to RQ3, the results indicate that coordination difficulties extend beyond isolated implementation problems. Participants identified uncertainty across regulation, licensing, connection, and administration. This should not be interpreted as evidence that no formal responsibilities exist. Rather, the governance problem is whether assigned responsibilities produce coherent and predictable procedural hand-offs for users. Amongst the similar evidence from the GCC, there are policy gaps and limited market conditions which limit the development of renewable energy in the region [11]. The current study refines this argument by showing how institutional fragmentation affects self-consumption at the implementation level. The issue is not the number of institutions, but whether their mandates, information flows, and procedures form a clear implementation pathway.

The findings also respond to RQ4 by demonstrating that current incentives are not sufficiently predictable or commercially attractive for all categories of users. The viability of residential PV in Saudi Arabia is sensitive to billing design [13], and current PV tariff conditions influence the attractiveness of rooftop PV systems [17]. Qadir et al. [32,50] likewise show that adoption outcomes vary across net-metering, net-billing, and other support scenarios. The present study adds that commercial enablement also depends on transparent compensation, administrative simplicity, ownership or service arrangements, implementation assistance, and confidence in how rules will be applied. Support mechanisms therefore exist, but participants did not consistently regard them as sufficiently clear, coordinated, or attractive for households and smaller organisations.

5.1. Implications for Distributed System Design

Finally, the study sheds light on the relationship between technical and regulatory conditions. Off-grid systems require clear safety, inspection, licensing, and operational standards. Storage-supported systems additionally require rules for battery approval, charging and discharge, control, and metering. Grid-connected systems with bidirectional exchange require predictable interconnection, metering, billing, compensation, and settlement procedures. Al-Hanoot et al. [15] demonstrate that distributed PV deployment in Saudi Arabia is influenced by technical, economic, and regulatory challenges. The implication is not that regulation determines technical feasibility by itself, but that technical and regulatory design must be aligned.

The policy implications are correspondingly specific. The electricity regulator should consolidate user-facing requirements and establish a regular process for updating technical and market rules. Electricity service providers should publish standardised application documents, responsibilities, timelines, technical criteria, and connection agreements. Licensing and permitting authorities should coordinate these requirements through a single, transparent procedural pathway, while billing and compensation arrangements should be

reviewed to improve commercial predictability. Together, these measures address legal operational clarity, institutional coordination, adaptive capacity, commercial enablement, and architecture-specific compatibility.

The study develops an integrated regulatory governance framework in which the five themes are interdependent: unclear procedures weaken incentives, fragmented responsibilities delay implementation, limited adaptability constrains emerging technologies, and architecture-specific uncertainty affects commercial viability. Because the study does not include engineering optimisation or economic modelling, it identifies governance and system design conditions rather than quantifying technical performance, costs, or adoption effects.

5.2. Theoretical Contribution: From Regulatory Recognition to Operational Regulatory Enablement

The theoretical contribution of this study lies in distinguishing formal regulatory recognition from operational regulatory enablement. Existing research shows that decentralised energy participation depends on regulatory design, institutional capacity, and the practical conditions under which new energy arrangements are implemented [19,46,51]. The Saudi case adds that these elements matter mainly through their combined ability to make self-consumption accessible in practice.

Formal recognition exists when regulation acknowledges self-consumption and sets general rules for licensing, connection, metering, billing, and storage. Operational enablement exists when users can apply these rules through procedures that are clear, coordinated, adaptable, commercially predictable, and suited to the relevant system architecture. This distinction explains why a developed regulatory framework may still produce uncertainty during implementation.

The findings identify five connected dimensions of operational regulatory enablement: legal operational clarity, institutional coordination, adaptive regulatory capacity, commercial enablement, and architecture-specific technical compatibility. Their effect depends on their alignment. Clear rules may achieve little when responsibilities are fragmented, while financial support may remain ineffective when connection costs, approval periods, or surplus compensation are uncertain. Recent studies similarly show that regulatory choices influence participation, system design, economic outcomes, and the operation of different self-consumption arrangements [52,53].

The framework may help explain why jurisdictions with similar formal rules experience different implementation outcomes. It does not propose a universally validated model but offers a theory-elaborating explanation derived from the Saudi case. Its wider relevance should therefore be examined through comparative research in other electricity systems and self-consumption arrangements.

6. Conclusions

6.1. Conclusion and Contribution

This study examined the regulatory and legislative conditions shaping renewable energy self-consumption in Saudi Arabia. The results suggest that regulatory and institutional conditions are important constraints on implementation, but the qualitative design does not establish that they are the single greatest barrier. Formal recognition has advanced; however, participants identified continuing ambiguity and implementation difficulties concerning licensing, grid connection, surplus electricity treatment, institutional coordination, and regulatory responsiveness to technological change.

The study's principal theoretical contribution is the concept of operational regulatory enablement. The findings distinguish between the formal recognition of renewable energy self-consumption and the governance conditions required to make that recognition usable in practice. Operational regulatory enablement arises through the interaction of legal

operational clarity, institutional coordination, adaptive regulatory capacity, commercial enablement, and architecture-specific technical compatibility. The study therefore extends regulatory governance theory by showing that the effectiveness of regulation depends not only on the existence of rules or the formal assignment of responsibilities, but on the alignment of procedural, institutional, adaptive, commercial, and technical–regulatory conditions. This framework is derived from the Saudi case and requires further comparative, technical, and quantitative examination before broader causal claims can be made.

6.2. Policy Implications

Saudi Arabia would benefit from a more coherent, adaptive, and implementation-focused regulatory approach to renewable energy self-consumption. The electricity regulator should consolidate user-facing requirements and establish a regular process for updating technical and market rules. Electricity service providers should publish standardised application and connection procedures, required documents, responsibilities, timelines, technical criteria, and connection agreements.

Licensing and permitting authorities should coordinate these requirements through a clear and transparent procedural pathway. Billing, compensation, and settlement arrangements should also be reviewed to improve commercial predictability, while practical implementation support should be provided for different user groups. Together, these measures would strengthen legal operational clarity, institutional coordination, adaptive regulatory capacity, commercial enablement, and architecture-specific technical compatibility. They would also help translate national ambition into an operational framework that is clearer in application, more responsive to technological change, and more predictable for prospective users.

6.3. Limitations and Future Research

This study has several limitations. First, it employed a qualitative approach based on interviews with 15 experts and documentary analysis. This approach provided detailed insights into regulatory and institutional conditions but was not intended to produce statistically representative findings. The results should therefore be interpreted within the context of the Saudi regulatory system and the expert sample examined.

Second, the study focused on Saudi Arabia at a particular stage in the development of its renewable energy regulatory framework. The policy and institutional landscape continues to evolve, and some findings may change as new regulations, procedures, or institutional arrangements are introduced. This also limits the direct transferability of the findings to other jurisdictions.

Third, the study did not include operational evidence such as grid performance records, voltage management data, or measured distributed generation impacts. The technical findings are therefore based on expert accounts and documentary evidence rather than engineering analysis. The study also did not undertake economic modelling of alternative compensation mechanisms, including net metering, net billing, or production-based incentives. Consequently, it identifies governance and system design conditions but does not quantify technical performance, costs, financial viability, or adoption effects.

Finally, the study did not examine consumer behaviour, willingness to pay, or household adoption preferences. Regulatory reform may not produce adoption without user acceptance and commercially attractive conditions. Future research should therefore combine legal and policy analysis with technical modelling, economic assessment, operational data, and end-user studies.

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