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International Energy Agency
Photovoltaic Power Systems Programme

Task 18 Off-Grid and Edge-of-Grid Photovoltaic Systems

PVPS

Success Factors for Renewable Island Mini-Grids

2026

Report IEA-PVPS T18-06:2026

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The objective of Task 18 is to identify the innovations that drive PV off-grid technology and impact the market. The scope covers the whole supply- and value chain including planning, financing, design, construction, operations, and maintenance of off-grid and edge-of-grid systems. The most important areas of innovation are addressed, including the technology change coming from lithium-ion battery systems, LED lighting, price reduction of solar modules and the whole area of digitalisation. The Task focuses especially on challenges that are common across nations, markets, and system scales. It aims to provide solutions, tools, guidelines, and technical reports for free dissemination to those who might benefit from them.

SUGGESTED CITATION

Blechinger, P., Hecker, H., Linke, A. (2026). Müller, M. (Ed.), *Success Factors for Renewable Island Mini-Grids* (Report No. T18-06:2026). IEA PVPS Task 18. DOI: 10.69766/AIHW9830

INTERNATIONAL ENERGY AGENCY
PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Success Factors for Renewable Island Mini-Grids

IEA PVPS
Task 18
Off-Grid and Edge-of-Grid Photovoltaic Systems

Report IEA-PVPS T18-06:2026
September 2026

ISBN 978-1-923734-14-2
DOI 10.69766/AIHW9830

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ACKNOWLEDGEMENTS

This paper received valuable contributions from several IEA-PVPS Task 18 members and other international experts during workshops and feedback sessions.

We also thank the members of the ExCo for their review and suggestions for improvement of the report, namely Flemming Vejby Kristensen, Klaus Prume, Yves Poissant, and Otto Bernsen.

LIST OF ABBREVIATIONS

AC	Alternating current
DC	Direct current
FC	Fred Cuvalay
GHG	Greenhouse gas
IEA	International Energy Agency
JJ	Jesper Jensen
JK	Jennifer King
KEA	Kodiak Electric Association
kWp	Kilowatt peak
LC	Leo Christensen
LCOE	Levelized Cost of Electricity
M&E	Monitoring and evaluation
MW	Megawatt
MWh	Megawatt-hour
O&M	Operation and maintenance
PV	Photovoltaic
RE	Renewable energy
SH	Søren Hermansen
VRE	Variable renewable energy

EXECUTIVE SUMMARY

Small islands continue to face profound energy-related vulnerabilities. Their electricity systems are typically isolated, diesel-dependent, and exposed to highly volatile international fuel markets. This dependency results in elevated electricity costs, recurring supply risks, and significant carbon emissions. At the same time, islands are disproportionately affected by climate impacts such as storms, sea-level rise, and saltwater intrusion, making the transition to resilient renewable electricity systems both an economic and environmental imperative.

This report examines how islands can successfully shift toward high shares of renewable electricity by analyzing eleven real-world case studies, most of which already operate between 80% and 100% penetration of renewable energy generated electricity, as documented in Hecker [25]. The goal is not merely to catalogue barriers but to extract actionable success factors that explain why certain island transitions succeed and how these lessons can be replicated elsewhere. The analysis rests on three components. First, an extensive literature review. Second, five expert interviews with island practitioners. Third, a structured assessment using a success-factor matrix spanning four project phases (Preparation, Design, Implementation, Monitoring & Evaluation) and five factor categories (Social, Political, Technical, Economic, Environmental). This mixed-methods approach enables a systematic comparison across diverse contexts while retaining the nuance necessary for small-scale, community-oriented systems. Across the case studies, the research identified 111 individual success factors, of which 13 key factors were distilled based on their recurrence across multiple interviews. Two social and political enablers stand out as the most universal across all islands, alongside strong technical universals such as long-term planning and grid strengthening for variable renewable energy integration:

1. Strong stakeholder engagement throughout all project phases, requiring transparency, trust-building, and continuous communication.
2. Local champions or leadership figures who mobilize support, maintain momentum, and bridge community, political, and technical actors.

One of the clearest findings is the decisive importance of the Preparation phase, which accounts for nearly half of all identified success factors. Early-stage actions, such as community engagement, resource and grid assessments, political alignment, financing strategies, and technical feasibility studies, provide the foundation for successful system design and implementation. Islands that invest heavily in preparation tend to experience smoother deployment processes, higher acceptance, and more reliable long-term operations. The implications are straightforward but powerful. Policymakers, utilities, development agencies, and island communities can accelerate renewable energy transitions by systematically addressing these success factors across all five dimensions. Success on islands is neither accidental nor purely technical, it results from sustained alignment of social legitimacy, political support, technical robustness, economic viability, and environmental stewardship. Overall, the report offers a structured, evidence-based roadmap for islands aiming to achieve resilient, affordable, and sustainable electricity systems, while contributing valuable insights for off-grid and edge-of-grid applications worldwide.

1 INTRODUCTION

Island energy systems occupy a unique position in the global transition toward sustainable and resilient electricity supply. Around 20 million people worldwide live on islands that rely on small, isolated grids, typically serving fewer than 100,000 inhabitants, which are still largely powered by diesel fuel. These systems collectively host an estimated 15 GW of diesel generation capacity, representing significant potential for renewable energy substitution and decarbonization efforts. Their structural characteristics, geographical isolation, contained system boundaries, and clear stakeholder constellations, make islands natural front-runners for demonstrating high-renewable-penetration energy systems.

Despite their pioneering roles, islands face persistent and often intensifying challenges. The dependence on fossil fuels exposes island utilities and communities to high and volatile energy costs, logistical uncertainties, and vulnerability to global market fluctuations. At the same time, islands are among the regions most affected by climate-related risks, including sea-level rise, stronger storms, and saltwater intrusion, all of which threaten local infrastructure and energy security. These pressures elevate the urgency of transition pathways that improve resilience, stabilize energy expenditure, and enhance self-sufficiency.

Against these risks stand substantial opportunities. Most islands possess rich renewable energy resource endowments, notably solar irradiation, coastal wind regimes, and in some cases hydro or biomass. Combined with advances in battery storage, hybrid power systems, and microgrid control, these resources allow islands to achieve high shares of renewable electricity without compromising reliability. This technological potential positions islands as testbeds for innovation, where lessons generated from real-world projects can inform both off-grid and edge-of-grid applications more broadly. Within the IEA PVPS Task 18 context, these experiences are especially valuable for understanding the enabling conditions that allow decentralized systems to operate reliably, economically, and sustainably.

The objective of this report is therefore twofold. First, it aims to identify success factors, rather than simply barriers, that have enabled islands to progress toward high renewable electricity shares. Focusing on success factors allows for a constructive, solution-oriented view that highlights what works, why it works, and under which conditions it can be replicated. Second, the report provides structured guidance consistent with the analytical approach of IEA PVPS Task 18, applying a multi-dimensional framework that spans the five factor categories across four project phases: Preparation, Design, Implementation, and Monitoring & Evaluation. This approach enables comparability across diverse island contexts and yields actionable insights for practitioners, policymakers, utilities, donors, and community organizations.

The report builds on a combination of literature review, expert interviews, case study analysis, and site visits, synthesizing qualitative and quantitative evidence from eleven islands that have already achieved, or are close to achieving, very high renewable electricity shares. By organizing these insights into a transparent and replicable success-factor matrix, the report contributes to the growing body of international knowledge on decentralized renewable energy systems. Ultimately, the findings are intended to support island stakeholders in designing, implementing, and sustaining resilient renewable mini-grids, and to provide guidance for broader applications within remote, off-grid, and edge-of-grid environments worldwide.

2 BACKGROUND

2.1 Isolated Island Systems

Islands provide a particularly relevant context for decentralized electricity supply because conventional grid extensions are often technically challenging or economically prohibitive. In such settings, microgrids function as the backbone of supply by integrating local generation, storage, and distribution within a controllable system boundary. They can operate in grid-connected mode—interconnected with a wider grid where one is available—or in fully islanded mode, switching between the two as conditions require to maintain supply adequacy and power quality. For isolated island grids, microgrids reduce dependence on imported fuels by leveraging natural renewable resources, most commonly solar PV, wind and small hydro, thereby improving resilience and energy access and security while lowering exposure to fuel price volatility. In interconnected island contexts, the same architectures enhance system stability through local balancing and black start capability and can export surplus energy where interties are properly dimensioned and regulatory frameworks allow it.

The benefits of such systems are well documented. Locating generation close to demand reduces transmission and distribution losses and transmission related capital costs compared with centralized supply, while smart controls and storage enable high shares of variable renewable energy without compromising reliability. Microgrids also stimulate local economic activity through installation, operation and maintenance jobs and by enabling productive uses of electricity in commerce and services. At the same time, barriers persist. Capital expenditure is concentrated upfront across generation, storage and balance-of-plant; sustained performance depends on the availability of skilled O&M personnel; and reconnection to a main grid, where relevant, introduces technical coordination challenges that must be addressed through appropriate standards and protection schemes. These considerations underscore the importance of robust planning, training, and clear operating procedures to ensure long-term sustainability.

2.2 Technology

Island microgrids typically combine non-dispatchable and dispatchable resources with storage and advanced controls. Non-dispatchable resources, principally solar PV, wind and small hydro, provide low-marginal-cost energy but are governed by local irradiance, wind regimes and hydrology. Dispatchable resources, diesel generators (increasingly as backup or peaking), firm hydro and biomass, offer controllability to cover residual demand and provide system strength where required [1], [2]. Storage plays a central role. Lithium-ion batteries dominate new deployments and have benefited from steep cost declines that improve overall economics for high-renewable configurations; pumped-hydro storage is viable in suitable geographies and can deliver longer-duration shifting and system services. An overview of main components for micro-grids is given in Table 1.

Three principal electrical topologies are used to organize these components. In AC microgrids, distributed energy resources synchronize to an AC bus through interfaces that condition frequency and voltage. In DC microgrids, DC sources and loads connect directly to a DC bus via DC/DC converters, with AC devices interfacing through AC/DC conversion. In hybrid AC–DC microgrids, AC and DC buses are bridged by bidirectional converters to optimize efficiency and integration flexibility across mixed resource portfolios [1]. Coupling to upstream networks ranges from directly coupled AC links to fully decoupled architectures that rely on powerelectronic conversion, selected according to isolation needs, power-quality requirements and protection philosophy [1].

Table 1. Description of the main components of hybrid microgrids [3]

Type	Component	Description
Non-dispatchable resources	Solar	suitable for many locations
	Wind	very site specific
	Small hydro	needs a river with a sufficient flowrate
Dispatchable resources	Diesel generator	mostly used as backup or as base load
	Hydro	geographical requirements
	Biomass	derived from organic material, carefully examine conflicts of use
Storage	Battery	Charging and discharging of electricity
Loads	Grids	Electrical and thermal loads integrated in grid
Balance-of-plant items	Converters	Transform power from one form to another
	Inverters	Convert DC to AC
Bus bars and local distribution networks	AC/DC	Dependant on the used technology
	Distribution networks	Lines, transformers and infrastructure

Advanced control systems form a critical element of all microgrids. In islanded operation, they must stabilize frequency and voltage within milliseconds, as well as optimizing dispatch, storage cycling, and load management. Modern energy management systems integrate these functions with forecasting and demand-side measures, allowing high shares of variable renewable energy without compromising reliability [2].

The advantages of such systems are well established: they can reduce fuel costs, lower carbon emissions, and improve resilience. Yet they require sophisticated design and ongoing maintenance. High technical standards and the availability of trained staff are therefore decisive for long-term performance [4].

2.3 Business Models

Experience on islands shows that multiple ownership and governance arrangements can deliver successful mini-grids, provided roles and risks are well aligned. Four archetypes dominate the literature. Community-based models rely on cooperative ownership and local management, often supported by NGOs or development partners; they can build strong social acceptance and stewardship but require sustained capacity development in technical and financial management to remain viable over time [3], [5]. Utility-based models place ownership and operation with state-owned or private utilities, frequently backed by public financing; they benefit from integration into national planning and established technical standards, though flexibility to tailor solutions to local conditions can be limited [3]. Private-sector models involve independent companies that develop, own and operate systems under clear licensing and tariff arrangements; their strengths lie in professional O&M and efficiency, but they depend critically on predictable regulation and bankable revenue frameworks [3]. Hybrid or shared models distribute responsibilities, such as public ownership of distribution and private operation of generation and retail, allowing risk allocation that can unlock investment, while also increasing the need for robust contracting and coordination at interfaces [3], [5].

Across these models, recurring success factors include transparent and enforceable regulation (licensing, interconnection and service quality), credible tariff and subsidy mechanisms that ensure cost recovery while protecting affordability, and long-term O&M plans that include local training and asset replacement strategies. Where these elements are in place, island mini-grids have achieved high renewable shares with reliable service; where they are weak, projects face operational and financial stress regardless of technical design quality [3].

3 METHODOLOGY & FRAMEWORK

This chapter outlines the methodological approach used to identify, structure, and analyze success factors for renewable island mini-grids. The approach combines a structured literature review, case study analysis, stakeholder interviews, and site visits. A dedicated analytical framework was developed to ensure systematic categorization and comparability of results across different island contexts.

3.1 Research steps

The methodological design builds on established approaches for identifying barriers and success factors in electricity systems with high renewable energy penetration. Painuly's hierarchical concept for organizing energy transition factors provides the conceptual foundation [6]. Consistent with prior studies on decentralized and island energy systems, the applied research methods combine literature review, case study analysis, and stakeholder engagement [2], [7], [8], [9], [10], [11].

The first step consisted of an extensive literature review to identify both successful island energy transitions and previously reported success factors. More than 60 academic publications and approximately ten public reports and databases were systematically screened using combinations of keywords such as island, renewable, microgrid, transition, and success factor. This step resulted in the identification of eleven island case studies that have either achieved or are close to achieving very high renewable electricity shares. In parallel, the same literature corpus was analyzed to extract an initial list of generic success factors supporting renewable island transitions [2], [7], [8], [9].

In the second step, case study analysis was conducted for the selected islands. The objective was to validate literature-based success factors with real-world experience and to identify additional context-specific drivers. Case studies were assessed across technical, social, political, economic, and environmental dimensions, following the multi-dimensional approach proposed in earlier comparative energy transition studies [2], [10], [11].

The third step involved stakeholder interviews. A total of 40 stakeholders associated with the selected island projects were contacted, of which five in-depth interviews were conducted. Semi-structured, open-ended interviews were used to capture experiential knowledge while ensuring comparability across cases. This approach is consistent with established qualitative research methodologies and allows for the triangulation of literature findings with practitioner insights [12], [13]. The interview guideline followed a four-part structure: personal background, project experience, success factors and barriers, and lessons learned. To ensure data validity, all identified success factors from the interviews were subsequently validated with the respective interviewees [12].

In addition to desk-based research and interviews, site visits were conducted on Lolland (Denmark) and Feldheim (Germany). These visits enabled direct observation of local energy infrastructure, governance models, and community participation mechanisms, and supported the contextual interpretation of interview results. The combination of literature review, interviews, and site visits ensured methodological triangulation and strengthened the robustness of the findings [2], [10], [11]. An overview of the applied methodology is depicted in Figure 1.

3.2 Interviewees

The stakeholder interviews form a central empirical pillar of this study. The following experts contributed directly through interviews and validation of results:

- Søren Hermansen – Community energy pioneer, Samsø (Denmark)
- Leo Christensen – Renewable transition lead, Lolland (Denmark)
- Fred Cuvalay – Energy utility, Bonaire (Caribbean Netherlands)
- Jennifer King – Island energy systems expert
- Jesper Krogh Jensen – Practitioner in renewable island systems

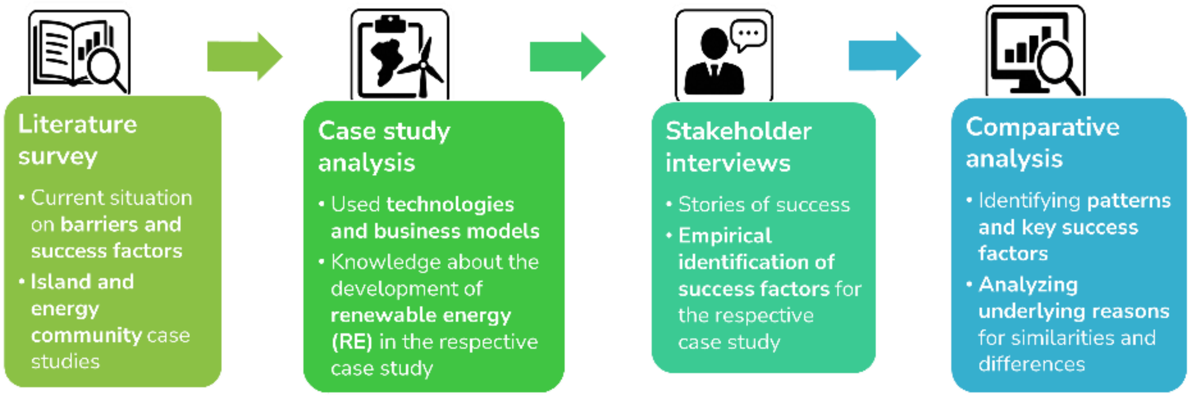


Figure 1. Methodological approach

These interviewees represent a balanced mix of community leadership, utility operation, project development, and technical implementation expertise. Their contributions provided both strategic and operational perspectives on renewable island mini-grid success. All interview-derived success factors were cross-checked with literature-based findings to ensure consistency and reproducibility of results.

3.3 Framework

This subsection introduces the analytical framework developed to systematically structure and compare success factors for renewable island mini-grids. The framework is designed to translate qualitative insights from literature and stakeholder interviews into a consistent and comparable structure across all case studies. It follows a two-dimensional logic that combines a content-based classification of success factors with a time-based project life cycle perspective.

The internal structure of success factors is based on the hierarchical model proposed by Painuly [6], which defines four analytical levels and is depicted in Figure 2. Level 1 represents the macro-level classification of success factors, where individual factors are grouped into

Success factor levels	Notations	Example
Level 1	Success factor category	Technical
Level 2	Success factor	Technical integration and design
Level 3	Success factor element	Plan wisely for the long term – at least 15 years
Level 4	Success factor dimension	Consider hardware lifecycles

Figure 2. Hierarchical structure of success factors after Painuly [6]

broad, overarching success factor categories. Level 2 contains sub-categories within each main factor category that represent the individual success factors, providing a clearer and more detailed understanding of what drives success. These are further specified at Level 3 through success factor elements, which represent more concrete expressions of the factor. Finally, Level 4 consists of success factor dimensions, which describe the most detailed, operational level and contains also recommendations for action. This hierarchy enables a progressive refinement from abstract categories to actionable project-level considerations and ensures analytical consistency across all cases. The complete set of 111 identified success factors, coded according to this four-level hierarchy, is provided in full in Annex C.

The first dimension of the matrix applies a content-based categorization of success factors. This approach follows the categorization logic established by Yaqoot and Blechinger, which has proven robust in the analysis of decentralized and island energy systems. Five categories are used in this study: Social, Political, Technical, Economic, and Environmental. Each category captures a distinct dimension of project success and allows for thematic structuring of drivers and enabling conditions [7], [9].

The second dimension introduces a temporal classification along the renewable energy project life cycle. Based on the project phase structure proposed by Madriz-Vargas et al., the development pathway is divided into four phases: Preparation, Design, Implementation, and Monitoring & Evaluation (M&E). Each phase is associated with characteristic project tasks. Preparation typically includes feasibility studies and demand assessments; Design covers system sizing and cost estimation; Implementation comprises procurement and construction; and Monitoring & Evaluation focuses on data collection, performance assessment, and reporting. This temporal differentiation ensures that success factors are not only categorized by content but also by their relevance within the project timeline [14].

By combining these two dimensions, a success factors matrix is formed in which the project phases form the horizontal axis and the factor categories the vertical axis. The intersection of both dimensions results in 20 analytical cells, into which the identified success factors are systematically assigned. This matrix structure enables phase-specific and category-specific aggregation, comparison across island contexts, and identification of dominant success patterns. It also provides a transparent analytical basis for translating empirical insights into transferable planning and policy recommendations. This schematic matrix is depicted in Figure 3 For a simpler illustration, the individual cells have been hidden and replaced by the word

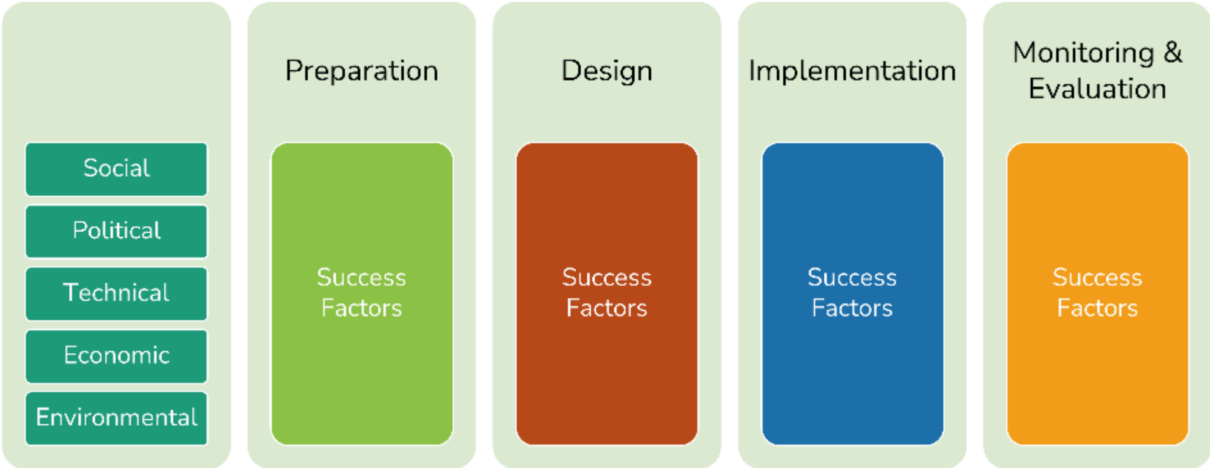


Figure 3. Success factors matrix

”Success Factors”.

3.4 Output

The application of the described framework to the empirical material resulted in a structured and validated catalogue of 111 success factors for renewable island mini-grids. These success factors were derived through the triangulation of three data sources: systematic literature review, case study analysis, and stakeholder interviews. All identified factors were classified according to the hierarchical structure and positioned within the success factors matrix.

The structured allocation within the matrix enabled a comparative cross-case analysis across all investigated island projects. This analysis served to identify

(i) recurring success factor patterns across different geographic and institutional contexts
(ii) phase-dependent concentrations of success factors along the project life cycle, and
(iii) category-specific dominance, such as the relative importance of social versus technical factors in different project stages.

Beyond individual case interpretations, the matrix-based approach allowed for the identification of generalizable and near-universal success factors that appear independent of island size, technology mix, or governance model. These universal factors form the empirical core for transferable recommendations for future island mini-grid projects and policy frameworks.

The final output of this study therefore consists of a structured success factor database, a comparative analytical assessment, and the identification of robust success patterns applicable to renewable island mini-grid development across diverse contexts [6], [7], [9], [14].

4 CASE STUDIES

To analyze success factors for renewable island mini-grids in a comparative manner, a set of eleven islands with a very high share of renewable energies in their electricity mix was identified. The selected cases represent a broad spectrum of geographical locations, technological configurations, governance structures, and project histories. Among the analyzed islands, two are interconnected to their respective national main grids, while nine operate as fully off-grid systems and are therefore completely self-sufficient in electricity supply. This distinction allows for the assessment of success factors under both isolated and grid-connected boundary conditions.

The selected islands are depicted in Figure 4 and include Kodiak Island (USA), Yaku-shima

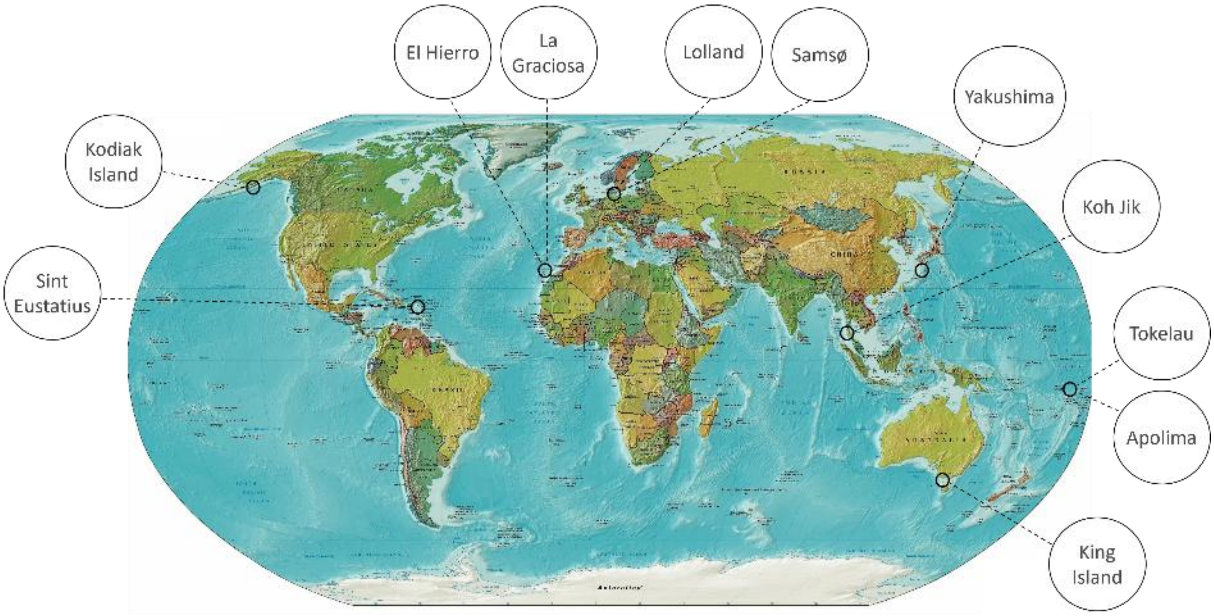


Figure 4. World map with marked island case studies

(Japan), El Hierro (Spain), Samsø (Denmark), Sint Eustatius (Caribbean Netherlands), King Island (Australia), La Graciosa (Spain), Lolland (Denmark), Tokelau (New Zealand), Koh Jik (Thailand), and Apolima (Samoa). Together, these cases cover small, remote island communities as well as large, densely populated islands with complex energy systems.

4.1 General Observations

The comparative analysis of the eleven case studies reveals significant heterogeneity with respect to scale, resource availability, technological configuration, and governance structures. The general information about all eleven case studies is summarized in Table 2. Population sizes range from very small communities such as Apolima, with around 90 inhabitants, to larger, more densely populated islands such as Lolland, home to more than 57,000 people. This wide range demonstrates that renewable island mini-grid solutions can be successfully implemented across vastly different system sizes.

Table 2. General information about case studies

Name	Nation	Continent/ Location	Population	Area (km²)	Density (p/km²)	Source
Lolland*	Denmark	Europe	57467	1243.11	46.35	[15]
Kodiak	Alaska, USA	North America	12720	8975	1.5	[16]
Yaku-shima	Japan	Asia	11858	504.29	24	[17]
El Hierro	Spain	Europe	11154	268.71	42.05	[18]
Samsø*	Denmark	Europe	3775	112.61	33	[15]
Sint Eustatius	Nether-lands	Central America	3293	21	150	[19]
Tokelau	New Zealand	South Pacific	1903	12.2	123	[20]
King Island	Australia	Australia	1570	1100	1.4	[21]
La Graciosa	Spain	Europe	695	29.05	24	[22]
Koh Jik	Thailand	Asia	400	1.12	357.14	[23]
Apolima	Samoa/ Polynesia	Pacific Ocean	88	1.4	63	[24]

* interconnected

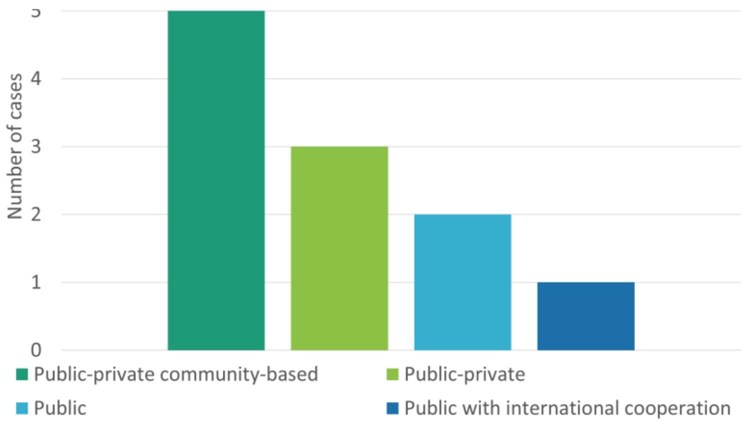
In terms of resource endowment, strong regional patterns emerge. Remote, solar-dependent island systems such as Tokelau and Koh Jik rely predominantly on solar photovoltaic generation coupled with battery storage, reflecting high solar irradiation and limited wind and hydro potential. In contrast, many European island systems such as Samsø, El Hierro, and Lolland are characterized by wind-dominated electricity generation, often complemented by hydropower or pumped hydro storage to balance variability.

Governance models differ substantially across cases. Utility-led systems, such as Kodiak Island, are operated and managed by professional public utilities with long-term experience in grid operation and maintenance. Community-led models, most prominently represented by Samsø, rely strongly on local ownership, citizen investment, and bottom-up engagement. Donor-supported transitions, such as in Tokelau, depend on external funding, international development cooperation, and centralized project coordination. These different governance approaches strongly influence the success dynamics observed across the case studies.

4.2 Detailed Results

The following subsection summarizes the key technical and organizational characteristics of the selected island case studies. An overview of installed capacities, renewable energy shares, business models, and storage technologies is provided in Annex A, while the distribution of business models across all cases is illustrated in Figure 5. The results highlight a wide range of technological configurations and governance approaches, reflecting the diversity of island contexts.

Figure 5. Distribution of island case studies among business models



Kodiak Island (USA)

Kodiak supplies approx. 99–100% renewable electricity based on a hydro–wind hybrid system operated by the member-owned utility KEA (Annex A). Installed capacity includes expanded hydropower and six wind turbines, supported by flywheels and lithium-ion batteries for grid stabilization. The case is characterized by a strong utility-led model and an advanced O&M culture, enabling reliable high-RE operation under extreme climatic conditions.

El Hierro (Spain)

El Hierro combines wind power with pumped hydropower storage (11.5 MW wind, 11.32 MW hydro, 6 MW pumping; Annex A). Renewable shares range between 70–100%, depending on weather and reservoir conditions. While internationally recognized as a flagship project, the system faces operational challenges related to intermittency and complex storage management.

Samsø (Denmark)

Samsø has reached 100% renewable electricity, primarily through onshore and offshore wind power (Annex A). The transition is driven by community ownership, citizen investment, and strong local leadership. The case is widely regarded as a model for social acceptance and participatory energy governance.

Sint Eustatius (Caribbean Netherlands)

Sint Eustatius operates a PV-battery-diesel hybrid system with renewable shares of 60–100% (Annex A). System development was enabled through Dutch governmental subsidies and is operated by the local utility STUCO. The case demonstrates the importance of public financing and strong utility commitment in small island systems with limited local investment capacity.

King Island (Australia)

King Island operates a highly sophisticated hybrid system combining wind, PV, batteries, flywheels, dynamic resistors, and diesel backup (Annex A). Renewable shares range from 65–100%. The project, led by Hydro Tasmania, is marked by technical innovation in diesel reduction and system stabilization.

La Graciosa (Spain – Canary Islands)

La Graciosa supplies 70–100% renewable electricity using a wind-PV-lithium-ion battery hybrid (Annex A). The system is continuously optimized during operation with respect to dispatch strategies and curtailment. The island demonstrates the feasibility of advanced storage-based hybrid systems for small grids.

Yaku-shima (Japan)

Yaku-shima supplies 100% renewable electricity from small hydropower alone, with no wind, solar, or storage capacity in the system (Annex A). The island's abundant rainfall and mountainous terrain provide a naturally reliable hydro resource base, and the case illustrates that very high renewable shares can be reached through a single, well-matched local resource rather than a diversified technology mix.

Lolland (Denmark)

Lolland produces significantly more renewable electricity than it consumes and exports large surpluses via multiple grid interconnections. Generation is dominated by onshore and offshore wind energy, complemented by biomass (Annex A). The transition is driven by early political commitment, strong local advocacy, and public–private cooperation.

Tokelau (New Zealand)

Tokelau operates a 100% solar-based electricity system with 930 kWp PV and 8.58 MWh of lead-acid storage (Annex A). The transition was fully supported by the New Zealand Aid Program. Tokelau exemplifies the decisive role of donor financing and international cooperation for highly remote island systems.

Koh Jik (Thailand)

Koh Jik operates a small PV-battery-diesel hybrid system with renewable shares of 80–100%, following a techno-economic redesign that replaced its original lead-acid storage with lithium-ion batteries (Annex A). The case demonstrates how targeted technical redesign and financing restructuring can substantially raise the renewable fraction of a very small, community-based off-grid system.

Apolima (Samoa)

Apolima supplies 100% renewable electricity from a small standalone solar PV system serving its tiny, isolated village population (Annex A). Publicly managed and operated without local storage, the case shows that even minimal, single-technology systems can achieve full renewable supply where demand and scale are small enough.

Across the case studies, very high renewable electricity shares are achieved through fundamentally different technological and institutional pathways. Utility-led hybrid systems with advanced storage dominate in isolated island contexts, while interconnected islands benefit from early political commitment and grid export opportunities. Despite their diversity in scale and geography, all cases underline the critical role of long-term governance stability, system optimization, and stakeholder commitment for sustained high renewable integration.

4.3 Success Factors for Islands

This section consolidates the key success factors that enable islands to transition toward high shares of renewable electricity. The factors are structured along the four project phases,

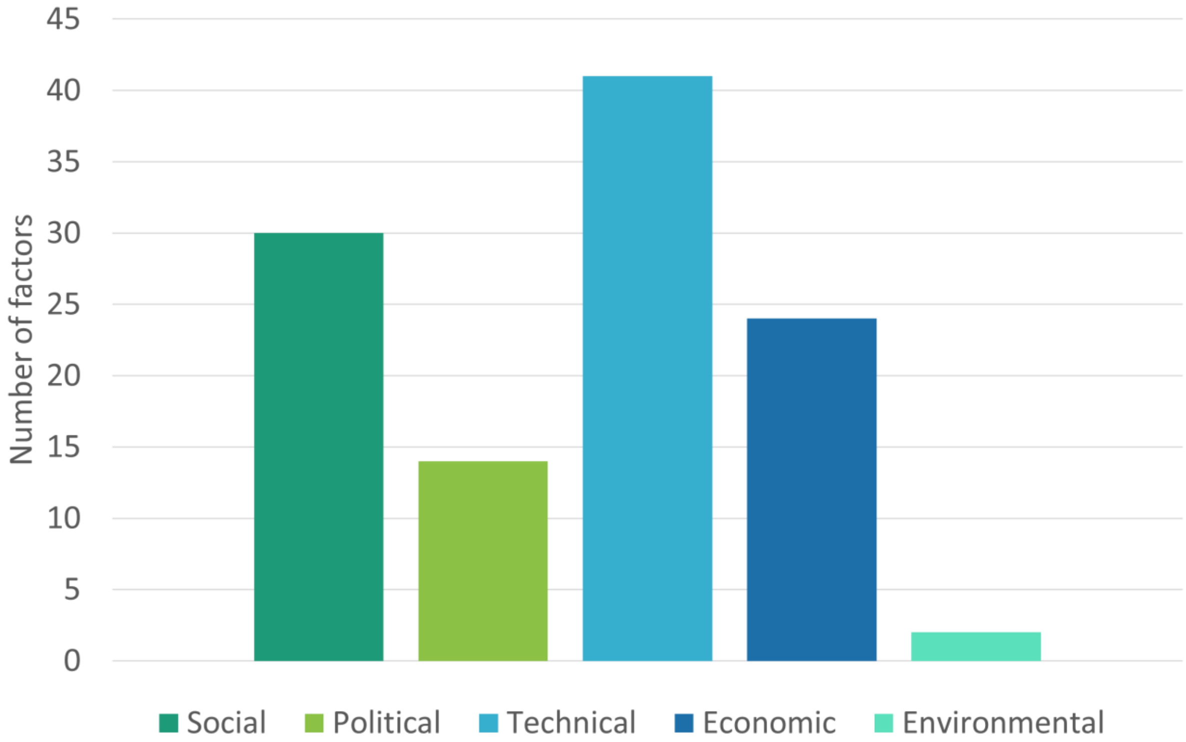


Figure 6. Distribution of success factors by factor category

Preparation, Design, Implementation, and Monitoring & Evaluation, and across the five factor categories defined in the Framework section. The synthesis integrates 111 factor elements identified in this study and visualized across the multi-level framework (Figures 7-10). The analysis confirms that the preparation phase is the most factor-dense, while technical and social factors play a critical role throughout all phases (see Figure 6). Rather than treating categories individually, the analysis follows the four project lifecycle phases and highlights how **social**, **political**, **technical**, **economic** and **environmental** aspects interact to shape outcomes.

Preparation Phase

Across the case studies, the preparation phase emerges as a decisive period during which island communities lay the institutional, social, technical, and financial groundwork for the transition toward renewable mini-grids. A recurring success factor in this early stage is strong **social** mobilisation. Islands that invested early in community involvement and education, such as Lolland, Samsø, and El Hierro, were able to build a shared understanding of the energy challenge and the potential benefits of renewable solutions. Awareness campaigns, public meetings, and transparent communication created a climate in which residents felt included in the direction-setting process, which later strengthened acceptance of new infrastructure and operational changes. At the same time, early consideration of employment opportunities and the availability of a local workforce supported realistic planning, while structured stakeholder

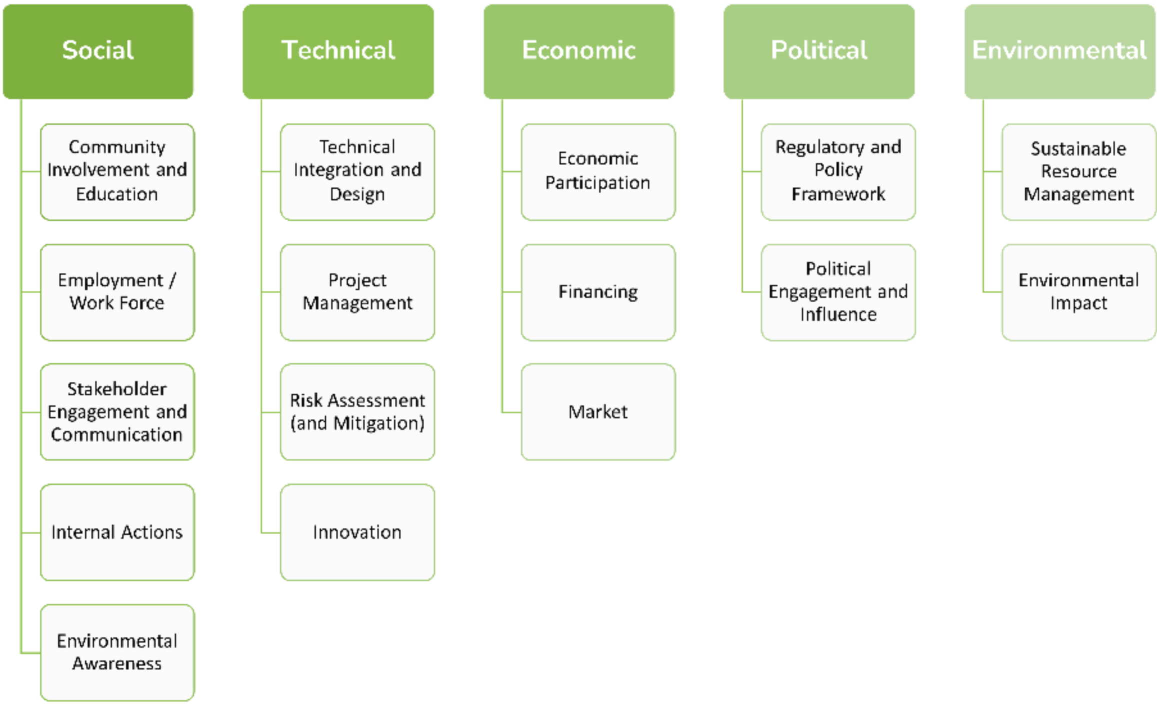


Figure 7. Success factors for the preparation phase

engagement ensured that utilities, municipalities, landowners, and external partners could coordinate their expectations. Internal actions within local institutions, such as clarifying responsibilities or appointing energy coordinators, helped stabilise these processes. Environmental awareness also played a role in shaping public motivation, particularly where islands faced direct exposure to climate impacts or dependence on imported fossil fuels.

The **political** dimension is equally influential during preparation. Islands with early regulatory support or supportive policy frameworks, such as Danish islands operating under national renewable energy mandates, benefited from clear procedural pathways and early legitimacy for their transition plans. Political engagement at the municipal level helped shape long-term visions and facilitated negotiations with national authorities or external partners. Preparation was therefore not only a social process but also a process of building political commitment and administrative readiness.

On the **technical** side, the preparation phase is characterised by foundational activities that determine the viability of later design choices. Conducting resource assessments, exploring system integration pathways, and identifying grid weaknesses enabled islands such as Kodiak and King Island to understand which combinations of wind, hydro, solar, and storage technologies would be technically feasible. Early project management structures, often established through utility leadership, helped coordinate these assessments, while risk assessment and mitigation processes enabled stakeholders to anticipate operational vulnerabilities such as intermittency, mechanical wear, or load spikes. Some islands also considered innovative approaches at this early stage, as seen in projects exploring pumped hydro, advanced flywheel integration, or hybrid AC/DC architectures.

The **economic** factors in the preparation phase centre on securing financing, shaping community participation, and establishing initial market considerations. Islands that explored cooperative ownership, municipal anchoring, or early-stage financial participation models were able to build broader legitimacy and reduce economic risk through distributed responsibility. Financing activities, such as securing grants, negotiating government subsidies (e.g., Sint

Eustatius, Tokelau), or planning long-term cost recovery mechanisms, formed a crucial precondition for later implementation. Early reflections on market structures, such as tariff implications or potential for energy exports, further strengthened the long-term economic sustainability of the transition.

Finally, **environmental** considerations in preparation included sustainable resource management and preliminary assessments of ecosystem impacts. These insights helped ensure that renewable development was aligned with local environmental objectives, particularly on islands with sensitive ecosystems.

Design Phase

The design phase translates early ambitions into concrete technical, institutional, and financial configurations. From a **social** perspective, continued community involvement plays a critical role, particularly where infrastructure siting, ownership models, or employment structures must be defined. Involving residents in decision-making, such as siting wind turbines on Samsø or configuring PV-battery systems on Sint Eustatius, helped align the project with local priorities and ensured that community members understood how the system would function. Employment considerations remained relevant as design choices affected training needs and future operational roles, while stakeholder engagement ensured that utilities, municipalities, regulators, and landowners coordinated commitments and resources.

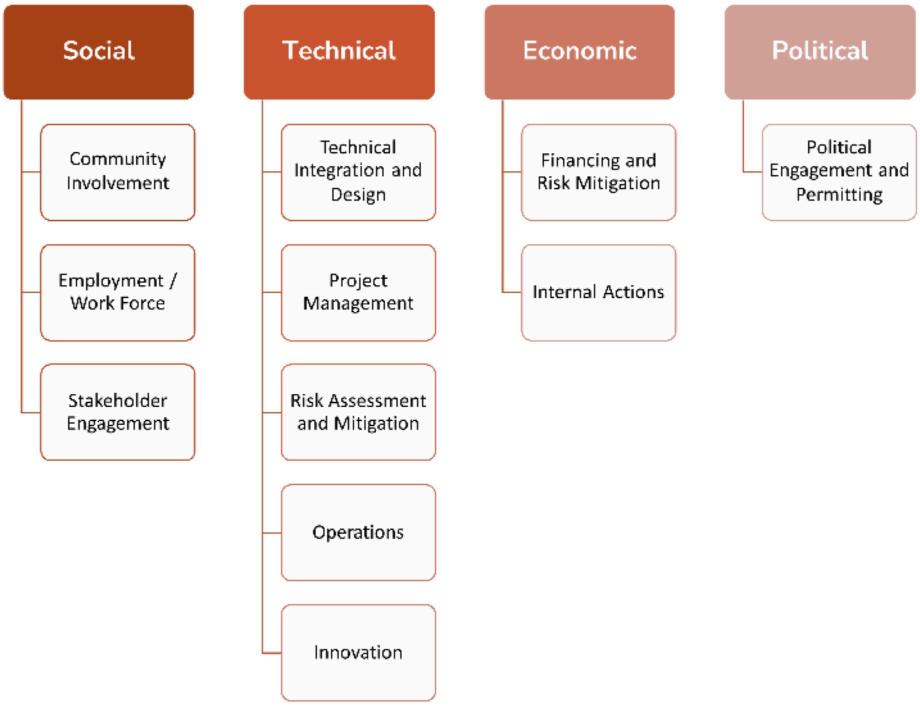


Figure 8. Success factors for the design phase

Political engagement during design focuses on permitting processes and securing formal approvals. Islands that managed these steps efficiently benefitted from supportive political environments in which administrative stakeholders remained engaged and responsive. Early alignment between technical planning and political expectations reduced delays and created a stable governance environment for procurement and contracting.

Technical factors are particularly prominent in the design phase. Technical integration and system design activities include dimensioning renewable generation portfolios, assessing storage requirements, evaluating hybrid system architectures, and planning for smart dispatch and grid stability. Islands such as El Hierro, Kodiak, and La Graciosa illustrate how careful system design can enable high renewable shares even under challenging conditions. Project management remains essential, coordinating engineering work, procurement planning, and timelines. Risk assessment and mitigation continue, as design choices must account for intermittency, supply chain uncertainties, and exposure to extreme weather events. Innovation also plays a role when islands explore novel solutions, such as integrating advanced flywheels, dynamic resistors, or pumped storage.

In the **economic** dimension, design requires developing financing and risk mitigation strategies that ensure long-term viability. This includes structuring public–private partnerships, securing loans or subsidies, refining internal financial processes, and aligning cost expectations among stakeholders. Economic participation mechanisms, such as cooperative shares or community bonds, are often finalised at this stage. Internally, utilities and project developers refine financial procedures and operational budgets, while the design stage may already consider future market structures or tariff implications.

Environmental considerations do not appear as a separate category in the design-phase figure, indicating that while ecological impacts are acknowledged, they do not constitute a dominant documented success factor during design compared with other phases.

Implementation Phase

During implementation, success depends on coordinating **social**, **political**, **technical**, and **economic** factors under operational conditions. From a **social** perspective, community involvement remains essential, particularly as new infrastructure becomes visible and construction affects local routines. Islands that maintained transparent communication, responded to concerns, and continued stakeholder engagement were better able to navigate disruptions and sustain public support. Personnel expertise also emerges as a key success factor in implementation, as skilled technicians, engineers, and operators ensure the safe and

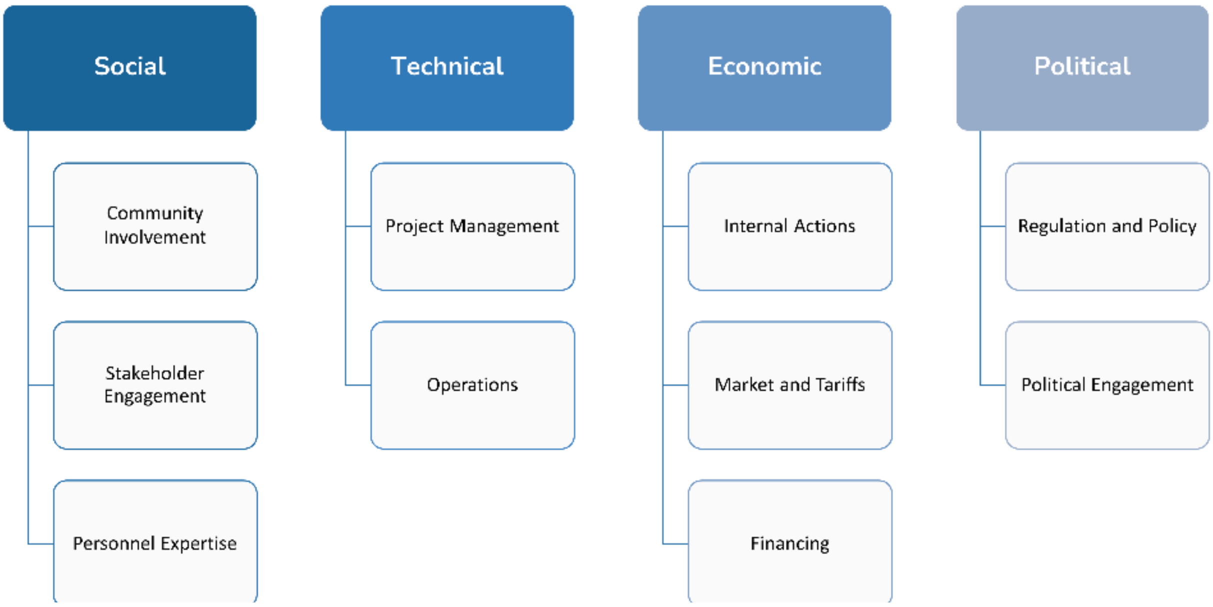


Figure 9. Success factors for the implementation phase

timely installation of equipment. Cases such as Kodiak and King Island demonstrate the importance of strong O&M cultures and experienced utility teams.

The **political** category during implementation focuses on regulatory and policy compliance as well as ongoing political engagement. Maintaining permits, adhering to reporting requirements, and ensuring alignment with regional or national regulations helped avoid project delays. Some islands relied on continuous communication with political authorities to manage unforeseen issues or adapt regulatory conditions as implementation progressed.

The **technical** domain becomes the centre of gravity in this phase. Project management ensures timely delivery of components, adherence to engineering plans, and coordination between contractors and local utilities. Operations-related success factors include ensuring smart dispatch decisions, continuous maintenance, and quick issue resolution, elements strongly illustrated in Kodiak's real-time balancing of wind and hydro and King Island's integration of flywheels and dynamic resistors. Technical teams must also monitor system performance closely during installation, validate assumptions, and correct deviations between modelled and actual behaviour. This phase tests the robustness of earlier risk assessments and often requires adaptive strategies to address unexpected technical challenges.

The **economic** factors during implementation relate to internal financial actions and the management of tariffs or cost structures. Operational budgeting, procurement cost control, and financial oversight ensure that the project remains within scope and that long-term cost expectations remain realistic. For donor- and subsidy-supported islands such as Tokelau or Sint Eustatius, implementation success depended on aligning internal actions with external funding requirements.

Monitoring & Evaluation Phase

In the monitoring and evaluation phase, sustained project success relies most strongly on **social**, **political**, **technical**, and **economic** factors. The **social** dimension is dominated by stakeholder engagement, which becomes essential for evaluating system performance, addressing issues, and maintaining trust. Islands that involve stakeholders in M&E processes, such as reviewing performance indicators, validating outcomes, or sharing progress through newsletters, demonstrate higher long-term stability. This reinforces the importance of collaboration and shared responsibility, particularly in systems that rely on distributed ownership or community involvement.

On the **political** side, continued political engagement and permitting oversight help ensure regulatory compliance and support ongoing adjustments. Political actors who remain committed during M&E provide stability for long-term system optimisation, especially when expansions or upgrades are planned.

In the **technical** category, M&E activities revolve around operations and risk assessment. Monitoring system components, analysing performance data, comparing projected and actual generation patterns, and evaluating safety and reliability form the technical core of this phase. These processes help identify optimisation opportunities and ensure that island systems maintain high renewable shares despite changing conditions, such as weather variability or load growth.

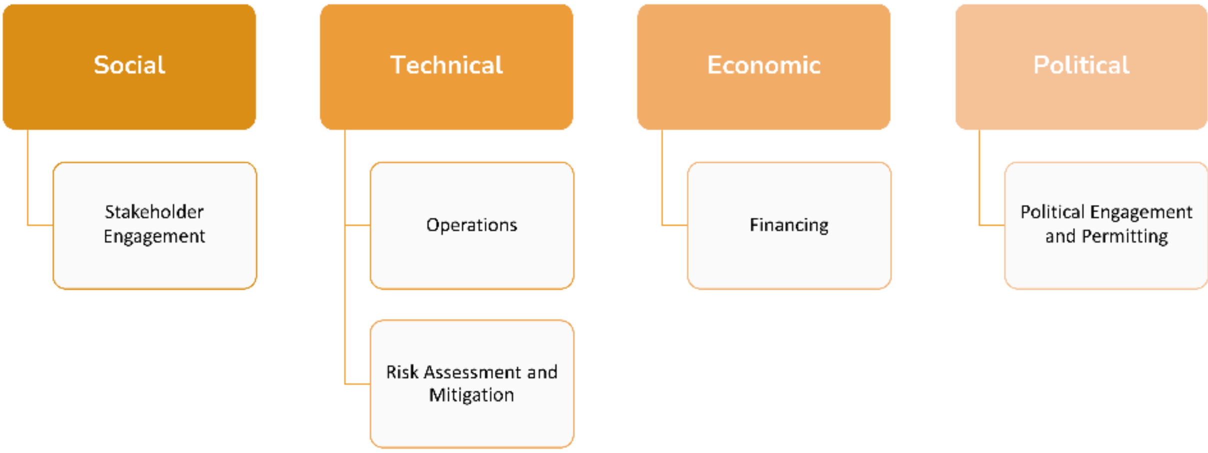


Figure 10. Success factors for the monitoring and evaluation phase

The **economic** dimension highlights the importance of securing financing for long-term maintenance and future upgrades. Sound financial management during M&E, including setting aside reserves, ensures that the system remains reliable beyond the initial implementation period, particularly for remote islands where maintenance costs and spare parts availability pose long-term challenges.

Across all lifecycle phases, successful island renewable energy transitions depend on the coordinated interaction of **social, political, technical, economic, and, where relevant, environmental** success factors. The preparation and design phases emphasise social engagement, political alignment, robust technical planning, and sound financial strategies, while implementation adds operational expertise and adaptive management. Monitoring and evaluation ensure long-term system stability through continued stakeholder involvement, regulatory oversight, performance monitoring, and financial sustainability. Although the prominence of categories shifts between phases, the cases show that islands achieve high renewable shares when these factors reinforce one another throughout the entire project lifecycle.

5 DISCUSSION & CONCLUSION

5.1 Key Success Factors for Islands

The synthesis of 111 identified success factors shows that island energy transitions rely on a tightly interlinked set of dynamics across the five factor categories. The preparation phase emerges as the decisive period for long-term success. (The full list of identified success factors is provided in Annex C). As illustrated in Figure 11, more than 50% of all success factors appear before implementation begins, emphasizing how foundational early planning, community engagement, and technical groundwork truly are. Throughout this section, codes

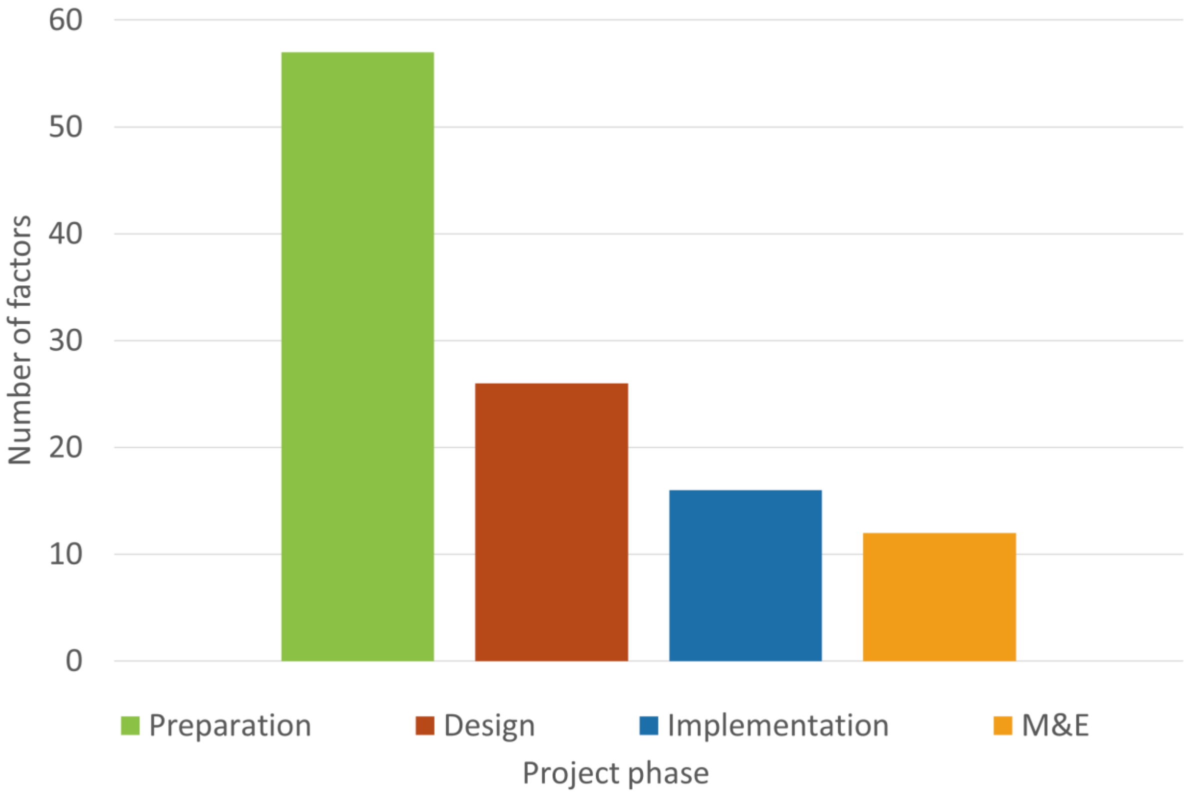


Figure 11. Distribution of success factors by project phase

such as (I1.3.1) or (M1.1.2) refer to the corresponding factor element documented in Annex C.

Across all cases, whether community-driven (Samsø), utility-led (Kodiak), donor-supported (Tokelau), or hybrid systems (El Hierro, King Island, La Graciosa), a **consistent pattern of enablers** becomes visible. First, **leadership and local champions** act as anchors for momentum, shaping narratives, mobilizing trust, and ensuring long-term commitment. Samsø's transition demonstrates how social identity and local ownership can fuel participation, while Kodiak highlights how strong technical leadership and a culture of operational reliability secure community confidence.

Second, **stakeholder involvement** is a universal, cross-phase success factor. It appears in every lifecycle stage, preparation, design, implementation, and M&E, underscoring that **transparent communication, respect for agreements (I1.3.1), and collaborative**

structures (M1.1.2) are critical from start to finish. Even highly technical decisions, such as technology selection and grid reinforcement, depend on stakeholder trust to be accepted and sustained.

Third, **policy support and political stability** are essential frameworks for implementation. Securing **political buy-in (P2.2.2)** and ensuring a predictable regulatory environment enable financing, streamline permitting, and prevent delays. Cases such as Sint Eustatius clearly illustrate how national-level policy support can offset limited local capacity and accelerate renewable deployment.

Fourth, **technical robustness and tailored system design** form the backbone of successful island transitions. The technical category contains the highest number of success factors (41 total), and the most frequently mentioned universal success factors, **long-term planning (P3.1.3)** and **grid strengthening for VRE integration (P3.1.6)**, reflect the importance of anticipating variability and ensuring system stability. Islands require **context-specific solutions**, such as hybrid wind–hydro systems (El Hierro), advanced storage integration (La Graciosa), or highly reliable dispatch strategies (King Island). **Predictive maintenance (M3.2.2)** and **comparison of operational data with initial models (M3.2.3)** ensure systems evolve based on real-world conditions.

Fifth, **financial viability and risk mitigation** determine whether projects can be implemented and sustained. **Local employment, capacity building (P1.4.5)**, and fair market structures support long-term operation and help retain economic value within communities. Many successful islands implement **public–private–community-based governance models**, balancing accountability, participation, and financial stability.

Finally, while environmental factors appear less frequently in the coded data, they remain **strategic motivators**, especially for climate-vulnerable islands such as Tokelau or Apolima. Even with only two environmental success factors, the transition to 100% renewable electricity delivers substantial global and local ecological benefits, reinforcing both legitimacy and urgency.

Taken together, these insights show that **island energy transitions succeed when leadership, participation, planning, technical integration, stable governance, and financial resilience reinforce one another across the lifecycle**. Despite vast geographic and economic differences, islands share a common pathway: careful early preparation, inclusive decision-making, context-specific technical design, and sustained stakeholder collaboration. Their experiences demonstrate that **100% renewable electricity systems are not only technically feasible but socially and institutionally achievable**, making islands valuable pioneers for broader decarbonization strategies.

5.2 Limitations

The findings of this study should be interpreted within several limitations. First, the majority of interviewees came from technical backgrounds, which may have increased the emphasis on technical and operational success factors. Perspectives from policymakers, NGOs, or social scientists might have broadened the social and political dimensions. Second, the availability of literature and public documentation shaped the selection of case studies, potentially introducing regional or technological bias. Third, obtaining economic data from small island utilities proved difficult, limiting the depth of economic analysis. Finally, renewable electricity systems are inherently complex, and although 111 factors were identified, each island remains unique, and no factor can be universally applied without contextual adaptation.

5.3 Outlook

Future research could expand the scope beyond electricity systems to include heating, transport, and integrated energy systems, especially for islands where these sectors significantly influence total emissions. The contrast between islands in the Global North and Global South also deserves deeper investigation, as governance structures, economic conditions, and climate vulnerability differ widely. Increasing the number of case studies and interviewing a broader range of stakeholders would further refine factor weighting and strengthen generalizability. Additionally, emerging themes, digital monitoring tools, resilience strategies, local justice issues, community dissent, and innovative financing models, offer valuable new directions. Within IEA Task 18, island insights could be linked to broader off-grid and edge-of-grid contexts, helping to identify scalable solutions for resilience, digitalization, and equitable access to renewable energy.

5.4 Conclusion

This work provides a structured and comprehensive success-factor matrix spanning four project phases and five categories, enabling a systematic assessment of what drives successful renewable energy transitions on islands. The analysis identifies 111 success factors for islands, with nearly half concentrated in the preparation phase, underscoring that meticulous early planning, both social and technical, is the most powerful determinant of project success. Among these, 13 factors emerged as key success factors, including universal elements such as long-term planning and grid strengthening, which apply across nearly all island contexts. Social involvement is especially critical: stakeholder engagement spans the entire lifecycle and remains one of the strongest predictors of enduring project acceptance and performance.

Across case studies, islands demonstrate that 100% renewable electricity systems are achievable today. Whether through community-driven approaches (Samsø), utility-led models (Kodiak), donor-supported initiatives (Tokelau), or hybrid technical systems (El Hierro, La Graciosa, King Island), the underlying principles remain consistent: leadership, trust, planning, tailored technical design, and resilient economic and governance structures. Islands thus offer not only successful demonstrations but a replicable roadmap for global energy transitions, showing that decentralized, renewable, and community-aligned systems can be both technically robust and socially anchored.

These success factors emerge from islands that ultimately succeeded, and their transferability is not unconditional. Several enabling conditions recur beneath the more visible factors across the case studies: a local institution capable of sustaining planning over several years, stakeholders with enough continuity and trust to stay engaged throughout, and financing that does not depend entirely on short-term donor cycles. Where these preconditions are weak, the same interventions tend to stall rather than fail outright. Stakeholder engagement loses momentum without a champion to sustain it. Tariff and business-model reforms struggle to attract investment where regulatory frameworks are unstable. And technical designs proven on better-resourced islands are hard to replicate where skilled O&M capacity or reliable supply chains are lacking. Replication is therefore hardest where several of these constraints coincide at once — most often on smaller, more remote, lower-income islands, and disproportionately in the Global South, where the institutional and financial foundations underlying this report's case studies are least likely to already be in place.

6 REFERENCES

[1] E. Unamuno and J. A. Barrena, 'Hybrid ac/dc microgrids—Part I: Review and classification of topologies', *Renewable and Sustainable Energy Reviews*, vol. 52, pp. 1251–1259, Dec. 2015, doi: 10.1016/j.rser.2015.07.194.

[2] M. Soshinskaya, W. H. J. Crijns-Graus, J. M. Guerrero, and J. C. Vasquez, 'Microgrids: Experiences, barriers and success factors', *Renewable and Sustainable Energy Reviews*, vol. 40, pp. 659–672, Dec. 2014, doi: 10.1016/j.rser.2014.07.198.

[3] E. I. Come Zebra, H. J. van der Windt, G. Nhumaio, and A. P. C. Faaij, 'A review of hybrid renewable energy systems in mini-grids for off-grid electrification in developing countries', *Renewable and Sustainable Energy Reviews*, vol. 144, p. 111036, Jul. 2021, doi: 10.1016/j.rser.2021.111036.

[4] A. Dagar, P. Gupta, and V. Niranjan, 'Microgrid protection: A comprehensive review', *Renewable and Sustainable Energy Reviews*, vol. 149, p. 111401, Oct. 2021, doi: 10.1016/j.rser.2021.111401.

[5] R. D'ARLON, 'Hybrid mini-grids for rural electrification: Lessons learned', *Brussels: Alliance for Rural Electrification (ARE)*, 2014.

[6] J. P. Painuly, 'Barriers to renewable energy penetration; a framework for analysis', *Renewable Energy*, vol. 24, no. 1, pp. 73–89, Sep. 2001, doi: 10.1016/S0960-1481(00)00186-5.

[7] M. Yaqoot, P. Diwan, and T. Kandpal, 'Review of barriers to the dissemination of decentralized renewable energy systems', *Renewable and Sustainable Energy Reviews*, vol. 58, pp. 477–490, May 2016, doi: 10.1016/j.rser.2015.12.224.

[8] G. R. Timilsina and K. U. Shah, 'Filling the gaps: Policy supports and interventions for scaling up renewable energy development in Small Island Developing States', *Energy Policy*, vol. 98, pp. 653–662, Nov. 2016, doi: 10.1016/j.enpol.2016.02.028.

[9] P. Blechinger, *Barriers and solutions to implementing renewable energies on Caribbean islands in respect of technical, economic, political, and social conditions*. in Schriftenreihe der Reiner-Lemoine-Stiftung. Aachen: Shaker, 2015.

[10] A. A. Adesanya, R. V. Sidortsov, and C. Schelly, 'Act locally, transition globally: Grassroots resilience, local politics, and five municipalities in the United States with 100% renewable electricity', *Energy Research & Social Science*, vol. 67, p. 101579, Sep. 2020, doi: 10.1016/j.erss.2020.101579.

[11] V. Brummer, 'Community energy – benefits and barriers: A comparative literature review of Community Energy in the UK, Germany and the USA, the benefits it provides for society and the barriers it faces', *Renewable and Sustainable Energy Reviews*, vol. 94, pp. 187–196, Oct. 2018, doi: 10.1016/j.rser.2018.06.013.

[12] Robert Bogdan; Sari Knopp Biklen, *Qualitative research for education*, 3rd ed. Boston, MA: Allyn & Bacon, 1998.

[13] Sharan B Merriam, 'Case study research in education: A qualitative approach'. Jossey-Bass, 1988.

[14] R. Madriz-Vargas, A. Bruce, and M. Watt, 'A Review of factors influencing the success of community renewable energy minigrids in developing countries', in *Proceedings of the 2015 Asia-Pacific Solar Research Conference, Brisbane, Australia*, 2015, pp. 8–9.

[15] Danmarks Statistik, 'Die Statistikbank'. Accessed: Dec. 13, 2023. [Online]. Available: https://www.statistikbanken.dk/BEF4

[16] 'U.S. Census Bureau QuickFacts: Kodiak Island Borough, Alaska'. Accessed: Dec. 13, 2023. [Online]. Available: https://www.census.gov/quickfacts/fact/table/kodiakislandboroughalaska/PST045222

[17] Thomas Brinkhoff, 'Yakushima (Kagoshima , Japan) - Population Statistics, Charts, Map, Location, Weather and Web Information'. Accessed: Dec. 13, 2023. [Online]. Available: https://www.citypopulation.de/en/japan/kagoshima/_/46505__yakushima/
[18] Data Commons, 'El Hierro - Place Explorer - Data Commons'. Accessed: Dec. 13, 2023. [Online]. Available: https://datacommons.org/place/nuts/ES703/?mprop=count&popt=Person&hl=de#
[19] 'Sint Eustatius: population 2023', Statista. Accessed: Dec. 13, 2023. [Online]. Available: https://www.statista.com/statistics/706806/population-of-sint-eustatius-in-the-caribbean-netherlands/
[20] 'Tokelau Population (2023) - Worldometer'. Accessed: Dec. 13, 2023. [Online]. Available: https://www.worldometers.info/world-population/tokelau-population/
[21] '2021 King Island, Census All persons QuickStats | Australian Bureau of Statistics'. Accessed: Dec. 13, 2023. [Online]. Available: https://abs.gov.au/census/find-census-data/quickstats/2021/LGA63410
[22] 'Instituto Nacional de Estadística. (Spanish Statistical Institute)'. Accessed: Dec. 13, 2023. [Online]. Available: https://www.ine.es/nomen2/index.do
[23] G. Veilleux *et al.*, 'Techno-economic analysis of microgrid projects for rural electrification: A systematic approach to the redesign of Koh Jik off-grid case study', *Energy for Sustainable Development*, vol. 54, pp. 1–13, Feb. 2020, doi: 10.1016/j.esd.2019.09.007.
[24] 'Apolima Island (Village, Samoa) - Population Statistics, Charts, Map and Location'. Accessed: Dec. 13, 2023. [Online]. Available: https://www.citypopulation.de/en/samoa/admin/aiga_i_le_tai/1415__apolima_island/
[25] H. Hecker, 'Success Factors for 100% Renewable Electricity Systems – A Case Study Analysis of Island Systems and Energy Communities', Master thesis, TU Berlin, 2024.

7 ANNEX

Annex A Technical information about island case studies

Name	RE-share [%]	Business model	Wind [MW]	PV [MW]	Hydro [MW]	Biomass [MW]	Diesel [MW]	Waste [MW]	Total Power [MW]	Storage
Lolland	100	Public-private community-based	482.47	158.5	0	5.25	0	5.25	651.47	/
Kodiak	100	Public-private community-based	9	0	3 x 11.25	0	40	0	82.75	3 MW/0.75 MWh Li-Ion; 2 x 1 MW Flywheel
Yaku-shima	100	Public-private community-based	0	0	56.66	0	0	0	56.66	/
El Hierro	70-100	Public-private	11.5	0	11.32 (+6 Pumping)	0	11.36	0	34.18	/
Samsø	100	Public-private community-based	33	0	0	0	0	0	33	/
Sint Eustatius	60-100	Public–private	0	4.15	0	0	0	0	4.15	5.9 MWh Li-Ion
Tokelau	70-100	Public with international cooperation	0	0.93	0	0	0	0	0.93	8.58 MWh Pb
King Island	65-100	Public	2.45	0.47	0	0	6	0	8.92	1.5 MW Dyn. Resistor; 3 MW/1.5 MWh Pb; 2 x 1 MVA Flywheel
La Graciosa	70-100	Public-private	4.5	1	0	0	4.61	0	10.11	6 MW/3.2 MWh Li-Ion
Koh Jik	80-100	Public-private community-based	0	0.04	0	0	0.05	0	0.1	0.24 MWh Pb (2 V, 1000 Ah)
Apolima	100	Public	0	0.015	0	0	0	0	0.015	/

Annex B Interview Guideline

This guideline structured the semi-structured expert interviews conducted for this study (see Interviewees). Each session followed the four-part sequence below.

I. Introduction

1. Introduction of research project and interviewer
2. Ask for permission to record the interview
3. Ask for permission to quote the interviewed person

II. Personal Experience

1. Could you briefly introduce yourself?
2. Could you tell me about your professional background within the last ten years of working in the (renewable) energy sector?
3. What were the most exciting projects?
4. A little bit more specific, what is your work experience within the project of your case study?
5. Which position did you hold in the aforementioned project?
6. What technologies with what capacities do you use in your system and what is the peak load? What is the current RE share?
7. Could you briefly explain how the project developed?
8. Which major problems did you face during this project and in which of the categories would you place them (political, social, economic, environmental, technical)?
9. Which were the enabling factors?
10. What lessons have you learned from this project?
11. Do you have any advice for anybody in your position in a future project on how to make his or her life easier and hence boost the project's chances of success?
12. Without necessarily knowing of other similar cases: do you believe your project had a one-of-a-kind issue that was a critical event to resolve? If yes, what was the problem and how did you resolve it?

13. This research is about supplying 100% renewable electricity. However, in some circumstances the transportation and heating sectors may be much greater GHG polluters. What do you think the next step toward 100% renewable energy should be in your case, or in general for islands?

14. What is your current position, and which responsibilities do you have in it?

15. Are you promoting and investigating renewable energy projects on islands (or energy communities) in your current position? If yes: What is your strategy for implementation? What advice would you give to stakeholders engaged in such projects? Do you get the impression that some of the challenges you faced during the transformation have been overcome or made easier in recent years?

III. Drivers, Barriers & Improvements

1. Introduction of the drivers matrix and definition of islands/energy communities.

2. Do you have any barriers in mind which are currently blocking the development of RE projects on islands? If possible, please categorize them according to the success factors matrix.

3. With whom do you think lies the responsibility for the advancement of RE?

4. Which group of stakeholders are the most relevant for the deployment of RE projects? If possible, please categorize them into the different project phases.

For each project phase (Preparation, Design, Implementation, Monitoring & Evaluation), the interview followed the same two-step structure:

General inquiry: What do you think are the most important success factors in this phase of a RE project on islands/energy communities? (A short description of typical tasks for the phase was read out – e.g. for Preparation: feasibility study, resource assessment, demand analysis, stakeholder identification and engagement.)

Specific inquiry: Listen, classify, and ask – noting which success factors were mentioned and checking them against the matrix; if a category was skipped, it was asked about directly. The interviewer then displayed the success factors matrix row for that phase and asked the interviewee to read through the individual factors, noting any they wished to highlight or disagree with.

IV. Finish

1. Is there anything you would like to add?

2. Can you think of any other projects – preferably islands or energy communities – that have a high share of renewable energy?

3. Can you think of other experts who could give more valuable information on this topic?

4. Would you like to receive a transcribed version of this interview once it is ready?

The interview closed with thanks to the participant for their time and for the valuable insights provided.

Annex C Success Factor Matrix

Project Lifecycle Phase	Level 1 Factor Category	Level 2 Factor	Level 3 Factor Element	Level 4 Factor (element's) dimension
Preparation (57)	Social (18)	Community Involvement and Education (8)	P1.1.1 Involve the community in all project steps (LitRev)	
			P1.1.2 Identify local actors and the role of a local champion (LitRev)	
			P1.1.3 Educate the community about RE (JK)	P1.1.3.1 Teaching children to educate their parents (LC)
			P1.1.4 Understand the communities perspective (JK)	P1.1.4.1 Evaluate if adressing energy concerns can also adress other citizen issues (SH)
			P1.1.5 Being patient when engaging with the public (SH)	
			P1.1.6 Establish a supportive community to create consensus(LitRev)	
			P1.1.7 Choose project locations that consider visual impact (JK)	
			P1.1.8 Understanding the why before adressing the how (SH)	
		Employment / Work Force (5)	P1.2.1 Relocating employment inside communities / create jobs within local communities (JK, SH, LC)	
			P1.2.2 Retooling employees, engines and suppliers (JK)	
			P1.2.3 Generating new job opportunities through attracting large companies (LC)	
			P1.2.4 Seeking for support from universities or PhDs (LC)	
			P1.2.5 Build necessary capabilities to local people for O&M (LitRev,LC, FC)	P1.2.5.1 Ensure proper training is undertaken to meet warranty conditions (FC)
		Stakeholder Engagement and Communication (3)	P1.3.1 Building trust among stakeholders (JK)	
			P1.3.2 Use your company as an ambassador for your ideas (LC)	
			P1.3.3 Asess each stakeholders risk tolerance (JK)	
		Internal Actions (1)	P1.4.1 Educate your own company about the project and the goals (LC)	P1.4.1.1 Involve board of directors in the information gathering process (FC)

		Environmental Awareness (1)	P1.5.1 Ensure Decision makers are informed about the real situation on-site (JK)	
	Political (8)	Regulatory and Policy Framework (4)	P2.1.1 Consistent and long-term energy policy (SH)	
			P2.1.2 Supportive policies for RE and electricity access (LitRev)	
			P2.1.3 Available inventives for RE (LitRev)	
			P2.1.4 Liberalisation of electricity market (LitRev)	
		Political Engagement and Influence (4)	P2.2.1 Pressure applied bureaucratic staff (JK)	
			P2.2.2 Gain key political support / Political Buy In (FC, JJ, LC)	P2.2.2.1 Table round with commissioner (FC)
				P2.2.2.2 Assist politicians in understanding and supporting new projects (LC)
			P2.2.3 Initiate new laws (JK)	P2.2.3.1 direct coupling - use electricity whre it is generated without charging (LC)
			P2.2.4 Obtaining property with governmental contribution (FC)	
	Technical (18)	Technical Integration and Design (7)	P3.1.1 Analyze the system as a whole (JK)	
			P3.1.2 Adapt plans to each islands unique conditions (JK, SH)	
			P3.1.3 Plan wisely for the long-term (20 years) (JK, SH, JJ)	P3.1.3.1 Anticipate technology advancements for long-term planning (LC)
				P3.1.3.2 Consider Hardware Lifecycles (SH)
			P3.1.4 Detailed planning in material supply and transportation (JK)	
			P3.1.5 Prepare a dispatchable backup (JK)	
			P3.1.6 Strengthen the existing grid for integrating high share of Variable Renewable Energy (JK, FC, LC, SH)	
			P3.1.7 Addressing environmental concerns by raising panels to manage erosion and vegetation (FC)	

		Project Management (5)	P3.2.1 Detailed and Individual preparation of Request for Proposal(FC)	
			P3.2.2 Establish a well defined and communicated project target as the primary goal (SH)	
			P3.2.3 Create a masterplan through conducting a Baseline Study (SH)	
			P3.2.4 Define off-ramps (abbruch meilensteine) throughout every step of the project (JK)	
			P3.2.5 Seek for a trustworthy implementing company (FC	
		Risk Assessment (and Mitigation) (3)	P3.3.1 Assess natural disaster risks (hurricane belt) (FC)	
			P3.3.2 Consider seasonal weather for operating (JK)	
			P3.3.3 Over-purchase essential materials (JK) Stock Parts on island to reduce delays and ensure reliable operation (FC)	
		Innovation (3)	P3.4.1 Explore Blue Biomass and Wave Energy Potential (LC)	
			P3.4.2 Use Hydrogen to store surplus electricity (LC)	
			P3.4.3 Consider two projects: one reference, one experimental (LC)	
	Economic (11)	Economic Participation (5)	P4.1.1 Foster a Sense of Ownership (LitRev)	
			P4.1.2 Identify cost-effective solutions while incorporating public participation (SH)	
			P4.1.3 Create standarized loan calculations for bank use by individual borrowers (SH)	
			P4.1.4 Priorization of more financially favorable options (SH)	
			P4.1.5 Community Support and Permits streamline fundraising (LC)	
		Financing (4)	P4.2.1 Utilize foreign aid (litRev)	P4.2.1.1 Obtain subsidies from the ministry (FC)
			P4.2.2 Attract private investments (LitRev)	
			P4.2.3 Fund the next RE phase with proceeds from previous expansion steps (SH)	
			P4.2.4 Plan with a 10-year average CRF (SH)	
		Market (2)	P4.3.1 Drive companies towards green energy adoption (LC)	

			P4.3.2 Reduce influence from monopolistic utilities (LitRev)	
	Environmental (2)	Sustainable Resource Management (1)	P5.1.1 Harvest rainwater for agricultural purposes - PV (FC)	
		Environmental Impact (1)	P5.2.1 Integrate environmental impact and sustainability aspects into the planning stages (SH)	
Design (26)	Social (4)	Community Involvement (2)	D1.1.1 Rethink Community involvement and their individual needs (SH)	
			D1.1.2 Consider social conflicts and potential Project Effects on the Community (SH)	
		Employment / Work Force(1)	D1.2.1 Organize a construction crew with remote area experience (JK)	
		Stakeholder Engagement (1)	D1.3.1 Create experimental test plants to engage and educate visitors (LC)	
	Political (2)	Political Engagement and Permitting (2)	D2.1.1 Get upfront permits to change Innovative Key Components (LC)	
			D2.1.2 Assess available land for project implementation (LitRev)	
	Technical (14)	Technical Integration and Design (5)	D3.1.1 Choose the right RE technology based on key criteria like LCOE (LitRev, SH, JJ)	
			D3.1.2 Size RE technologies using cost-effectiveness analysis (JK)	
			D3.1.3 Consider the interaction between technical and social aspects (JK)	
			D3.1.4 Integrate various RE technologies for synergy (JK)	
			D3.1.5 Applying a certain level of field engineering (JK)	
			D3.2.1 Establish service level agreements with suppliers for monitoring and maintenance (FC)	

		Project Management (4)	D3.2.2 Demand high quality components (panels, batteris) with specific warranties (FC)	
			D3.2.3 Plan technical operations strategically (LitRev)	
			D3.2.4 Detailed planning of logistics and transportation (due to remoteness) (JK)	
		Risk Assessment and Mitigation (3)	D3.3.1 Evaluate Initial risks due to uniqueness of one's island (JK,SH)	
			D3.3.2 Make sure that all possible out-of-date components are easily replaceable (LC)	
			D3.3.3 Optimize Solar panel angles for better hurricane resilience (FC)	
		Operations (1)	D3.4.1 Maintain precise Supply-Demand Balance at microsecond level (JK)	D3.5.1.1 Use transients for smoothing sinus curve (LC, JK)
		Innovation (1)	D3.5.1 Establish energy efficient technologies and educate citizens (LitRev)	
	Economic (6)	Financing and Risk Mitigation (5)	D4.1.1 Ensuring financial and commercial viability (Litrev)	
			D4.1.2 Fair risk distribution amongst stakeholders (sh)	
			D4.1.3 Securing low-interest bank loans for financing (sh)	
			D4.1.4 Offering stranded-cost guarantees (LC)	
			D4.1.5 Renting necessary site-specific equipment (JK)	
		Internal Actions (1)	D4.2.1 Maintaining ownership of intellectual property rights (LC)	
Implementation (16)	**Social (3)**	Community Involvement (1)	I1.1.1 Provide through education for end-users (LitRev, FC)	
		Stakeholder Engagement (1)	I1.2.1 Show genuine respect for agreements with stakeholders (JK, JJ)2	
		Personnel Expertise (1)	I1.3.1 Having a dedicated environmental compliance monitor (JK)	
	Political (2)	Regulation and Policy (1)	I2.1.1 Establishing a 24-hour bidding system to maintain consistent energy prices and support the grid's stability (LC)	

		Political Engagement (1)	I2.2.1 Collaboration with Immigration Authorities to facilitate Foreign Workers (FC)	
	Technical (5)	Project Management (3)	I3.1.1 Ensuring timely delivery of equipment and payments in the contract (FC, JJ)	
			I3.1.2 Adherence to recommended planning framework (SH)	
			I3.1.3 Document intial issues comprehensively (JK)	
		Operations (2)	I3.2.1 Dispatching desicions based on resources and not on agreements (JK)	
			I3.2.2 Continous maintenance and quick issue resolution (LitRev)	
	Economic (6)	Internal Actions (3)	I4.1.1 A resilient, resourceful logisitcal and adaptful team (JK)	
			I4.1.2 Trust in the company leading the project (FC)	
			I4.1.3 Operate RE projects with a consistent crew (LC)	
		Market and Tariffs (2)	I4.2.1 Using flexible tariffs to optimize energy usage (FC)	
			I4.2.2 Politics-aligned tariff structure (SH)	
		Financing (1)	I4.3.1 Requirement of bid security and bank guarantees to ensure project success (FC)	
Monitoring & Evaluation (12)	Social (5)	Stakeholder Engagement (5)	M1.1.1 Recognize and involve all different stakeholders in Monitoring and Evaluation processes (JK)	M1.1.1.1 Identify metrics of success amongst every stakeholder (JK)
			M1.1.2 Form a committee of stakeholders to foster collaboration and shared responsibility (SH,JJ)	
			M1.1.3 Collaborate with relevant individuals/groups pursuing similar goals (LC)	
			M1.1.4 Maintain a steady flow of information through regular newsletters (SH)	
			M1.1.5 Establish connections with universities or PhDs to analyze collected data (LC)	
	Political (2)	Political Engagement and	M2.1.1 Ensure timely follow-up documentation for permitting to maintain project compliance (JK)	
			M2.1.2 Involve relevant administrative bodies to enhance collaboration and oversight (JJ)	

		Permitting (2)		
	Technical (4)	Operations (3)	M3.1.1 Monitor every possible component (LC)	
			M3.1.2 Predict systems future behavior from monitored data (LC, JJ)	
			M3.1.3 compare calculated theory to measured reality (JJ, LC)	
		Risk Assessment and Mitigation (1)	M3.2.1 Analyze the safety and practicability (JK)	
	Economical (1)	Financing (1)	M4.1.1 Allocating funds as reserves (SH)	

Technology Collaboration Programme

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