European Commission

Clean energy for EU islands:

Study on connection policies and management of energy systems under conditions of asynchronous generation in the non-interconnected islands

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List of Abbreviations

ACER	Agency for the Cooperation of Energy Regulators
ACM	Authority for Consumers and Markets
ARERA	Autorità di Regolazione per Energia Reti e Ambiente
BESS	Battery Energy Storage System
CAPEX	Capital Expenditures
CETA	Clean Energy Transition Agenda
CEER	Council of European Energy Regulators
CRE	Commission de Régulation de l'Énergie
DPE	Direction polynésienne de l'énergie
DRAAC	Direção Regional do Ambiente e Alteracoes Climaticas
DSM	Demand-side management
DSO	Distribution System Operator
EDA	Electricidade dos Açores
EDF	Électricité de France
EDF SEI	Électricité de France, Systèmes Énergétiques Insulaires
EdT	Énergie de Tahiti
EEM	Empresa de Electricidade da Madeira
ELMAR	Electriciteit-Maatschappij Aruba
ENTSO-E	European Network of Transmission System Operators
ERSE	Entidade Reguladora dos Serviços Energéticos
EV	Electric vehicle
EU	European Union
FiT	Feed-in tariff
HEDNO	Hellenic Electricity Distribution Network Operator
HVDC	High Voltage Direct Current Systems Code
IDAE	Instituto para la Diversificación y Ahorro de la Energía
IPTO	Independent Power Transmission Operator S.A.
JTF	Just Transition Fund
LV	Low voltage
MITECO	Ministerio para la Transición Ecológica y el Reto Demográfico
MoU	Memorandum of Understanding
MV	Mid-voltage
NRA	National Regulatory Authority
OLB	Openbaar Lichaam Bonaire
OPEX	Operational Expenditures
PCI	Project of Common Interest
PNRR	National Recovery and Resilience Plan
PPA	Power Purchasing Agreement
PPE	Programmation pluriannuelle de l'énergie
PTECan	Plan de Transición Energética de Canarias
PV	Photovoltaic
RAEWW	Regulatory Authority for Energy, Waste and Water

RES	Renewable energy sources
SER	Sociaal Economische Raad
SIDELEC	Syndicat intercommunal d'électricité de Réunion
SWAC	Seawater air-conditioning system
S2RENR	Schema de Raccordement au Reseau des Énergies Renouvelables de Réunion
TEN-E	The Trans-European Networks for Energy
TEP	Transport d'Énergie électrique en Polynésie
TFEU	Treaty on the Functioning of the European Union
TPP	Thermal power plant
TSO	Transmission System Operator
UNIEM	Unione Nazionale Imprese Elettriche Minori
V2G	Vehicle to grid
WEB	Water- en Energiebedrijf
ZNI	Zone non interconnectée

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Executive summary

In 2021 and 2022 the Clean energy for EU islands secretariat (the secretariat) conducted a study on the regulatory barriers affecting the clean energy transition of islands.[1] This provided significant insights on the operation of islands' electricity systems and formulated recommendations to overcome existing challenges. Grid constraints and the lack of security of supply were identified as two of the key barriers for the decarbonisation of EU islands' energy systems.

Building on that study, the secretariat has been focusing its recent work on the connection policies of renewable energy power plants and the management of energy systems under conditions of asynchronous generation, specifically in non-interconnected islands. The goal of the study is to develop key recommendations and guidance to support the integration of increased renewable energy production and storage while ensuring system stability and security of supply. The study deepens the understanding of the existing grid regulatory and operating constraints in 10 representative islands and groups of islands.

Scope

The secretariat analysed the legislative and regulatory framework in relation to renewable energy technologies, storage and grid flexibility solutions, renewable energy share, planned transition, permitting procedures, existing energy systems, existing and planned interconnections to other islands or mainland, grid connection and grid management policies.

To achieve the secure operation of electricity systems with a high share of asynchronous generation, three main components had to be analysed for the selected systems:

- Technology developments on the supply and demand side
- Electricity system operational practices
- Regulation reflected in grid connection policy and codes

[1] CE4EUI Secretariat, January 2023 (link)

The islands or groups of islands selected as case studies for this investigation are:

France

1. Réunion
Indian Ocean
EU's outermost regions

2. French Polynesia archipelago
Pacific Ocean
Overseas Countries and Territories

Netherlands

3. Aruba
Caribbean Sea
Overseas Countries and Territories

4. Bonaire
Caribbean Sea
Overseas Countries and Territories

Spain

5. Gran Canarias, Fuerteventura, and Lanzarote islands
Atlantic Ocean
EU's outermost regions

Italy

6. Aeolian Islands
Mediterranean Sea

Greece

7. Kos-Kalymnos
Mediterranean Sea

8. Rhodes
Mediterranean Sea

Portugal

9. Madeira and Porto Santo
Atlantic Ocean
EU's outermost regions

10. Azores archipelago
Atlantic Ocean
EU's outermost regions

Key challenges and recommendations

The in-depth analysis of the case studies, through desk research, interviews, and workshops provided tangible examples of the challenges that non-interconnected islands' electricity systems are facing in the transition to full decarbonisation. The identified challenges are grouped into the following five main categories:

- Power interruptions and outages due to multiple grid instabilities and system vulnerability to extreme weather conditions.
- High curtailment of variable renewable energy power plants to ensure system reliability.
- Lack of sufficient controllability of existing systems' assets and slow uptake of smartening initiatives due to financing needs.
- Limited resources to support the formulation of targeted regulatory frameworks to enable the transition from thermal to renewable-based systems.
- Complex and fragmented permitting and connection policies for renewable energy power plants.

In parallel, operational, regulatory, and legislative good practices, often tailor-made to the specific conditions of each case study, have been identified. From these, a list of recommended measures and actions for grid operators and energy regulators to enable the full decarbonisation of islands electricity systems was compiled. While the study provides more recommendations, 10 key recommendations are highlighted below. Of 10 recommendations 6 relate to technical solutions for grid operations and management while 4 relate to the required enabling regulatory and policy framework.

Recommendations

Operations and management

1 Promote hybrid power systems to integrate more renewables sources in island systems and enhance stability.

Hybrid power systems, combined technology power plants, consist of renewable generation integrated with other renewable generation or energy storage systems. Integrating hybrid solutions into the island electricity systems enables the integration of additional variable renewable energy generation. Hybrid power plants decrease curtailments, decrease the need for additional infrastructure investments, and provide system services, all while increasing security of supply and resilience of the system.

Best Practices:

Greek legislation provides strong support for the integration of hybrid power systems in non-interconnected islands with Law 5037/2023 (FEK B’ 78/28.03.2023).

Graciosa island in Azores, Portugal has achieved 60 % share of renewable energy in total energy demand. A hybrid power plant consisting of a wind power plant (4.5 MW), a PV power plant (1 MW), a Battery Energy Storage System (7.4 MW, 2.6 MWh), and an Energy Management System replaces the functioning diesel thermal power plant (4.7 MW) during longer periods throughout the year.

2 Procure centralised storage systems to reduce curtailments and benefit from the provision of ancillary services.

The addition of centralised storage in electricity systems increases operational flexibility of the grid and provides grid services. Additionally, on islands, centralised storage can bring benefits to multiple renewable energy system owners while taking advantages of economies of scale and land use optimisation. The results from operating such systems show grid stabilisation and increase in security and quality of supply while increasing variable renewable energy generation and decreasing curtailment. Battery Energy Storage Systems (BESS) also provide smoothing electricity generation, frequency and voltage control support, energy shifting and could lead to grid investment deferral.

Best Practices:

Centralised BESS is used as optimal techno-economic solution on the French EDF SEI operated islands’ electricity systems for the purpose of frequency regulation, voltage control, compensation due to fluctuations caused by renewable energy variability, shifting of renewable energy generated electricity, grid forming and black start.

In Madeira, Portugal the electricity company EEM has successfully used centralised BESS on the islands of Madeira and Porto Santo, to decrease curtailment of the renewable energy generation and to improve the quality and security of supply to the customers. Both systems have grid following capabilities, providing support for frequency regulation, voltage control and active and reactive power. In addition, the BESS in Porto Santo has grid forming capabilities as well provides inertia to the system.

3 Integrate long duration energy storage systems in energy planning to tackle the impact of seasonality.

Many EU islands face significant energy demand fluctuations due to tourist seasons. In some islands peak summer demand can be up to six times higher than the winter baseload. Long Duration Energy Storage systems, defined as modular large-scale energy storage solutions that can discharge over long periods of time, can be used to maximise the exploitation of variable renewable energy sources and ensure the security of supply throughout the year. Long Duration Energy Storage systems include thermal, electrochemical, mechanical, and chemical technologies which are often promoted as ideal solutions for the industrial decarbonisation. However, options such as pumped hydro, new battery solutions, hydrogen, or mechanical storage are of great benefit for non-interconnected island systems too. Choice of the optimal technology for Long Duration Energy Storage should be based on detailed techno-economic assessment of the overall island system.

Best practices:

The Island of Mallorca aims to create the first green hydrogen ecosystem in the Balearic Islands through the Green Hysland project. It will produce, generate, and distribute 300 tonnes of renewable hydrogen per year exploiting the abundant solar potential on the island. The transformation of solar energy to hydrogen will contribute to tackling seasonal energy demand. Green hydrogen will have multiple applications on the island: supply a fleet of fuel cell buses, generate heat and power for commercial and public buildings, supply auxiliary power for ferries and port operations and decarbonise the gas network.

4 Improve monitoring, control, and forecast of existing distributed renewable energy generation

Large scale renewable energy generation, and especially wind farms are subject to close control of system operators. However, distributed small-scale PV systems are not subject to the same control requirements and most often freely inject their electricity production to the electricity system. As a consequence, on many islands this causes congestion in the electricity systems, unable to take up additional renewable energy.

The integration of automated remote monitoring and control to existing renewable energy plants allows the system operator to dynamically control the plants and operate the system with higher flexibility and decrease curtailment. Regulation should ensure that the metering infrastructure installed with the distributed solar generation allows for future applications and interaction with grid operators. Further integration of monitoring and forecasting tools for existing power plants can provide system operators with essential data to enable dispatching optimisation under conditions of rapidly changing weather and load demands.

Existing publications:

Advanced forecasting of variable renewable power generation, IRENA, 2020. This study states that a key factor to enable deployment of advanced forecasting tools for variable renewable energy generation is the sufficient regulatory environment incentivising their use.

Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions, IEA Task 51, 2022. This report highlights best practices and recommendations for among others, forecasting tools and real-time measurements for grid operators and utility-scale generation.

5 Require the deployment of sector coupling solutions between islands' loads and infrastructures.

Sector-coupled operation of loads and infrastructures (sector-coupled with water, waste, transport, tourism etc.) can contribute to the integration of additional renewable energy generation into the electricity systems with limited capacity and ensure that the investments have multiple benefits for not only the energy sector. Sector-coupling, focusing on the island ecosystems, refers to the virtual or physical combined operation of electricity generation and supply, with other centralised or distributed loads. Such loads may be water and waste management infrastructures, charging infrastructure for electric vehicles, but also heating and cooling loads, depending on the climate zone of each island. To enable sector coupling, it is necessary to include sector coupling options in energy investment planning of grid operators and to incentivise end-users to effectively shift, delay or decrease their demand to help optimise the operation of the electricity system (matching supply and demand through demand side management).

Best practice:

The vehicle to grid project in Sao Miguel, Azores, Portugal operated for a period of a year and a half and showed that if not optimised with a system perspective, electric vehicle charging can cause additional needs for the operation of the thermal power plant; if optimised, electric vehicles can increase variable renewable energy integration during low demand periods, and thereby decrease curtailment. This pilot phase one is followed by the second phase currently operational.

6 Prioritise the smartening of the distribution grid, through advanced metering and control of demand and supply side, to enable the integration of more flexibility in the systems.

Broader digitisation and upgrading of electricity systems' infrastructure of the islands is necessary for a more stable and reliable system operation. Smartening the grid and developing the required communication tools are essential to efficiently operate a grid which integrates high amounts of variable RES, distributed generation and prosumers. Improved visibility and monitoring can help system operators leverage the available data to improve modelling and forecast of their systems. In addition, with available data regulatory bodies and governments can make informed decisions on the future tariffs. Tariffs can be used to control injection to the grid.

Best practice:

The Greek system operator for non-interconnected islands HEDNO implemented a project to develop infrastructure upgrades needed to apply the non-interconnected islands grid code. The project has already led to the smartening of energy management on 28 non interconnected islands. Infrastructure has been operative since 2022 including ICT equipment which has been installed in the premises of wind parks and hybrid power stations. A follow-up project will be implemented as of 2024-25 to upgrade and enhance the capabilities of existing systems by the integration of even smarter power management techniques. The result is anticipated to be the transformation of SCADA into energy control systems to support even greater renewable energy shares.

Planning, enabling regulatory and policy framework

7 Modernise grid codes to include requirements of increased operational functionalities for renewable energy systems to improve reliability and security of supply.

National grid codes often do not distinguish non-interconnected islands from the mainland electricity system. National grid codes should be updated to require additional/different capabilities from variable renewable energy generation operating in island electricity systems which can help ensure optimal costs and safe grid operation. The grid codes could, for instance, require renewable energy generators to have capabilities such as low-voltage ride through, bidirectional frequency control, high wind ride through, and high-temperature ride through, or include requirements on power quality, automatic control, or protection.

Best practice:

The Madeira grid code adopted in 2019 has added specific and demanding connection requirements for new renewable energy generation facilities that improve the integration of variable renewable energy in the electricity grid on Madeira and Porto Santo, and ensure that the variable renewable energy can help support the system when needed (e.g. during or following grid fault), such as: Low Voltage Ride Through; High Voltage Ride Through; Reactive and Active Current Injection; Rapid recovery of active power; and Frequency sensitivity modes.

8 Loosen the rules on unbundling and storage ownership to allow small island DSOs to develop and operate infrastructure to optimise system operation and asset management.

Some non-interconnected islands that are not exempted from the unbundling rules, face a lack of staff and skilled staff to enable the decarbonisation of islands' electricity systems. Unbundling rules, especially when applied in non-interconnected islands with very limited electricity market size, bring additional administrative burdens to system operators that can outweigh the potential benefits. Additionally, the prohibition for system operators to own, develop, manage, or operate energy storage facilities, can make it burdensome for system operators of non-interconnected island systems to adequately manage grid infrastructure. A derogation of specific articles of Directive 2019/944 can be requested for those islands where the benefits of unbundling do not outweigh the burden to utilities for non-interconnected energy systems. Regulations should nevertheless ensure fair access to the energy markets.

Existing publications

In Short paper on the ownership of Storage Facilities in the Electrical Distribution System, CEER, 2023 CEER provides a step-by-step guide on the tendering procedure and the derogation process defining under which circumstances DSOs are allowed to own, develop, operate, or manage electricity storage facilities. Steps include: tender design, ex-ante review by NRA, outcome of the tender procedure, request for approval by the DSO, ex-post assessment by NRA and regular public consultation.

9 Enable management of multiple aggregated distributed generation systems, through establishment of Virtual Power Plants, to improve system operation.

On islands, specifically due to their topography, wind speed and direction can vary in different areas. Consequently, joint management of multiple wind power plants, for instance into a single Virtual Power Plant, can help minimise curtailment and optimise use of existing generation plants. Additionally in case of system instability, aggregated control of small, distributed renewable energy generation systems can provide support to the non-interconnected island systems in terms of grid balancing and smoother operation. A regulatory framework can be put in place to allow joint management of multiple renewable energy plants provided that they bear the minimum compatibilities in terms of technical capabilities. Additionally, the legal framework should allow system operators, in case of emergencies, to control distributed renewable energy generation and ensure that the grid infrastructure can support it, as discussed under recommendation 4.

Best practice:

The VPP4ISLANDS project is a Horizon 2020 project that is integrating virtual energy storage technology, digital twin, and distributed ledger technology to enable enhanced VPPs and the creation of smart energy communities on islands. Here as well, aggregated control of distributed assets is being tested. Results of the project have not been made public yet, as the project has only ended in April 2024.

10 Develop tailor-made **remuneration schemes for curtailment** of renewable systems for the transitioning phase to full decarbonisation.

Curtailment of renewable energy generation is necessary to maintain system stability and security. While for the system operator it might be more economically and technically feasible to curtail generation than to invest in increasing grid flexibility, a solid and transparent regulatory framework on curtailment compensation mechanisms is needed. In some cases, curtailment remuneration schemes and arrangements are included in power purchasing agreements with the renewable energy generation plant owner. However, regulation should clarify in which instances which party (producer or system operator) bears the financial responsibility for curtailed energy. Such regulation decreases investment risk for both plant owner and the system operator.

Best practice:

On the island of Terceira, Azores, Portugal private investors get compensated for electricity-sale-loss in case of curtailment within their power purchase agreement. An agreement between the system operator and the private investors owning the wind power plant defines the profile of generation that would happen on the basis of the registered wind speeds and the technical limitations associated with the condition of the wind turbines available from SCADA systems of the wind power plant. Once the wind power plant is curtailed, the overall generation profile is used to calculate the electricity which is not accepted to the grid but would otherwise be generated from the installation.

Conclusions and next steps

While the analysis in this study focuses on non-interconnected islands, each recommendation in the study indicates if it can also be applied to electrically interconnected or even remote areas on the mainland, as well as weakly interconnected islands. Acknowledging that each of the island electricity systems is unique in the way it is operated and requires its own system analysis, most recommendations defined in this study can be taken up by all islands aiming to decarbonise and, specifically use variable renewable energy to harness their locally available natural resources for energy generation. Moreover, each of the recommendations has actions which can be implemented at the EU, national or local level.

Recommended actions are aimed to:

- **Improve planning** and operation of islands' electricity systems
- **Sensitise national grid** and renewable energy regulation to characteristics of island electricity systems

- **Prepare island electricity grids** for safe and reliable operation through energy transition
- **Ensure beneficial increased** integration of variable renewable generation

The responsibility for implementation lies with system operators, national regulatory authorities, and national and regional governments. Regulators and system operators active on the islands can collaborate and share experiences, learn from each other, and implement appropriate measures to achieve decarbonisation on (non-interconnected) islands. Additionally, the EU can play a significant role through gathering best practices, providing guidelines, and shaping funding programmes to require systemic changes. The Clean energy for EU islands secretariat will continue its role to bring islands and their stakeholders together in the joint aim to accelerate energy transition and foster sustainable development.

Introduction

In this study, the Clean energy for EU islands Secretariat (the secretariat) analyses the renewable energy sources **(RES) connection policies and management of energy systems under conditions of asynchronous generation in non-interconnected island electricity systems**. Based on the overview of existing policy and practice, the report indicates examples of best practices and provides recommendations and guidance to support the energy transition and sustainable uptake of RES on the European Union (EU) islands. This assessment has been done in collaboration with stakeholders engaged in policy development and the operation of island electricity systems. The study includes, in particular, recommendations and guidance on policy and regulatory developments needed for increased integration of renewable energy into the islands' electricity systems and consequent decarbonisation of EU islands.

In 2023, the secretariat published the **Study on regulatory barriers and recommendation for clean energy transition on EU islands**, which included a detailed analysis of the regulatory framework for seven Member States.[2] The study identifies several regulatory challenges faced by the seven Member States and proposes multiple measures for overcoming each of the challenges.[3] The barriers are common for all analysed Member States, while being uniquely reflected in local conditions. For instance, one of the barriers includes grid constraints and security of supply, which is reflected mainly in the inability of islands' electricity systems to integrate additional variable renewable energy sources. This barrier stems from renewable energy connection rules and procedures, lack of grid modernisation methodologies and lack of regulation for implementation of innovative technologies including energy storage.

Scope of the study

This study focuses on the policy and regulation for the operation of electricity systems of islands aiming to increase the integration of variable renewable energy generation. Stakeholders involved in the preparation of the study are electricity grid operators, national regulatory authorities, regional/national governments, and relevant European associations.

The **goal** of this study is to **further develop the understanding of the existing grid regulatory and operating constraints** and to help **prepare the grid regulation and operating procedures for the increasing uptake of renewable energy** technologies and the sustainable decarbonisation. Ten case studies of non-interconnected islands or groups of island systems, identified at the beginning of the study, have been chosen to represent the geographical, governance and technological variety of non-interconnected islands. The case studies provide tangible examples of challenges faced by non-interconnected island electricity systems and give a sense of the gaps in the policy or regulatory framework in the transition to further decarbonisation.

The study is presented in **four parts**. In the first part, the secretariat presents an overview of the EU policy and regulation that provides a basis for the enabling framework for the upgrade and development of electricity systems to support the decarbonisation, with a focus on island or non-

[2] Croatia, Greece, Italy, Spain, Ireland, Estonia, and Sweden

[3] Clean energy for EU islands, Study on Regulatory Barriers and Recommendations for Clean Energy Transition on EU Islands, 2023, (link)

interconnected systems. In the second part, the methodology used during the study development process is detailed. In the third part, the secretariat presents each of the 10 chosen case studies and the specific challenges their electricity systems are facing. In the last part, the recommendations and guidelines on overcoming these challenges through local, national, or EU action with identified if the action is applicable to non-interconnected islands only, or all EU islands. Finally, where possible recommendation is followed by reference to an existing publications and best practices from the islands.

Framework of the Study

Decarbonisation of non-interconnected island electricity systems

The EU has more than 100 islands which have non-interconnected island electricity systems. These non-interconnected islands are mainly part of six EU Member States: Greece, Italy, Spain, Portugal, France, and the Netherlands.[4]

As the electricity systems must have their own back-up and flexibility, the decarbonisation of non-interconnected islands and the related integration of variable renewable energy is more challenging, from the point of view of the grid, than on the interconnected islands or the mainland.

To achieve the secure operation of electricity systems with a high share of asynchronous generation, **three components** need to be analysed:

1. **Technology developments** both from the supply and demand side;
2. **Changes in electricity system operation** practices; and
3. **Electricity system regulation** reflected in grid connection policy and grid codes.

The current study identifies the challenges related to all these components.

While not all electricity systems have specific grid codes, they all have rules for operation and responsibilities defined by regulation, guidelines, or contracts between key stakeholders. The characteristics of these rules are defined based on the technical studies of the electricity systems, data collection and local, regional, or national strategic plans.

This report focuses mainly on energy planning, energy policy, RES connection, and operational practices.

Island context within the EU framework

The **Treaty on the Functioning of the European Union (TFEU)**[5] places particular emphasis on the unique situation and challenges of insular territories and specifically outermost regions.[6] Islands are included as type of region that faces severe and permanent natural or demographic challenges. Consequently, they shall be especially considered in the EU's economic, social, and territorial cohesion efforts aimed towards reducing regional disparities in development levels. Further, Member States are obliged to take this into account when implementing economic policies, towards the achievement of the Union's cohesion goal.[7]

TFEU lays out the many handicaps experienced by a specific group of islands, the outermost regions: Guadeloupe, French Guiana, Réunion, Martinique, Mayotte, and Saint-Martin (France), the Azores and Madeira (Portugal), and the Canary Islands (Spain). These permanent challenges include their remoteness, insularity, small size, difficult topography and/or climate, and economic dependence on a few products. Thereby, EU legislation foresees a number of derogations to account for the particular circumstances of these most remote islands.

[4] Excluding island Member States, such as Cyprus.
[5] Consolidated version of the Treaty on the Functioning of the European Union, *OJ C 326, 26.10.2012,* (link)
[6] Articles 174 and 349 of the TFEU, (link).
[7] Article 175 of the TFEU, (link).

Aside from the outermost regions, **TFEU**[8] stipulates that overseas countries and territories that have special relations with Denmark, France, and the Netherlands may also be associated with the EU. These include among others, New Caledonia and Dependencies, French Polynesia, French Southern and Antarctic Territories, Wallis and Futuna Islands, Mayotte, Saint Pierre and Miquelon, Aruba, Bonaire, Curaçao, Saba, Sint Eustatius, and Sint Maarten.

EU legislation for the clean energy transition

In 2020, the European Commission launched the **Clean Energy Package for all Europeans** that defines European climate and energy policy beyond 2020. Island regions were specifically referenced as ideal test beds for pilot initiatives on clean energy transition, turning them into lighthouses at the international level.

The **revised Renewable Energy Directive (RED 2023)**[9] sets renewable energy targets at the EU level and sub-targets for specific sectors.[10] With regards to grid management policies, the **Directive on common rules for the internal market for electricity (IMED)**[11] and the **Regulation on the internal market for electricity (IMER)**[12] set the rules for the internal energy market.

In 2021, the European Commission launched its **European Green Deal** setting the 2050 Net-Zero Emission goal for Europe, and an emissions reduction goal of 55% by 2030 (compared to 1990 levels). More ambitious energy and climate targets have been agreed by the EU's co-legislators within the framework of the **"Fit-for-55" package**.[13] Among others, it supplements the **RED** by increasing the targets set therein and aims to further accelerate the deployment of renewables.

In March 2022, the European Commission launched the **REPowerEU Communication**,[14] which reflected the EU's aim to end the dependency on Russian fossil fuel imports by 2030. REPowerEU encouraged Member States to find the quickest and cheapest ways to address the current energy crisis. The new, recast Energy Efficiency Directive (EED)[15] introduced changes from the previous directives 2018/2002 and 2012/27/EU, and included some updated clean energy targets.

The **current energy objectives** are:

- At least 55% cut in greenhouse gas emissions compared to 1990 levels;
- At least a 42.5%, with an aspiration to reach 45%, share of energy from renewable sources in the EU's gross final energy consumption in 2030; and
- At least 11.7% increase in energy savings/efficiency compared to the 2020 EU Reference Scenario .

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[8] Article 198 of the TFEU, (link).
[9] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), amended by Directive (EU) 2023/2413 (consolidated version), *OJ L 328 21.12.2018*, (link)
[10] European Commission, Renewable Energy Directive (link)
[11] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity, *OJ L 158, 14.6.2019, p. 125–199*, (link)
[12] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, *OJ L 158, 14.6.2019, p. 54–124*, (link)
[13] European Commission, Delivering the European Green Deal, (link)
[14] European Commission, REPowerEU – Affordable, secure, and sustainable energy for Europe, (link)
[15] Directive (EU) 2023/1791 of the European Parliament and of the Council of 13 September 2023 on energy efficiency and amending Regulation (EU) 2023/955 (recast), *OJ L 231, 20.9.2023, p. 1–111*, (link)

Network Codes

Achieving the above goals will **require significant upgrades to the electricity grid and the restructuring of the electricity sector and market**. To facilitate the internal energy market and the energy efficiency of the electricity market, EU DSO Entity and the European Network of Transmission System Operators (ENTSO-E) develop network codes under the guidance of the Agency for the Cooperation of Energy Regulators (ACER).

During the preparation or the update of network codes, the following aspects are reviewed to inform and shape the rules' characteristics: voltage levels, distribution and flexibility of load and generation, characteristics of thermal generators, energy policy, energy planning, and operational practices.[16] Each code is implemented independently by the European DSOs and TSOs.

These binding rules can be divided into four code families: connection, operations, market, and cybersecurity. On grids, the **following codes are applicable**:

- The **Demand Connection Code** sets harmonised requirements for the connection of large renewable energy and demand response facilities in the Member States.[17]
- The **Requirements for Generators Code**[18] sets out guidelines for connecting new or significantly upgraded power generating facilities, aiming to safeguard fair competition and renewable energy integration. Both this and the Demand Connection Code are currently under ongoing review, as the submitted revised versions have not yet been adopted.[19]
- The **High Voltage Direct Current Systems Code (HVDC)**[20] lays out harmonised criteria to connect these systems to the grid. This code creates a clear framework that safeguards legal certainty, system security, and electricity trading. However, as this code applies to HVDC transmission systems, it does not apply to most small connected systems or those outside of the TSO synchronous energy market areas.[21] Moreover, it allows for exceptional derogations to preserve the stability of the local network.
- The **Transmission System Operations Code**[22] creates a frequency control and services' framework, outlining requirements and principles for grid operational security, and detailing the division of responsibilities among system operators.
- The Electricity Directive (EU) 2019/944 includes key provisions to bring more flexibility in the form of demand response to the electricity markets and to improve their integration across the EU, by introducing a robust framework on demand response participation in the electricity market. Additionally, the current legal framework shall be extended by a new **Network Code on Demand Response**. EU DSO entity and ENTSO-E have drafted a proposal in close cooperation with key stakeholders based on ACER's framework guideline. This is the first time that both ENTSO-E and EU DSO Entity have worked on a network code draft together. They submitted the draft to ACER in May 2024. ACER will review the Network Code and submit it in 2025 to the European Commission for adoption. Demand response is crucial for integrating a growing share of renewables and new electricity loads safely and in a cost-effective manner. The new Network Code on Demand Response aims to address the remaining barriers to the participation of demand response and other distributed energy resources in the markets.
- ACER's guidelines aim to streamline access for smaller actors like consumers, filling regulatory gaps without overlapping existing laws, and opening participation in wholesale electricity markets. In this sense, distributed energy resources would benefit from support

measures to help them overcome the barriers preventing their entry into the market. In line with ACER's findings in its market monitoring report "**Demand response and other distributed energy resources: what barriers are holding them back?**", the implementation of an enabling legal framework, adequate incentives promoting flexibility, retail price interventions and/or clear boundaries concerning congestion management and balancing services market, could be some of the most impactful measures.[23]

Specificities of insularity reflected in the EU legislative framework

When it comes to EU legislation, island electricity systems are exempted from specific requirements. In this study, the secretariat highlights the differences in application of EU legislation and regulation to mainland and island electricity systems and points out where **specific regulatory solutions enable** the energy transition of small electricity systems, namely of small isolated systems[24] and outermost regions.

A detailed overview of relevant EU legal provisions that are either directed solely at islands or include, directly or indirectly, EU islands within its scope of application is provided in Annex 1: Extended EU policy framework. In particular, the EU legislative framework is analysed mainly on the following **6 key issues** that are of **high interest to achieve the decarbonisation** of the EU's islands, taking into account listed legislative framework:

- **Flexibility in distribution;**
- **Unbundling of system operators;**
- **Phasing out non-RES and fossil fuels;**
- **Financial incentives supporting renewable energy integration;**
- **Non-financial support for renewable energy integration; and**
- **Provisions concerning further aspects of grid operation.**

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[16] IRENA, SCALING UP VARIABLE RENEWABLE POWER: THE ROLE OF GRID CODES
[17] Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection, *OJ L 223, 18.8.2016, p. 10–54*, (link)
[18] Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators, *OJ L 112, 27.4.2016, p. 1–68* (link)
[19] ACER, ACER proposes amendments to the electricity grid connection network codes, 2023, (link)
[20] Commission Regulation (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules *OJ L 241, 8.9.2016, p. 1–65,* (link)
[21] ENTSO-E, Europe synchronous areas, (link)
[22] Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation*, OJ L 220, 25.8.2017, p. 1–120,* (link)
[23] ACER, 2023 Market Monitoring Report, 2023, (link)
[24] 'Small isolated system' means any system that had consumption of less than 3,000 GWh in the year 1996, where less than 5 % of annual consumption is obtained through interconnection with other systems. – Directive (EU) 2019/944 on common rules for the internal market for electricity (2019), *OJ L 158 p. 125–199*, Article 2(42).(link)

The wide projection of EU islands' clean energy transition

EU Grid Action Plan

As the EU's power grid experiences increasing pressure from the growing share of renewable energies, clean mobility, and electrification of demand, the electricity network needs to become more flexible, decentralised, and smart, and the crucial role of DSOs needs to be supported, for example in long-term investments and grid planning. In this sense, **ENTSO-E's Ten-Year Network Development Plan** indicates the need for cross-border transmission infrastructure to accommodate this demand.[25] Legislative revisions, such as the **revised RED**, aim to streamline the permitting process for renewable energy plants and their related infrastructure. The **IMER and the IMED** also contain pertinent rules concerning planning, network tariffs, and the roles of ENTSO-E and EU DSO Entity.

In light of these efforts, the European Commission issued in November 2023 the **Communication Grids, the missing link - An EU Action Plan for Grids (EU Grid Action Plan)**.[26] Its objective is to make Europe's electricity grids stronger, more interconnected, more digitalised and cyber-resilient, with a 14-point strategy and a strong focus on distribution networks. The measures range from flexible energy asset integration to demand response, focusing on the timely implementation of the agreed legal framework to align with the Union's 2030 targets for energy and climate as laid out in Article 2(11) of **Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action**.[27]

The **EU Grid Action Plan** lists **seven horizontal challenges** for advancing the EU's grid development:

- Accelerating the implementation of **existing PCIs and developing new** projects;
- Enhancing **long-term network planning**;
- Introducing a supportive, **future-proof regulatory framework**;
- Making **better use of existing grids and smartening** them;
- Improving **access to financing**;
- Ensuring faster and leaner **permitting processes**; and
- Strengthening **supply chains**.

The **EU Grid Action Plan** outlined fourteen actions to tackle the above challenges, out of which six show to be particularly relevant for island energy systems:

1. **ENTSO-E to enhance top-down planning towards 2050 by integrating the identification of offshore and onshore system needs and further considering hydrogen**: ENTSO-E is tasked with enhancing top-down planning towards 2050 by integrating offshore and onshore system needs, with a focus on hydrogen. National regulatory authorities (NRAs) are urged to ensure system operators assess flexibility needs in line with the upcoming revised Electricity Market Design, while TSOs and Member States must ensure adequate electricity transmission projects to meet EU infrastructure needs by 2030, 2040, and 2050, aligning with National Energy and Climate Plans.
2. **EU DSO Entity to support DSO grid planning by mapping the existence and characteristics of distribution development plans**: The EU DSO Entity is directed to support DSO grid planning by mapping distribution development plans and establishing best practices for coordinated

[25] ENTSO-E, The reference for the future European electricity system, (link)

[26] European Commission, Commission Communication: Grids, the missing link - An EU Action Plan for Grids, COM(2023) 757 final, (link)

[27] Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, *OJ L 328 21.12.2018, p.1* (link)

planning with TSOs. By mid-2024, the entity should explore case studies and publish recommendations for improving distribution network planning, engaging stakeholders transparently. This effort complements National Energy and Climate Plans, supporting distribution network development reforms by Member States. It is important to note that small DSOs serving less than 100,000 customers and small isolated systems may be exempted from this duty.

3. **European Commission to propose guiding principles identifying conditions under which anticipatory investments in grid projects should be granted**: The Commission will propose guiding principles for anticipatory investments in grid projects, focusing on future-proof infrastructure such as offshore networks, connections to ports, and smart grids supporting electric vehicle (EV) infrastructure and heat pump rollout.
4. **ENTSO-E and EU DSO Entity to agree on harmonised definitions for available grid hosting capacity for system operators and to establish a pan-EU overview**: ENTSO-E and the EU DSO Entity are urged to agree on harmonised definitions for available grid hosting capacity and establish a pan-EU overview by mid-2025. This overview will provide project developers with transparent information on grid connections, which in the end will benefit new projects on renewable energy and demand flexibility.
5. **ACER, in its next tariff report, to recommend best practices in relation to the promotion of smart grids and network efficiency technologies through tariff design, focusing on the consideration of operational expenditure (OPEX) in addition to capital expenditure (CAPEX) and benefit sharing**: In the upcoming 2025 tariff report, ACER will recommend best practices for promoting smart grids and network efficiency technologies through tariff design. NRAs are encouraged to regularly review network tariff methodologies, considering both CAPEX and OPEX, and implementing innovative approaches such as benefit sharing.
6. **European Commission to increase visibility on opportunities from EU funding programmes for smart grids and modernisation of distribution grids**: The Commission will increase the visibility of EU funding programmes for smart grids and distribution grid modernisation, urging Member States to consider available options for financing distribution grid projects. Technical assistance will be provided to help enterprises prepare funding applications, and collaboration with the EU DSO Entity will raise awareness of funding opportunities among DSO members.

Lastly, the **EU Grid Action Plan** emphasises **stakeholder engagement as crucial for the energy transition**, to minimise adverse effects on communities and on the environment while redistributing benefits equitably. The Plan introduced a Pact for Engagement to ensure early and consistent interaction with stakeholders, to address potential opposition and uphold high engagement standards. The targeted stakeholders are Member States, ACER and NRAs, ENTSO-E and TSOs, EU DSO Entity and DSOs, project promoters, and civil society.

Projects of Common Interest

Regulation (EU) 2022/869 on guidelines for trans-European energy infrastructure (the revised TEN-E Regulation) lays down new rules for **cross-border energy infrastructure**, with a main focus on implementing **Projects of Common Interest**. PCIs are key infrastructure projects with cross-border impact that are **necessary to interconnect** the European Union's energy infrastructure, as identified by the European Commission. Crucially, PCIs enjoy a **priority status** that ensures their rapid administrative and judicial treatment. Likewise, these projects are **eligible for financial assistance** both at the EU and national levels, the latter being subject to State aid rules.

The revised TEN-E Regulation identified 14 priority energy infrastructures. These are classified into 11 priority corridors for electricity, offshore grids, and hydrogen and electrolysers, and three new priority thematic areas: smart electricity grids, smart gas grids and a cross-border carbon dioxide network. On the contrary, natural gas and oil infrastructures are now excluded. Nevertheless, not all Member States are yet connected sufficiently to the European gas network, and island Member States particular continue to face significant challenges in terms of security of supply and energy isolation.[28] For this reason, ongoing PCIs approved under the previous Regulation's criteria shall not be negatively impacted by the revised Regulation's requirements.

In line with the **REPowerEU Plan**, the **revised TEN-E Regulation** incorporates **offshore grids as a new priority corridor**. Offshore grids play a key role in accommodating the growing share of RES into, for instance, meshed grids. Furthermore, with its five sea basins, the European Union holds great potential for offshore energy generation. Although still immature and expected to be mostly dependent on radial connections for their main grid integration,[29] offshore grid development presents itself as a very promising pathway to achieving sustainability goals, especially on islands.[30]

To be **considered PCI**, a project shall be **necessary** to realise at least one priority energy infrastructure, to present a **positive balance** between its **(long-term) benefits and costs**, and either have a significant **cross-border impact or involve at least two Member States**. Moreover, PCIs must **advance sustainability** in the European Union. Depending on which energy infrastructure it belongs to, this is assessed by the project's (aggregated) contribution to some of the following: market integration, security of supply, network security, flexibility, smart sector integration, quality of supply, efficient use of resources, increased resilience or security of CO_2 emissions' transport and storage, CO_2 emissions avoidance, enhanced competition, better service for customers, and overall sustainability advancements.

Moreover, **island projects** within the hydrogen interconnection, electrolyser, and smart electricity grid infrastructures must, besides their respective infrastructure-specific requirements, help to decrease energy isolation, support innovative solutions involving at least two Member States with a significant positive impact on the EU's 2030 targets for energy and climate and the 2050 climate neutrality objective, and contribute significantly to the sustainability of the islands and EU energy systems.

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[28] Revised TEN-E Regulation, Recital 13.
[29] ENTSO-E TYNDP, Sea-Basin ONDP Report, South and West Offshore Grids, 2024, (link)
[30] European Commission, Offshore Renewable Energy, (link)

Just transition of island electricity systems

In the broader context of transitioning to clean energy, it is crucial to recognise the specific energy dynamics of islands, which require customised solutions to meet their unique needs, and to effectively serve their communities and industries. European energy and climate policies should take these differences into account and empower local communities to actively participate in the transition process, fostering strong stakeholder engagement.

The Clean energy for EU islands Secretariat supports the multi-stakeholder energy transition in all its activities. The secretariat published the **Engagement guide**[31] in 2023 and the handbook **"From vision to action: how to tackle transition on EU islands: Methodological handbook."**[32] Both of these guideline documents stress the importance of quadruple helix stakeholder involvement, from public authorities and academia to civil society organisations and local business, for the successful decarbonisation of islands. **All the secretariat's activities involve engagement of local stakeholders**. While this report provides a specific look to the view of public authorities, NRAs and energy utility companies, the recommendations, guidance, and follow-up action should make sure to include all relevant stakeholders for the full decarbonisation of islands.

Similarly, the **EU Grid Action Plan** underscores stakeholder engagement as a fundamental aspect of the energy transition. A **key strategic measure** involves the launch of a **Pact for Engagement**, aiming for early, regular, and meaningful engagement with stakeholders. However, quantifying and monetising the successful avoidance of conflicts and delays can be challenging within complex regulatory frameworks. Best practices are shared among project promoters, but reinforcing the engagement framework is still essential to mitigate impacts on communities and nature and redistribute benefits. The Pact for Engagement, aimed at Member States, NRAs, system operators, and civil society, helped address potential public opposition and ensure high standards in stakeholder engagement.

Moreover, the **revised TEN-E Regulation** will continue to guide the identification and building of Projects of Common Interest, enhancing inclusivity and transparency in decision-making processes.

Lastly, **Eurelectric's Key recommendations on the decarbonisation of European Islands**[33] highlight stakeholder engagement as essential for island decarbonisation efforts. A **just transition requires having a skilled local workforce** trained in new energy technologies, crucial for installing, maintaining, and operating innovative energy systems like storage, micro-grids, and smart grids. However, skilled workforces have shrunk across all the key sectors, and this trend is only expected to continue in the future. For this reason, it is crucial to increase the workforce in these sectors, namely focusing on learning and life-long learning, enhancing relevant skills, and creating quality jobs and apprenticeships.[34] Moreover, **islands** (especially smaller or more isolated ones), many of which constitute border regions and/or are located on a Member State's peripheric area, tend **to face substantial limitations on their economic growth potential**. Islands are usually too small to allow economies of scale and may lack human capital and possess limited public resources in research and

[31] Clean energy for EU islands, Engagement guide, 2023 (link)

[32] Clean energy for EU islands, From vision to action: how to tackle transition on EU islands: Methodological handbook, 2022, (link)

[33] Eurelectric, Key recommendations on the decarbonisation of European Islands, (link)

[34] Regulation (EU) 2024/795 of the European Parliament and of the Council of 29 February 2024 establishing the Strategic Technologies for Europe Platform (STEP), *OJ L, 2024/795,* Recital 7. (link)

innovation.[35] Thus, in the insular context, building and retaining local capital becomes even more crucial. Raising public awareness and creating attractive working conditions are vital to avoid brain drain to other sectors.[36] For this reason, **Eurelectric advised that stakeholder engagement in islands should follow a bottom-up approach and effectively involve local community-level stakeholders** in the energy transition. In turn, this will create new duties for bigger actors: policymakers and local entities will play a vital role in tailoring solutions to island needs, while island energy managers will raise awareness among local populations, and utilities will provide the technical expertise needed to implement political objectives.

[35] European Parliament, European Parliamentary Research Service, Vasilis Margaras (rapporteur), *Islands of the EU: Taking account of their specific needs in EU policy*, PE 573.960 (Brussels: Members' Research Service, January 2016) (link)

[36] WWAP (United Nations World Water Assessment Programme), The United Nations World Water Development Report 2016, UNESCO, 2016, (link)

Methodological approach

This study addresses specific **policy and regulatory issues affecting the operation of non-interconnected island electricity systems under conditions of asynchronous generation**. The systems studied have a goal to increase the share of renewable energy generation, increasing variable generation. To identify challenges and provide recommendations related to renewable energy connection policies and management of electricity systems, **10 islands/groups of islands** were chosen as case studies. While these 10 islands/groups of islands are analysed in more detail, the barriers and recommendations outlined in the study are also relevant and replicable to other electrically connected and non-interconnected island systems within the EU.

The study is implemented in three steps starting with the choice of 10 case studies followed by data collection, workshops, and trainings.

Selection of 10 case studies

The secretariat selected islands or groups of islands to ensure representative geographical and jurisdiction coverage. The evaluation criteria to select the case studies were general (geographical) characteristics of the island/group of islands and the characteristics related to the Member State's legislative and regulatory framework. Geographical characteristics include geographical location, Member State, size, distance from the mainland, population, urban to rural ratio and island governance. Outermost regions and Overseas Countries and Territories were included in the selection of islands/group of islands.[37] The legislative and regulatory framework includes supported renewable energy, storage and grid flexibility solutions, renewable energy share, planned transition, permitting procedures, existing energy system, existing and planned interconnections to other islands or mainland, grid connection and grid management policies.

The **list of 10 islands/groups of islands taken as case studies** for this study are:

1. Gran Canarias, Fuerteventura, and Lanzarote islands, Canary Islands, Spain, Atlantic Ocean, EU's outermost regions
2. Azores archipelago, Portugal, Atlantic Ocean, EU's outermost regions
3. Madeira and Porto Santo, Portugal, Atlantic Ocean, EU's outermost regions
4. Réunion, France, Indian Ocean, EU's outermost regions
5. Rhodes island, Greece, Mediterranean Sea
6. Kos-Kalymnos islands, Greece, Mediterranean Sea
7. Aeolian Islands, Italy, Mediterranean Sea
8. Aruba, Netherlands, Caribbean Sea, Overseas Countries and Territories
9. Bonaire, Netherlands, Caribbean Sea, Overseas Countries and Territories
10. French Polynesia archipelago, France, Pacific Ocean, Overseas Countries and Territories

Data collection

The data for the study has been collected for the case studies on:

- The issues facing electricity systems of non-interconnected islands with an increased share of renewable energy, and
- Tools, instruments, and actions to prepare these systems and ensure their stability.

[37] European Commission, OCT, (link)

Different methods of data collection were used to complete the information needs for the study which include:

- Desk research gathering the information for the selected case studies. Relevant information from local stakeholders was collected through articles in local newspapers, or as part of communications provided by (local) advocacy groups. The information gathered included the governance on the islands, the relevant key actors, the energy system, and the renewable energy policy on the islands. This part of the research was done from April to December 2023.
- Information templates which were sent to regulators, island DSOs, and national authorities to collect very specific information/feedback. This included the collection of experiences (successful or unsuccessful) from local stakeholders, available through one-on-one contacts. This part of research was conducted from April 2023 until March 2024.
- Forty Semi-structured open-ended interviews with relevant actors on local and national level. This includes local DSOs, TSOs, NRAs, regional or national authorities, academic institutions, relevant European organisations. The aim of the interviews was to understand the current state of the electricity system and identify the key actions, drivers, opportunities, and obstacles for the implementation of the renewable energy specifically regarding renewable energy connection policies, renewable energy operation, grid management, use of innovative solutions (including storage and demand-side management), including possible ways to address or overcome them.

Forty interviews were conducted from June to September 2023 with relevant stakeholders on the local and national level. The list of interviewed stakeholders is provided in Annex 2. Based on the collected data the study provides an overview of the case study electricity systems, and the challenges faced to integrate variable renewable energy generation.

Workshops

The identified challenges were used to design 11 workshops, including a series of six online technical workshops titled "Future-proofing electricity systems" and five in-person workshops. These workshops were used to further dive into specific challenges and exchange best practices. The workshops also explored recommendations for steps different stakeholders could take to improve enabling frameworks for increased uptake and integration of renewable energy into the islands' electricity systems, ensuring secure and reliable operation.

The series of six online thematic workshops "Future-proofing electricity systems"

The series of thematic workshops "Future-proofing electricity systems" consisted of six online technical workshops. The goal of the technical workshops was to provide a platform for island stakeholders, namely DSOs, TSOs, regulatory authorities, and the governments to exchange experiences and jointly shape solutions to the identified challenges. EU associations (such as EU DSO Entity, Eurelectric) were involved in specific relevant topic discussions.

The series opened with a workshop designed to provide the big picture and set the stage. The goal was to introduce the main aspects needed for safely operating the non-interconnected grid with integrated variable renewable energy generation. The following workshops covered specific aspects in more details, such as requirements for renewable energy asynchronous producers, use of Battery Energy Storage Systems (BESS), demand-side management and flexibility of the system, and finally, what is needed for the complete decarbonisation of island systems to a 100% RES integration. The workshop series closed with the workshop focused on de-risking investment in renewable energy both from planning, government, and DSO point of view, but also from RES producer point of view.

The workshops were organised in English. They were designed to be interactive with the above-mentioned stakeholders taking active participation. The topic material was shared prior to the workshops with the invited participants, and they were asked to prepare material with examples.

The series of online workshops started on 11 October 2023 and lasted until 13 December 2023 with six workshops on the following topics:

- **Workshop 1: Key aspects of grid operation**
  The key aspects of safely operating non-interconnected systems with high share of asynchronous renewable energy generation
- **Workshop 2: RES requirements and rights**
  RES asynchronous generation in non-interconnected island systems
- **Workshop 3: BESS**
  Use of BESS within high-RES non-interconnected system
- **Workshop 4: Demand-side management**
  Use of distributed flexibility to help grid management for non-interconnected islands
- **Workshop 5: The 100% decarbonised systems**
  What is needed to completely turn off thermal power plants for 100% RES secure system operation?
- **Workshop 6: De-risking investments**
  De-risking investments in RES on the non-interconnected islands

All materials presented at the workshops together with the agendas can be found on the Secretariat's **website**. Additionally, Annex 3 provides the agendas for all workshops including participating stakeholders and topics discussed.

Five local in-person workshops

Five local in-person workshops were organised in five Member States (on islands whenever possible) to create follow-up actions for issues discussed in the thematic workshop series. These workshops were topic-specific depending on which enabling framework was the most important to discuss for the specific group of islands. The workshops were organised in local languages and took place from 13 November 2023 to 20 March 2024.

In-person workshops were implemented as follows:

- **Workshop Spain – Madrid, 13 November 2023**
  Topic: Energy storage regulation supporting Spanish islands' energy transition
  Stakeholders: Endesa (DSO), Red Electrica (TSO), Canary Islands regional government, Balearic Islands regional government, IDAE (energy agency), and MITECO (Ministry).
- **Workshop Portugal – Madeira, 25 January 2024**
  Topic: Ingredients needed for high-RES penetration and security of supply on Portuguese islands: Legislation, grid planning, remuneration schemes, and technical requirements for renewable energy.
  Stakeholders: EDA and EEM (DSOs), ERSA (national energy regulatory agency), Azores regional government, Madeira regional government, INESC TEC (research institution), associations of renewable generation investors.
- **Workshop Italy – Palermo, 26 January 2024**
  Topic: Towards a high penetration of RES in small Italian islands: what technical and

legislative challenges.
Stakeholders: Academia (Politecnico di Torino, La Sapienza, CNR), small islands DSOs (Liprari, Favignana,), UNIEM (Association of small DSOs), e-distribuzione (ENEL Group), Sicily regional government, local island governments (Lampedusa, Pantelleria, Lipari, Sicily), ARERA (Regulatory energy agency), MASE (Ministry for environment and energy), representatives of private companies.

- **Workshop Greece – Athens, 15 March 2024**
  Topic: Challenges along the way for the decarbonisation of the Greek islands
  Stakeholders: Ministries (Energy and Mineral Resource), DAFNI, RAEWW (NRA), HEDNO (DSO), ADMIE/IPTO (TSO), PPC, Waste Energy and Water Regulatory Authority
- **Workshop France – Tahiti, 20 March 2024**
  Topic: Facilitating the energy transition in the French Overseas: technical and legislative challenges
  Stakeholders: DPE (NRA and policy), EdT Engie (DSO), TEP (TSO), Polynesian Ministry of Energy

Full agendas, list of participating stakeholders and conclusions for each of the workshops can be found in Annex 4.

The findings of the desk research and workshops form input for the recommendations and guidance for overcoming the identified barriers in this study.

Electricity systems of non-interconnected islands

The study identifies and analyses specific issues facing the management of non-interconnected islands' electricity systems under conditions of a high share of asynchronous renewable energy generation. To identify and address specific issues, as well as make challenges of non-interconnected island systems more tangible, 10 islands or island groups were selected as case studies and analysed in more detail.[38]

Each case study presented below gives an overview of the governance, the key stakeholders, the energy system, electricity generation, grid status and management, and the renewable energy policy and connection policy of the island or group of islands. Each case study ends with the list of key challenges faced by the electricity system of the relevant island or group of islands in the process of integration of variable renewable energy generation. The chapter concludes with the overview of the main challenges faced by all case studies.

[38] For detailed motivation on the selection of the case studies, please see: CE4EUI3 T3 Proposal of 10 islands FINAL 20230512.docx.

Gran Canaria, Fuerteventura, and Lanzarote islands, Canary Islands, Spain

Governance

Gran Canaria, Fuerteventura, and Lanzarote are three of the seven islands constituting the Canary Islands archipelago. The Canary Islands have a population of 2.2 million inhabitants, representing 47% of the overall insular population in Spain. Annually, the islands are visited by a tourist population of typically 6-7 times the local resident population.

The Canary Islands are an autonomous region of Spain. This means that they have a certain degree of self-government within the framework of the Spanish state. The islands have a parliamentary system of government, with a unicameral legislature. The president of the Canarian Government (Gobierno de Canarias) is the head of the regional executive and is elected by the Parliament.

While the Spanish Government is responsible for certain areas of governance, such as foreign policy, defence, and national security, the Canary Islands' regional government has significant autonomy in most other areas. Competences over energy are shared between both governments.

The powers and responsibilities of the Canarian Government are set out in the **Statute of Autonomy of the Canary Islands (Estatuto de Autonomía de Canarias)**, which was approved in 1982 and subsequently amended in 1996, 2006, and 2018. The Statute defines the institutional framework of the autonomous community, including its competences in areas such as education, healthcare, culture, and the environment.

The capital of the Canary Islands is shared between the capital cities of its two provinces: Las Palmas de Gran Canaria, of Las Palmas, and Santa Cruz de Tenerife, of the homonymous province. Gran Canaria is the third largest island of the archipelago, after Tenerife and Fuerteventura, and Lanzarote is the fourth. The new regional government has been set up after the regional elections in June 2023. Gran Canaria and Tenerife have their own energy agencies and smaller islands have similar offices: the Insular Council or insular offices. The insular offices do not have own competences and fall under the authority of the regional government.

Relevant key actors

The electricity grid on the small and medium voltage level is operated by the DSO Endesa.[39] Endesa is a leading Spanish electricity company and is 70% owned by the Enel Group.

The high voltage grid is operated by Red Electrica, the partially publicly owned TSO of the Spanish mainland and island region. It is a part of the Redeia Group.

The Ministry for the Ecological Transition and the Demographic Challenge, Ministerio para la Transición Ecológica y el Reto Demográfico (MITECO) is responsible for the elaboration of the national legislation on energy, national energy policy including renewables, measures intended to ensure the energy supply, as well as the proposal and execution of the Government's policy to combat climate change. Furthermore, MITECO is the coordinator for the national organisation for energy matters, the Institute for the Diversification and Saving of Energy, Instituto para la Diversificación y Ahorro de la Energía (IDAE). IDAE has a technical office for clean energy and smart projects on the islands which acts as a coordinator fostering information exchange among various stakeholders on the islands,

[39] Endesa (link)

promoting dissemination of best practices, and implementing support programmes for energy transition on the islands.[40]

Energy system

The Canary Islands' government declared a climate emergency in 2019, announcing a plan to decarbonise the Canary Islands economy by 2040.[41] The plan on how this will be implemented was integrated in the **Energy transition plan of Canary Islands, Plan de Transición Energética de Canarias (PTECan)**.[42] In the PTECan, several specific strategies for the energy sector are prioritised to achieve the complete decarbonisation: PV self-consumption, energy storage, electric vehicles, geothermal energy, manageable generation, marine renewables, green hydrogen and smart grids.[43]

Generation

The Canary Islands' electricity systems had a share of 20.2% renewable energy in the overall electricity generation in 2022. The energy mix of all islands for 2022 is provided in the Figure 1 below.

In 2022, Gran Canaria had a 23.7% share of renewable energy in electricity generation, while the electricity system of Fuerteventura-Lanzarote had a 14.8% share.

Fuentes de energía primaria	Gran Canaria	Tenerife	Lanzarote	Fuerteventura	La Palma	La Gomera	El Hierro	Canarias
PRODUCTOS DERIVADOS DEL PETRÓLEO								
Centrales térmicas	999,2	1.046,5	232,3	187,0	105,3	21,2	14,9	**2.606**
Refinería	-	25,9	-	-	-	-	-	**25,9**
Cogeneración	24,9	39,2	-	-	-	-	-	**64,1**
Total productos derivados petróleo	**1.024,1**	**1.111,6**	**232,3**	**187,0**	**105,3**	**21,2**	**14,9**	**2.696**
FUENTES RENOVABLES								
Eólica	238,4	222,6	31,5	64,9	7,0	0,36	-	**565**
Fotovoltaica	71,2	107,6	7,5	17,9	3,3	0,01	0,03	**208**
Minihidráulica	-	1,2	-	-	0,8	-	-	**2,0**
Hidroeólica	-	-	-	-	-	-	22,8	**22,8**
Biogás (vertedero)	-	1,6	2,1	-	-	-	-	**3,7**
Total fuentes renovables	**309,6**	**333,0**	**41,1**	**82,8**	**11,0**	**0,4**	**22,8**	**801**
TOTAL	**1.334**	**1.445**	**273**	**270**	**116**	**21,5**	**37,7**	**3.497**

Unidades: Megavatios MW. Potencia fotovoltaica en inversores. Tecnologías de productos derivados del petróleo: potencia en bornes del alternador.

Figure 1 Table of primary energy generation sources for each of the Canary Islands. Units are expressed in MW. The table is taken directly from the Annual energy report of the Canary Islands 2022.[44]

The main sources of renewable electricity on all islands are wind power plants, followed by PV. Hence, most of the installed renewable energy is variable.

[40] IDAE's Technical office for clean energy and smart projects (link)
[41] Canaries Government, Decarbonisation Plan, 2019, (link)
[42] Canaries Government, PTECan, 2019, (link)
[43] Canaries Government, PTECan, 2019, (link)
[44] Canaries Government, Table 50 of *Anuario Energético de Canarias 2022,* 2022, (link)

While the Canary Islands have potential for locally produced renewable energy, they still mainly depend on imported fossil fuels. In addition, the islands set a high priority on a water-energy nexus[45] with desalination needs.

Grid status and management

The Canary Islands' electricity system consists of 6 non-interconnected electricity systems. Of these, Gran Canaria on the one hand, and Fuerteventura and Lanzarote islands on the other hand, represent two non-interconnected island systems, with Fuerteventura and Lanzarote interconnected with line connections, as shown in Figure 2. Prior to the **Transmission Network Development Plan 2021-2026**, there was one 66 kV interconnection in service. The Transmission Network Development Plan 2021-2026 introduced one 132 kV connection in 2022. The interconnection has helped stabilise the grid for both islands and allow for excess energy to be shared between islands.

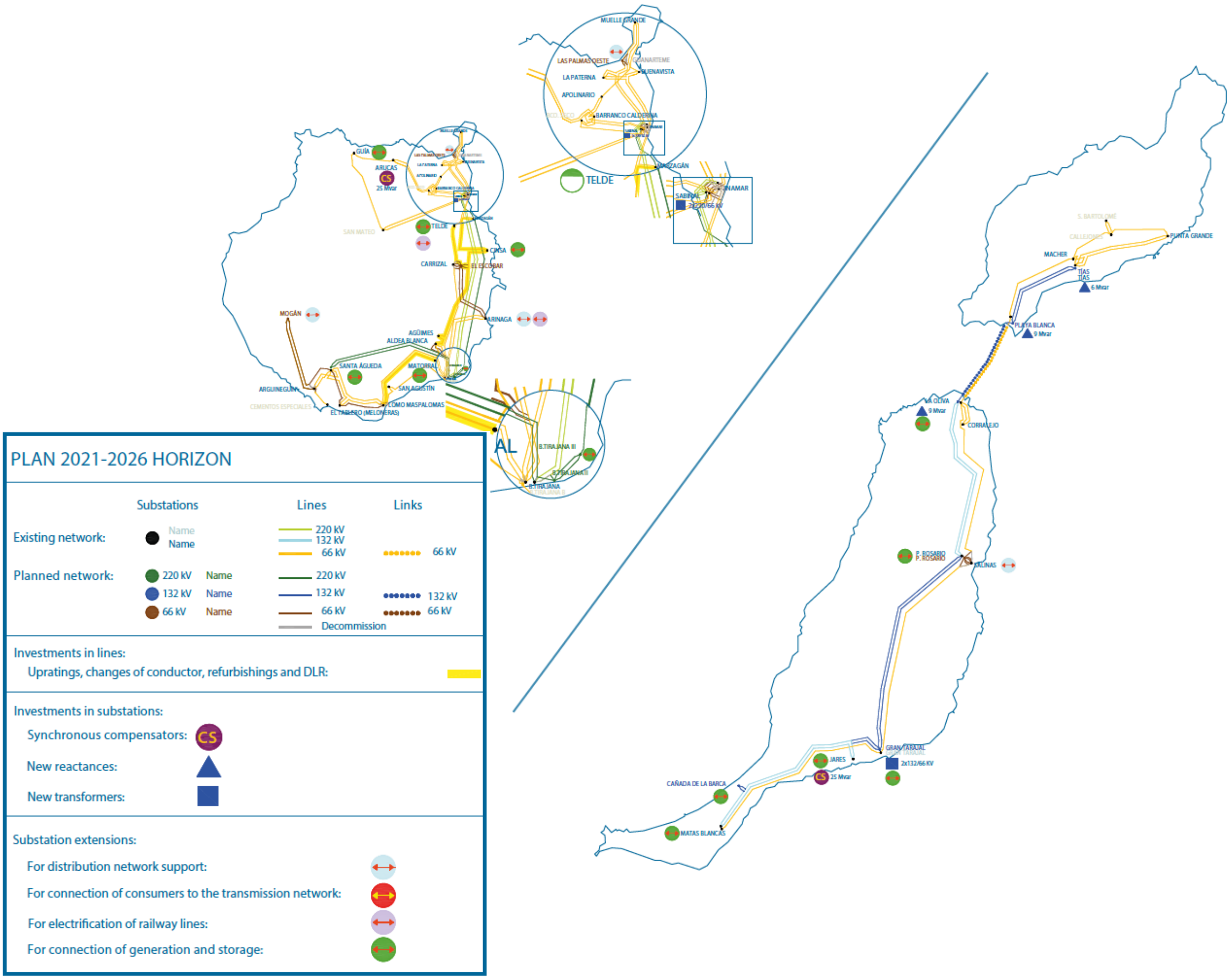

Figure 2 Electricity transmission systems of the Gran Canaria system and the Fuerteventura-Lanzarote system with planned modifications, taken from the Transmission network development plan 2021-2026[46]

[45] IEA, Introduction to the water-energy nexus, 2020 (link)

[46] RED Eléctrica, Transmission network development plan 2021-2026, (link)

The southeast of the Gran Canaria island has a high wind/PV potential and therefore has a high capacity for additional renewable energy generation, and especially the northern but also the southern side of the island, where the majority of the touristic infrastructure is located, have a concentrated consumption. This situation creates a challenge for the system. In consequence, the TSO foresees an increase in system inertia and improved voltage regulation through the introduction of a synchronous condenser in the north part of the island. Similarly, a synchronous condenser is planned to be added to the system of Fuerteventura. Both synchronous condensers are represented in Figure 8 with a burgundy circle.

While the **Transmission Network Development Plan 2021-2026** introduces some key investments needed for increased stability of the electricity system, there is a need for enhanced coordination in the development plans of the transmission and Distribution System Operators.[47] Only a coordinated effort and planning of the complete electricity system can ensure optimal techno-economic investments enabling higher integration of renewable energy. This includes attention to grid infrastructure, assets, and planned generation plants and their technical capabilities.

The growing capacity of RES in the Canary Islands sees a steady increase in curtailment, reaching more than 3.25% for Gran Canaria and more than 6.9% for Fuerteventura-Lanzarote for 2022. **Increased curtailment** in the islands presents particularities:

- Happens mostly **during summer**. When the renewable energy generation is high, the variable RES curtailment for grid stability purposes increases, specifically that related to decreased frequency variations. That being said, most curtailment situations are due to balancing between demand and the technical minimum of thermal must-run units. Active power management, including frequency control (frequency variation sensitivity mode – overfrequency-underfrequency) has been introduced as a requirement[48] for variable renewable energy generation, helping decrease the problem. Currently still half of the installed renewable energy generation do not comply to the active power management requirement.
- Presents the need for **spinning reserve at low load periods**, requires thermal power plants to operate. Due to their relatively high technical minima for operation, there is no need for additional generation, leading to curtailment of RES. Upgrades or renewal of the thermal power plants are needed. The overall system could benefit from increased flexibility by using energy storage systems.
- **Investments in the grid flexibility** are needed to ensure a decrease in curtailment with current and future integration of RES. In addition, delay to grid-forming regulation is creating delays in storage development.

The addition of a pumped hydro plant to the Gran Canaria energy system is expected to decrease curtailment by providing flexibility and inertia to the system.

Historically, the TSO had collaboration with large consumers that offer needed demand-side management (reduction of consumption and disconnection during underfrequency events) for the

[47] The process of defining the national transmission development plan in Spain is a participative procedure comprising several iterations where all system stakeholders can participate, proposing and discussing the foreseen developments. The DSOs are fully involved in this process.

[48] Network code related to technical capabilities applicable to non-peninsular territories, P.O. 12.2 SENP

benefit of a lower electricity tariff. Aside from this, price signals[49] are currently defined based on demand, which is not optimal for fostering the use of storage or demand response.

Renewable energy policy

The renewable energy policy of the islands foresees an increased use of local resources for energy generation, including a pumped hydro plant, additional PV generation, and geothermal generation.

Gran Canaria

With already over 20% RES share, including 266 MW of installed wind power and 62 MW of installed PV, there are plans for additional developments including:

- 1 pumped hydro station with 200 MW installed capacity (Chira-Soria);
- 16 PV plants (totalling 37,948 MW) through the government's SolCan programme; in total, approved PV developments amount to 373 MW of capacity;
- 1 geothermal power plant; and
- 52 MW of wind power.

Fuerteventura and Lanzarote

Fuerteventura is one of the oldest and most eroded Canary Islands and has the flattest topography of the archipelago. On the contrary, Lanzarote presents a rugged terrain, partly the result of the intense volcanic eruptions in the 18th and 19th centuries. The islands have a good potential for wind which is already used on the islands. While the energy generation systems on Fuerteventura and Lanzarote have over 20% share of RES, there are plans for additional installations, specifically:

- Fuerteventura, with an additional 2 PV plants (totalling 6,330 MW) through the SolCan programme; in total, there are 18 MW of wind and 110 MW of PV developments planned (adding up to the 70 MW of wind and 28 MW of PV installed); and
- Lanzarote, with the installation of 48 MW of new PV, some new 38 MW of wind adding up to the already installed 25 MW, and a 10 MW geothermal power plant.

Most of the planned installations above are in the permitting process.

The mutually connected islands of Fuerteventura and Lanzarote experience annual variations in electricity demand. Exceeding a 50% share of renewable energy penetration would lead to periods of excess generation and capacity shortage.[50] As potential solutions, it would be useful if the Fuerteventura-Lanzarote system could be interconnected with other islands to export the surplus generated energy, make use of options for seasonal storage, and implement demand-side management to decrease or shift demand at peaks. Feasibility studies are currently being carried out.

Renewable energy connection policy

Renewable energy generation with an installed capacity of more than 0.5 MW requires approval for connection from both the DSO and the TSO. This regulatory requirement creates a barrier for increased renewable energy generation. In the access and connection procedure for applications above 0.5 MW, there has to be grid capacity both at the DSO and TSO levels. Due to capacity

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[49] For detailed description of the electricity price signal in the non-peninsular systems please refer to the Annex 2 of the *Study on regulatory barriers and recommendations for clean energy transition on the islands – Spain* (link)

[50] P.M. Batista, Upsala University, Feasibility analysis for the decarbonisation of a decentralised grid system: A case study for the island of Fuerteventura, Spain, 2022 (link)

constraints on the transmission grid, the result of the analysis of the TSO is that, in most cases, there is not enough capacity to install new plants above this capacity threshold. In fact, outdated existing RES installations have a considerable negative impact on grid capacity at the TSO level. Due to these capacity constraints, the TSO has concluded that some network nodes reached their capacity limit and hence impede the overall installation of new plants above this capacity. As a consequence, requests do not get approved even if there is significant available capacity on the distribution level.[51] Therefore, only renewable energy generation smaller than 0.5 MW will avoid experiencing problems with regard to permitting. Consequently, the distribution system experiences increased installation of the distributed low-capacity RES installations. This in turn requires an increase in local flexibility or implementation of demand-side management.

In addition, permitting procedures are also complex for larger plants of above 0.5 MW of installed capacity, with administrative (land use) and environmental authorities delaying the permitting process beyond allowed legal time limitations. In the current situation, many investors decide on small RES installations that do not require environmental permits.

Key challenges

Based on the above analysis, the key challenges facing the Canary Islands' electricity systems relevant for the increased integration of variable renewable energy generation are:

- **Increased curtailment of variable renewable energy generation.** Variable renewable energy generation has been causing undesired frequency variations. Even though the grid codes in force in the Canary Islands are more demanding compared to the mainland, additional solutions are needed for the increased flexibility of the electricity system.
- **Lack of system flexibility, voltage variations, and the requirement of minimum system inertia** are slowing down the integration of additional variable renewable energy generation and enforcing the dependence on generation based on fossil fuels.

  Existing thermal power plants are fossil fuel-based, and there is a need for their upgrade or renewal. There is a need for increased flexibility of the electricity system using battery storage systems or other alternatives (such as hydrogen, seasonal storage, stand-alone storage, and demand response). Solutions should be analysed to find an optimal energy mix for the full decarbonisation of the islands.
  - **A new regulation for stand-alone energy storage** is being established.[52] Under these rules, stored energy fed into the grid shall be treated in the same way as power plants in terms of access and connection to the grid and in permit-granting processes in the future.
- **Long and unnecessarily complex permitting procedures for renewable energy plants above 0.5 MW.** As explained above, the permitting procedure for renewable energy plants above 0.5 MW is complex (including land use, and environmental permits). Additionally, the permitting request needs approval from the DSO and TSO from the point of view of network capacity, which is specifically an issue on the level of the transmission grid. This results in the installation of a large number of small-capacity distributed generation plants.

[51] Analysis provided by Canary islands DSO, Endesa.

[52] By means of Royal Decree-Law 23/2023 which introduced an amendment in Article 6 of Law 24/2013, of 26th December. Later on, several aspects were regulated in Royal Decree 1183/2020 and Article 115 of Royal Decree 1955/2000.

Madeira and Porto Santo, Portugal

Governance

Madeira and Porto Santo are two inhabited islands in the Madeira archipelago, shown in Figure 3. The islands are not connected to the mainland, nor to each other. Madeira is 741 km^2 in size and Porto Santo is much smaller with an area of 42 km^2. The total population of Madeira and Porto Santo is of 252,693 inhabitants (247,484 on Madeira and 5,209 on Porto Santo), which represents 51% of the total island population of Portugal.[53]

The Madeira archipelago (Madeira and Porto Santo) is an autonomous region of Portugal with its own regional government.[54] The regional capital, Funchal, is located on Madeira. Madeira has 10 municipalities and Porto Santo has 1 municipality. The regional government of Madeira is responsible for the policy of the region and adopts the necessary measures to promote economic and social development.

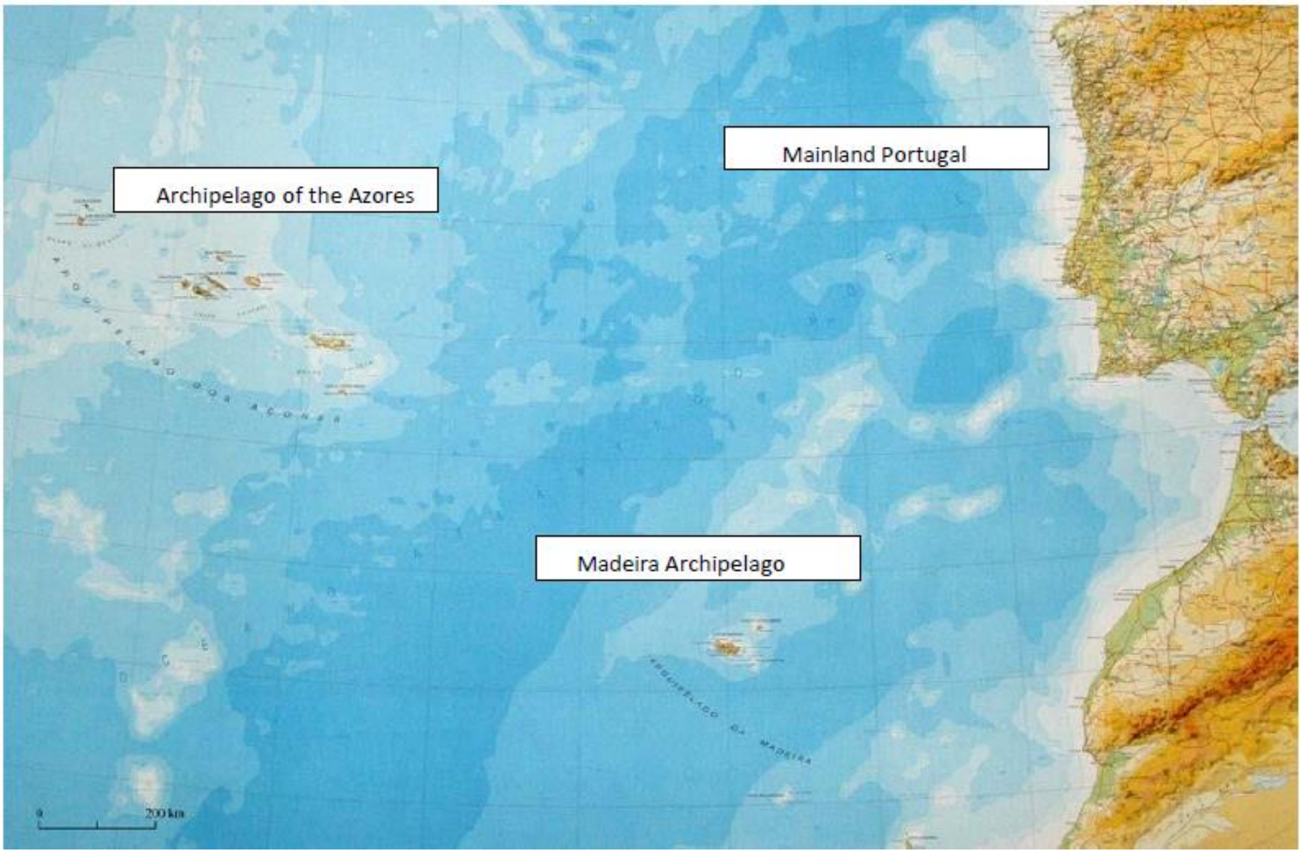


Figure 3 Location of Madeira and Azores archipelagos in relation to Portugal's mainland[55]

Relevant key actors

The electricity systems of the Madeira islands are operated by the Empresa de Electricidade da Madeira (EEM). EEM is a vertically integrated company, responsible for the generation, transmission, distribution, and supply of electricity, and for the acquisition of electric energy from private producers. Unlike stipulated in the **IMED**, the activities of the energy system on these islands are not

[53] Madeira in figures 2022 (link)
[54] Madeira regional government (link)
[55] Carta de Portugal Continental e Regiões Autónomas, IGP, 2003, SECAP Madeira (link)

unbundled. EEM's activities are regulated by the national Energy Services Regulatory Authority, Entidade Reguladora dos Serviços Energéticos (ERSE) since 2003. EEM is 100% owned by the regional government of Madeira.

ERSE regulates the natural gas and electricity sectors in Portugal. It is an independent entity with competences to organise regulations on access to the grids, commercial relations, tariffs, quality of service of the DSO and TSO, and approval of investment plans on the grids.

Direção Regional do Ambiente e Alteracoes Climaticas (DRAAC) is the Madeira region's regional department for the environment and climate change,[56] and the Direção Regional de Energia (DREn) is the Madeira region's regional department for energy.[57] DREn is responsible for licencing and technical regulations such as the Grid Code.

Energy system

Madeira's electricity system has a peak power of 146 MW, with 874 GWh of energy demand in 2022. Its electricity system includes a 6.6 kV, 30 kV, and 60 kV network. The smart meter installation rate in Madeira is low at 4.3 %, with an ongoing project to complete the rollout by 2025.[58]

On the other hand, Porto Santo has a smaller electricity system with a peak power of 7.9 MW, with 36 GWh of electricity demand in 2022. Porto Santo is characterised by high seasonality due to tourism. The Porto Santo network is operated at 6.6 and 30 kV networks. The smart meter installation is 100%.

Generation

Madeira Island's electricity system had a 33.4% share of renewable energy **in electricity production in 2022**, while Porto Santo Island had a 12.2% share of renewable energy in electricity production for the same year**.**

In Madeira, electricity generation is provided by various sources, as shown in Figure 4 below. Renewable energy generation mainly consists of hydropower (including small run-off hydro and pumped hydro installations operational since 2006), wind farms, PV, and biogas waste generation.

The electricity generation plants in Madeira Island include:[59,60]

- 2 thermal power plants (203 MW – 1 on diesel, and 1 on diesel and natural gas);[61]
- 10 hydropower plants (73 MW);
- 9 wind power plants (63 MW);
- 3 PV plants (15 MW);
- 770 distributed PV micro or mini producers (10 MW); and
- 1 solid waste plant (8 MW).

In addition, the system flexibility is supported by:

- 2 pumped hydro storage (27.75 MW, 160 MWh); and

[56] Direção Regional do Ambiente e Alteracoes Climaticas (link)
[57] Direção Regional de Energia (link)
[58] EEM Smart metering project (link)
[59] Madeira Lighthouse island INSULAE project (link)
[60] Renewable energy dispatch in Madeira island, 6th International Hybrid power systems workshop, 2022 (link)
[61] There is also a private thermal power plant that runs on diesel, far from EEM's thermal power plants.

- 1 BESS (15 MW/16.4 MWh).

To further support the system, there is a plan for the installation of a synchronous condenser (15 MVA, 10s).

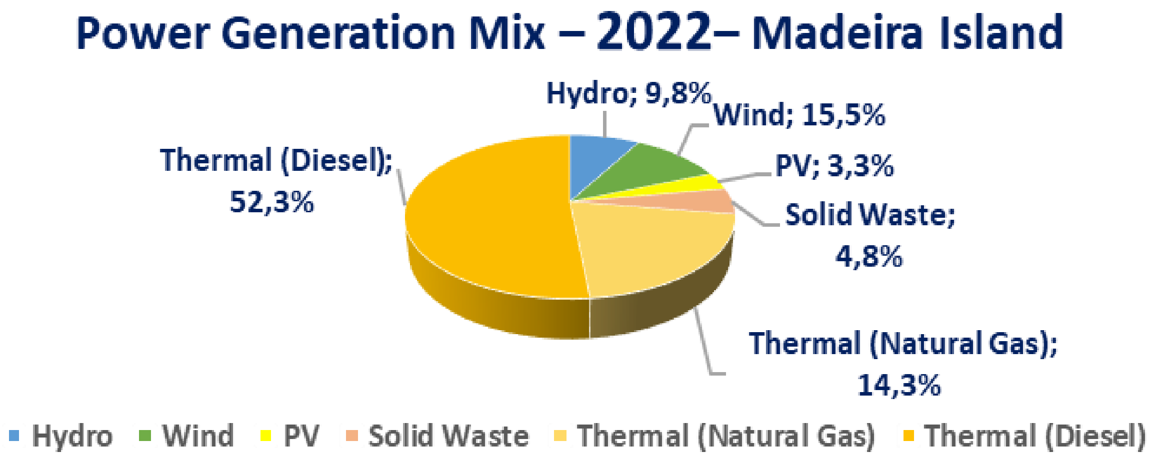


Figure 4 Madeira electricity generation share by technology, EEM 2023

In Porto Santo, electricity production comes from thermal generation, PV and wind installations as indicated in Figure 5:

- 1 thermal power plant (17 MW);
- 1 wind power plant (0.7 MW);
- 1 PV plant (2 MW); and
- 20 micro-PV plants (0.6 MW total).

With regards to the electricity system (Figure 6), flexibility is further supported with BESS (5.4 MVA / 4.3 MW -minimum power- / 3.3 MWh -BoL-) with plans for an additional BESS installation (8.9 MW, 17.8 MWh).

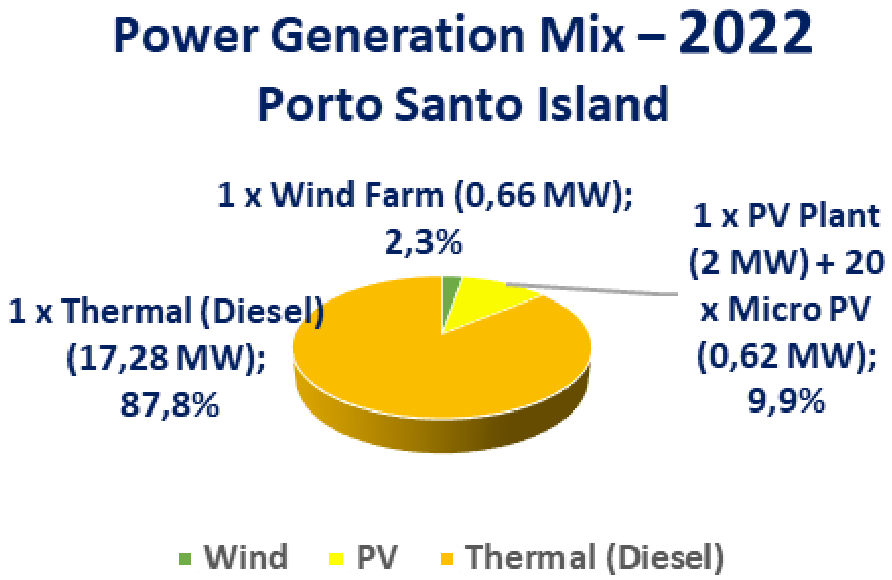


Figure 5 Porto Santo electricity generation share by technology, EEM 2023

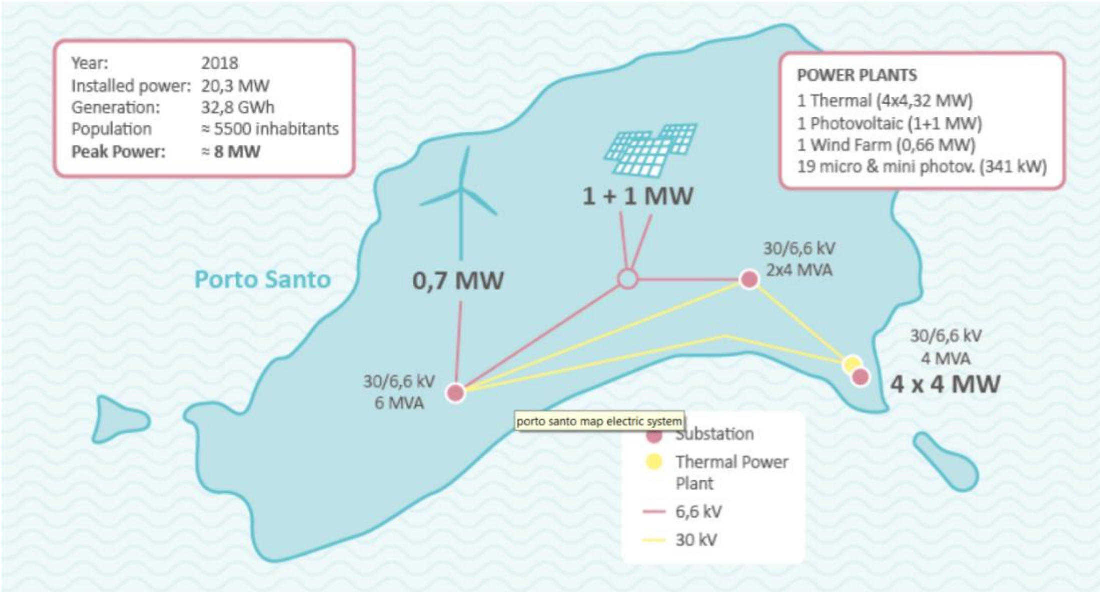


Figure 6 Porto Santo electricity system scheme [62]

Grid status and management

Madeira and Porto Santo have two electrically non-interconnected electricity systems.

The general rights and obligations of consumers, prosumers and plant operators are defined in **Decree-Law 15/2022, from 14 January 2022**, that establishes the organisation and functioning of the Portuguese electricity grid system, transposing **IMED** and **RED 2018**. Based on this law, ERSE defines the roles and tasks of the TSO and DSO, such as:

- Regulation for network operation (**Regulamento de Operação das Redes**);[63]
- Manual of procedures for the global management of the electricity system (**Manual de Procedimentos da Gestão Global do Sistema**).[64]

In addition to the national legislation, the autonomous systems of Madeira and the Azores archipelagos adopted bespoke regulations and procedures to manage the operation of the electrical systems, such as:

- Fundamentals of the Electricity Sector – **Regional Legislative Decree No. 10/2023/M of 19 January 2023** - Establishes the organisation and functioning of the electrical system of the Autonomous Region of Madeira, adapting the regime provided for in **Decree-Law no. 15/2022**;
- Madeira Grid Code – **Regional Regulatory Decree No. 8/2019/M of 6th of November 2019** – Defines the operation of electricity transmission and the distribution network in the Autonomous Region of Madeira;

[62] Porto Santo electricity system scheme, Hybrid systems conference 2022 (link)
[63] Regulamento de Operação das Redes (link)
[64] Manual de Procedimentos da Gestão Global do Sistema (link)

Regional Legislative Decree No. 1/2021/M of 6th of January 2021 - Adapts to the **Autonomous Region of Madeira Decree-Law No. 162/2019, of October 25**, which approves the legal regime applicable to self-consumption of renewable energy; and

- **Regional Regulatory Decree No. 6/2023 of 15 February 2023** - Approves the grid regime applicable to the production of electricity under a special regime for renewable energy sources, based on a single production technology, with an installed capacity equal to or smaller than 5 MW.

Every two years, EEM presents the plan for investments for the reinforcement and expansion of the grid to the Madeira Regional government for approval by ERSE. These plans are taken in consideration when the tariffs for grid use are defined. The investments for connecting new renewable energy plants to the grids are the responsibility of the investors. The investment planning responds to the need to cover increases in demand and to the need to connect new generation facilities, while maintaining the system's reliability and keeping the grid losses low. These investments align with mechanisms of incentives and penalties defined in the national regulation.

Security of supply assessments are mandatory for TSOs on the Portuguese mainland. In the autonomous regions of Madeira and Azores, security of supply studies is voluntary and developed by the DSOs, when considered necessary.

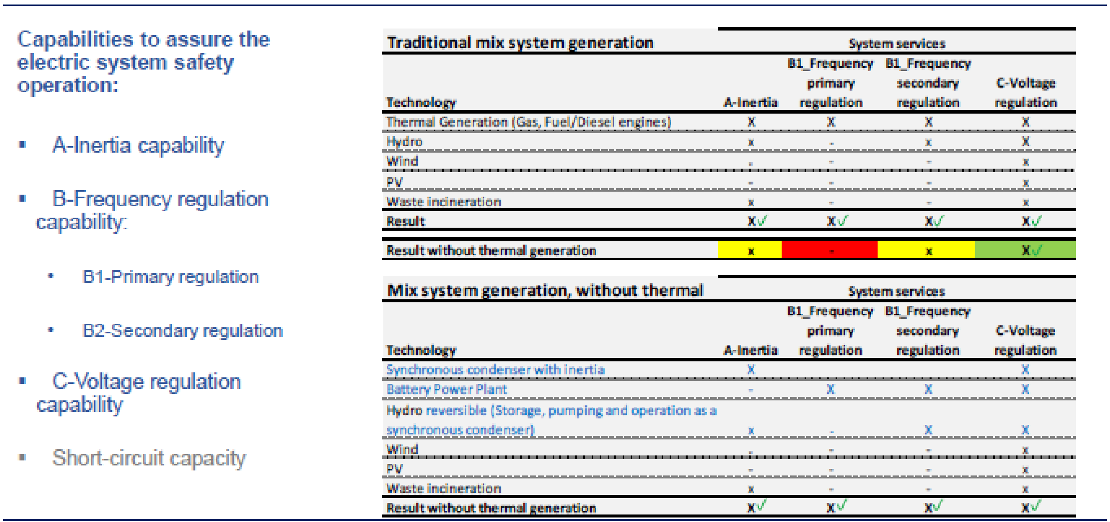
In Madeira and Porto Santo's energy systems, renewable energy generation curtailment is applicable due to system dynamic security restrictions that impact the dispatch decisions. Curtailment may take place to keep the dynamic security operation of the grids by avoiding large frequency variations that could trigger the operation of load shedding relays or even generation shedding relays when responding to frequency deviations.

On Madeira and Porto Santo, challenges in integration of electricity generated from wind power plants come from, among others, the mismatch between resource availability and demand and complex wind behaviour which is not trivial to forecast. In addition, due to the geography of the Madeira islands, wind is available during the winter season and less so during the summer season.

- On Madeira's electricity system, nine wind power plants are located across the island. To take the full advantage of the available wind, seasonal storage (such as pumped hydro) is needed. To improve integration of the generated electricity from wind power plants to the grid, EEM has been using a "virtual power plant" method to aggregate electricity generated from nine wind farms.
- On Porto Santo and Madeira, BESS (with grid-forming capability) have been installed to substitute as much as possible the thermal power plant based on diesel. The objective of the BESS is to contribute to renewable energy integration, improved efficiency of the thermal power plants, reduce costs, and to provide voltage and frequency control.

Grid forming includes any inverter controller that regulated instantaneous terminal voltage and can coexist with other grid-following and grid-forming inverters and synchronous generation on the same system. Grid forming capabilities of inverters are especially used on island grids where the inverter assumes it has responsibility to form and maintain healthy grid.

For complete decarbonisation of the electricity system, solutions are needed to replace the thermal power plants, including for grid services. Figure 7 shows the strategy to use other technologies, such as synchronous condensers, BESS, reversible hydro power plant and RE, to provide grid system services which have been provided by the thermal power plants in Madeira island.



Traditional mix system generation	System services			
Technology	A-Inertia	B1_Frequency primary regulation	B1_Frequency secondary regulation	C-Voltage regulation
Thermal Generation (Gas, Fuel/Diesel engines)	X	X	X	X
Hydro	x	-	x	X
Wind	-	-	-	x
PV	-	-	-	x
Waste incineration	x	-	-	x
Result	X✓	X✓	X✓	X✓
Result without thermal generation	x	-	x	X✓

Mix system generation, without thermal	System services			
Technology	A-Inertia	B1_Frequency primary regulation	B1_Frequency secondary regulation	C-Voltage regulation
Synchronous condenser with inertia	X			X
Battery Power Plant	-	X	X	X
Hydro reversible (Storage, pumping and operation as a synchronous condenser)	x	-	X	X
Wind	-	-	-	x
PV	-	-	-	x
Waste incineration	x	-	-	x
Result without thermal generation	X✓	X✓	X✓	X✓

Figure 7 EEM assessment of the different technologies that can replace thermal power plants in providing system services[65]

Renewable energy policy

The **action plan for sustainable energy and climate in the autonomous region of Madeira**, adopted in 2022,[66] defines the goals to achieve a 55% and 95% share of renewable energy in the total electricity production by 2030 and 2050 respectively. In addition, it aims to achieve an 18% and 60% share of renewable energy in primary energy consumption by 2030 and 2050 respectively.

Key actions include increasing and diversifying renewable energy generation, decreasing the use of fossil fuels in all energy sectors, and updating the electricity system to fit the needs of the energy transition. The action plan also includes measures to integrate storage systems, demand-side management, and the introduction of green hydrogen.

Madeira Island and Porto Santo have plans for additional wind and PV installations, while Madeira Island also has plans for the installation of additional pumped hydro for seasonal storage and grid stabilisation purposes.

Moreover, the action plan foresees an interconnection of the islands of Madeira and Porto Santo to optimise a joint electricity system, increase RES integration, and improve the resilience and stability of the electricity systems.

For the support of renewable energy generation, feed-in tariffs (FiT) are still the main adopted approach for remuneration. In Madeira, a new competitive approach is under development for the definition of new FiT, to be defined by technology. For this purpose, an auction will be launched having as reference price the value of the levelised cost of electricity for a given technology and a

[65] EEM's strategy to maximise the integration of renewables in the electric grid of Madeira island, 6th International Hybrid Power Systems workshop, 2022 (link)
[66] The action plan for sustainable energy and climate in the autonomous region of Madeira, 2022 (link)

given range of capacity of the RES facilities. The winners are the ones with lower FiT values offered. This will minimise the impacts of FiT on the tariffs.

Renewable energy connection policy

Madeira has adopted a modified grid code, **Decreto Regulamentar Regional n.º 8/2019/M**, in 2019.

The main technical requirements in Madeira, addressed by the grid codes are much more demanding than the mainland grid codes, even for low-capacity generation. The codes include the following:

- Ranges of injections of reactive power in steady state mode;
- Local dynamic modulation of active and reactive power as a function of voltage;
- Under and over voltage fault ride through;
- Sensitivity to under and over frequencies
  - Voltage-sensitive current control during faults (both reactive and active current injection)
- Recovery of active power after faults;
- Dynamic control of active and reactive current during faults.

The legal procedure for the connection of RES units to the grids in Madeira and Azores follows similar approaches to the ones used on the mainland. This involves:

- Applying for a title of reserve for capacity of injection;
- Obtaining a generation licence, which includes:
  - the identification of the connection point with the public network
  - the maximum power that can be injected into the public network without constraints
  - when applicable, the maximum power that can be injected into the public network together with associated constraints,
  - the minimum output for stable operation, and
  - the description of the necessary works, to be promoted by the holder of the licence, to make the electrical connection from the generation plant to the connection point;
- Obtaining the operation licence.

Key challenges

Based on the above analysis, the key challenges facing the Madeira electricity systems relevant for the increased integration of variable renewable energy generation are:

- **Lack of control of distributed PV generation.** Distributed PV generation has reached the capacity of large-scale PV generation. However, the distributed generation cannot be aggregated or controlled, and it can cause severe frequency disturbances to the system.
- **Curtailment of variable renewable energy generation** (wind and PV). While curtailment has been significantly decreased in Madeira and Porto Santo with the introduction of BESS and pumped hydro systems, it is still a concern considering the foreseen planned increase in renewable generation.
- **The need for variable renewable energy forecasts with high quality.** Qualitative forecasts, adapted for the specifics of the islands, are needed to ensure the balancing of the system with high shares of variable renewable energy.
- **Demand-side management is currently not very much utilised** for additional flexibility of the grid. There are planned tests to use electric mobility for additional flexibility. However, the tourism sector (cooling loads) still offers an opportunity for activating additional flexibility,

which is not currently utilised. The method of remuneration for such service is still to be defined.

Azores archipelago, Portugal

Governance

The Azores archipelago, in the North Atlantic Ocean, is composed of nine islands spread along 600 km, with the nearest continental area being the Portuguese mainland, 1,600 km away to the east. According to a 2019 census[67], the population in the Azores was 242,796 inhabitants. There is no electrical interconnection between the islands and the mainland of Portugal.

The Azores has an autonomous region status mentioned in the constitution with its own legislative powers. On the islands of the Azores, the vertically integrated electricity company Electricidade dos Açores, S.A. (EDA) is responsible for the generation, acquisition, transmission, distribution, and supply of electricity. Unlike stipulated in the **IMED**, the activities of the energy system on these islands are not unbundled. Nevertheless, renewable generation activities can be pursued by independent private companies in the Azores.

The Azorean Directorate of Energy is the entity of the Azorean government for all energy-related matters. It drives the regional programmes for energy, namely energy efficiency programmes, renewable energy generation, energy transition, sustainable mobility, promotion of energy literacy, and cooperation with other regions.

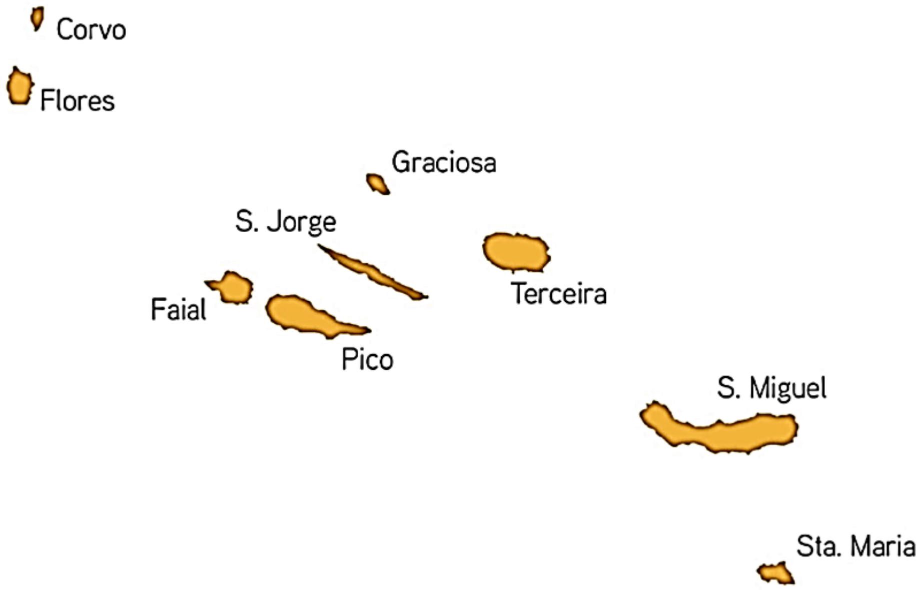


Figure 8 Map of Azores (EDA, 2023)

[67] Azores 2019 census data (link)

Relevant key actors

In the Azores, the vertically integrated electricity company EDA is 51% owned by the regional government of the Azores. EDA operates the low, medium, and high voltage grids under concession by the regional government. EDA is responsible for voltage balancing, frequency reserve, unit commitment and dispatching, as well as the electrical system management. A specific grid code for the Azores islands' grids is under development, following the Madeira islands' example. EDA's activities are regulated by ERSE.

Energy system

The Azores islands are not interconnected with each other. The electricity system includes nine non-interconnected island systems, as shown in the table below. The largest island electricity system is São Miguel (76.9 MW Peak Power), and the smallest is Corvo (0.31 MW Peak Power).[68]

Autonomous Electricity system	Peak power (MW)	Grid Voltage (kV)
São Miguel	76.9	60 (transmission) 30 (overhead distribution) 10 (underground urban distribution)
Terceira	33.5	30 (transmission) 15 (distribution)
Graciosa	2.52	15
São Jorge	5.44	15
Pico	8.26	30 (transmission) 15 (distribution)
Faial	9.21	15
Corvo	0.31	15
Flores	2.18	15
Santa Maria	3.84	10

Table 1: Electricity demand on the islands of the Azores (EDA, 2022)

Achieving interconnections between the Azores islands is very difficult from a technical point of view due to sea currents, volcanic nature, bathymetry, and characteristic structure of the seabed. Due to this, investments are very high and often do not justify interconnection over improving the island's electricity system.

[68] EDA, 2022 (link)

Generation

The Azores islands' electricity systems had a combined share of 36.5% renewable energy in 2023. Renewable energy installed in the Azores is mainly geothermal, wind and hydro. PV generation has seen a slow uptake.

Traditionally, the power generation in the Azores islands has been based on the consumption of heavy fuel oil (HFO) in the four larger islands (São Miguel, Terceira, Pico and Faial) and diesel in smaller islands for thermal power plants. In the early 1990s, more than 90% of the electricity supply relied on fossil fuels. However, over the past three decades, the share of renewables for power generation has progressively increased. Figure 9 shows this increase starting from 1999 to 2021.

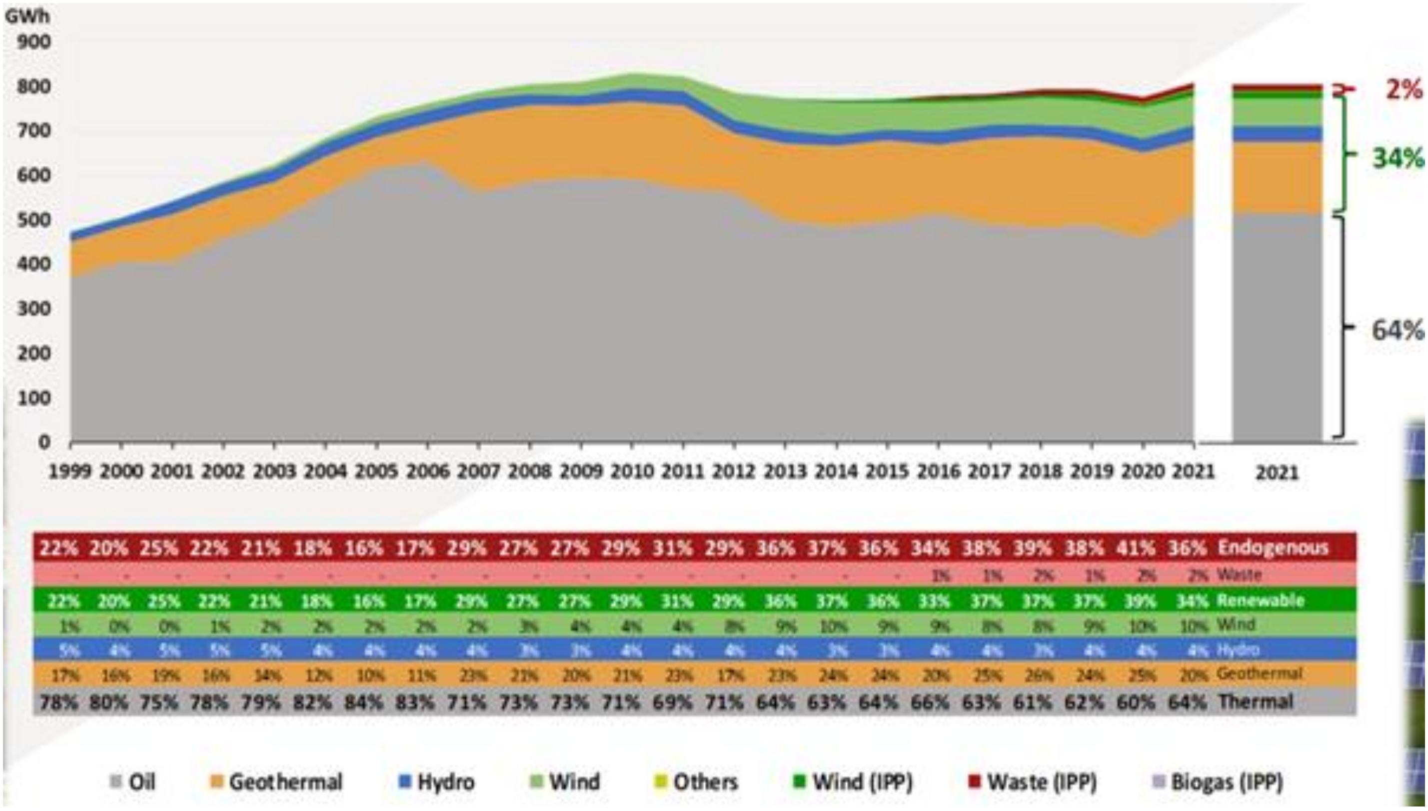


Figure 9 Net Electricity Generation in the Azores from 1999 to 2021 (EDA, 2022)

In 2023, the total generation was 836 GWh coming from:

- 9 Thermal Power Plants (225 MW)
- 9 Wind Farms (37 MW)
- 3 Geothermal Power Plants (27 MW)
- 12 Small Hydro Power Plants (8 MW)
- 1 Waste to Energy Plant (3 MW)
- 3 PV Power Plant (2 MW)
- 1 Biogas Power Plant (1 MW)

These are distributed as shown in the table below:

Autonomous Electricity system	Installed capacity of Thermal Power Plants (MW)	Installed capacity of Wind Parks (MW)	Installed capacity of Geothermal Power Plants (MW)	Small Hydro Power Plants (MW)	Installed capacity of Waste to Energy Plants (MW)	Installed capacity of PV Parks (MW)	Installed capacity Biogas Power Plant (MW)
São Miguel	98 (1 plant)	9 (1 park)	23 (2 plants)	5 (7 plants)			1 (1 plant)
Terceira	78 (1 plant)	12.6 (2 wind farms)	3.5 (1 plant)	1.4 (3 plant)	2.6 MW (1 plant)		
Graciosa	5 (1 plant)	4.5 (1 park- part of Hybrid Station)				1 (1 park- part of Hybrid Station)	
São Jorge	8 (1 plant)	1.8 (1 park)					
Pico	17 (1 plant)	2.4 (1 park)					
Faial	19 (1 plant)	4.25 (1 park)		0.3 (1 plant)			
Corvo	0.97 (1 plant)					0.075 (1 park)	
Flores	4 (1 plant)	0.6 (1 park)		1.6 (1 plant)			
Santa Maria	6 (1 plant)	1.5 (1 park)				10.6 (1 park)	

Table 2: Distributed renewable energy in the islands of the Azores (EDA, 2023)

The small islands of Graciosa and Flores have achieved a high percentage of RES integration, as indicated in Figure 10. In São Miguel, RES integration is achieved mainly by the development of geothermal energy and in Terceira by a combination of geothermal and wind energy.

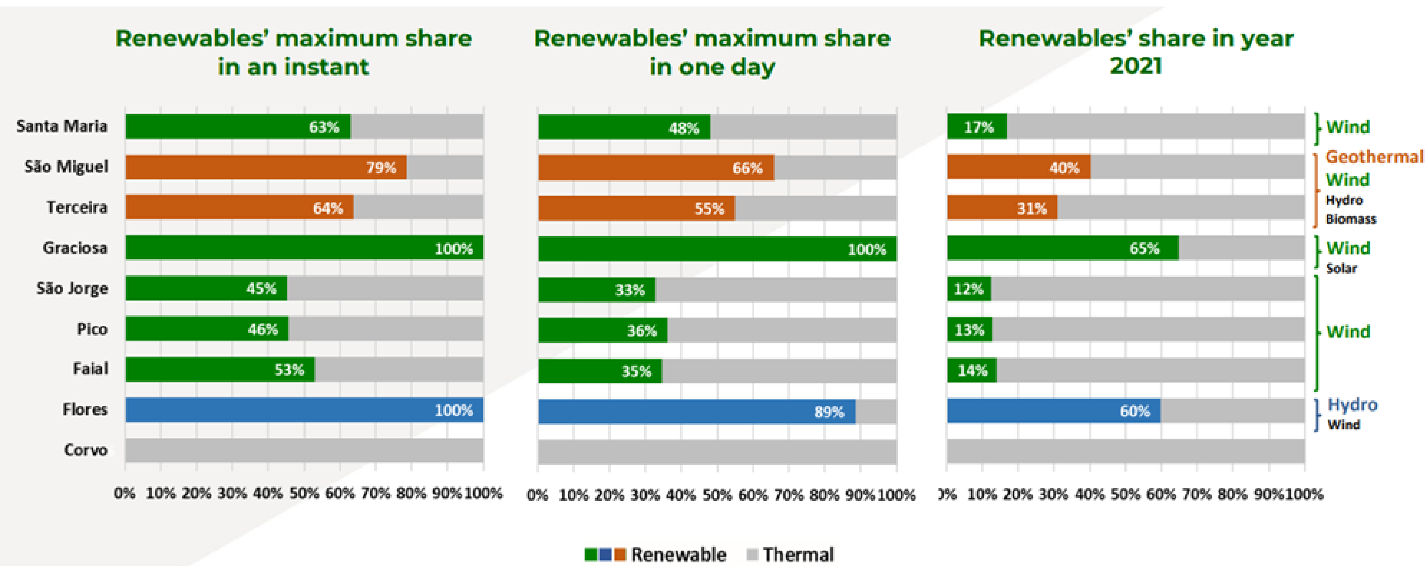


Figure 10 Renewable Energy Integration - Maximum share achieved 2021 (Source: EDA)

Grid status and management

The regulations and rules that apply for the management of the grids in Portugal are:

- **Regulamento de Operação das Redes** (Manual of Operations of Grids);
- **Manual de Procedimentos da Gestão Global do Sistema** (Manual of Procedures for the global management of the System)

In addition, in the autonomous regions of the Azores and Madeira the local utilities adopt tailor-made procedures to cope with grid operation, namely in what concerns curtailment of renewable generation.

A specific grid code for the Azores islands' grids is in preparation, taking the Grid code of Madeira (**Decreto Regulamentar Regional no. 8/2019/M**)[69] adopted in 2019, as an example.

EDA is responsible for presenting an expansion grid development plan to ERSE every 4 years, corresponding with every regulatory period. The plan aims to respond to the evolution of foreseen demand and to the presence of new generation facilities. The security of supply assessment is also developed by EDA for all the Azores islands on a voluntary basis.

The operation of the energy system in the Azores keeps reserve margins to be able to face a sudden disconnection of the largest generation unit, as well as to manage the time variability of renewable energy and the variability of demand. In the Azores, operation procedures related to the values of the wind speeds mainly constrain the integration of additional variable renewable energy.

Variable renewable energy generation is curtailed, due to system dynamic security restrictions that impact the dispatch decisions. However, aside from Terceira, no data is available on how much energy generated by RES is curtailed. In Terceira, private investors get compensated for the curtailed electricity from wind power plants, due to the historical context of the installation of the plants; the wind power plants were installed prior to the geothermal power plant.[70] In the Azores, geothermal power plants are not subject to operation limitations, while thermal power plants have technical minima, leaving variable RES to be used as flexible generation.

In the islands of São Miguel and Terceira, the installation of batteries with power converters operating in grid-forming mode is contributing to the reduction of curtailed RES, since these batteries assure the required reserve to cope with variations in VRE and/or if one thermal generation unit trips.

Renewable energy policy

For the support of the renewable energy generation, FiT are the main adopted approach for remuneration. Furthermore, the **Azores Energy Policy 2030 (the Estratégia Açoriana para a Energia 2030**, defined in the **Resolução do Conselho do Governo n.º 92/2018**)[71] is a strategic policy document that defines the regions' ambitious targets for renewable energy integration.

The seven targets for 2030 are:

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[69] Decreto Regulamentar Regional no. 8/2019/M (link)

[70] The investor keeps forecast of electricity generated from the wind power plant and is compensated for the electricity, which is curtailed, not allowed to be injected into the grid.

[71] The Azores Energy Policy 2030 - the Estratégia Açoriana para a Energia 2030, defined in the Resolução do Conselho do Governo n.º 92/2018 (link)

- 50% reduction in the use of butane gas through the electrification of consumption, compared to 2010, including the elimination on islands with smaller populations;
- Energy efficiency of 25% in land transport, by reducing the final energy consumption in road transport by 25% compared to 2010;
- Energy efficiency of 28% in buildings, by reducing the final energy consumption in the residential sector and in the trade and services sector by 28% compared to 2010;
- Energy efficiency of 40% in businesses, by reducing the final energy consumption in the industry, construction, agriculture and fishing sectors by 40% compared to 2010;
- 70% renewable electricity, by increasing the ratio of electricity production from renewable energy sources;
- Energy efficiency of 33%, by reducing primary energy consumption by 33% compared to 2010;
- Reduction of greenhouse gas emissions by 40% for the energy sector compared to 2010.

There are three subsidy systems running specifically in the Azores:

- PROENERGIA is a subsidy-driven programme designed to maximise the production and utilisation of renewable energy by Azorean consumers. It does so by subsidising renewable energy projects that aim to produce and store electricity from renewable resources (article 2, paragraph 1, letter (a) of **DLR 14/2019/A**).
- E-mobility subsidy. The system of financial incentives (non-refundable grants) for the acquisition of e-vehicles in the Autonomous Region of the Azores constitutes one of the main pillars of the archipelago's strategy to fully implement electric mobility in the region. By means of granting subsidies to the purchase of light vehicles (for the transport of passenger and goods), two-wheeled motorcycles, tricycles, quadricycles, and bicycles – all exclusively electric (article 2 of **DRR 4/2021/A**).
- SOLENERGE is a support scheme that covers 100% of the acquisition and installation of photovoltaic solar systems for self-consumption, up to a maximum of 1,500€ per installed kW. It is a non-refundable grant for individuals and legal entities intending to acquire and install photovoltaic solar systems in buildings located in the Azores are eligible for SOLENERGE, except for the regional autonomous administration and the direct state administration. With this support, the installed solar power capacity will increase by 11.2 MW. (**DLR 12/2022/A** and **DRR 17/2022/A**).

There has been a slow uptake of PV in the Azores islands. Since technology is becoming more affordable and the projects are feasible with lower remuneration, it is expected that the uptake will increase in the coming years. In addition, renewable energy producers/promoters may propose new production through their application for a licence to the regional directorate for energy.

Some of the ongoing projects that help to improve flexibility of the island grids in Azores are presented in Figure 11. Few of those include:

- In São Miguel, a vehicle-to-grid (V2G) project was developed with the goal to measure the benefits of this innovation for the users and the operation of the island's electricity system.
- In São Miguel and Terceira, a BESS has been added to achieve higher penetration of variable RES in the energy mix.
- In Graciosa, adding a hybrid power plant to the island electricity system has resulted in approximately two-thirds of the island's electric energy requirements being supplied by renewable energy.

Figure 11 Projects in Azores, Azorean Directorate for Energy, 2020[72]

While these projects provide tests for the use of various assets (such as EVs, BESS) that could provide flexibility services to the grid, an enabling regulatory framework is still missing. Tenders for storage in the small islands have low interest from investors, delaying the needed projects that could provide additional flexibility to the grid.

The absence of remuneration for curtailment is an uncertainty and risk for the investors looking into new renewable energy generation projects. A detailed analysis is needed to define the optimal regulatory framework for curtailment, but also to assess the optimal techno-economic remuneration scheme for curtailment versus the implementation of additional flexible assets, such as storage.

Renewable energy connection policy

The legal procedure for the connection of RES units to the grids in Madeira and the Azores follows similar approaches to the ones used on the mainland. This involves:

- Applying for a title of reserve for capacity of injection;
- Acquiring a generation licence; and
- Acquiring an operation licence.

[72] Azores Directorate for Energy (link)

The **Azores Grid code** is currently under preparation, and concrete steps are being taken to make it a reality in the near future. In the meantime, specific requirements for producers/promoters have been issued to cope with difficulties in the connection of renewable energy generation by the local utility, EDA, which include ranges of injections of reactive power in steady state mode, undervoltage fault ride through, and sensitivity to overfrequencies.

Key challenges

Based on the above analysis, the key challenges facing the Azores' electricity systems relevant for the increased integration of variable renewable energy generation are:

- **Integrated variable RES create system disturbances.** While the Azores grid code is under development, the Azores region uses requirements such as those included in the Madeira grid code, with some adjustments. The grid code is still to require RES to support frequency on the islands by injecting active power, instead of reactive current. Studies for the design of a new grid code in the Azores are supposed to start soon, but it will take at least another year before the new grid code is adopted and implemented. For the success of the integration of renewables in islands, the capability to control frequency is needed, which is possible with batteries and synchronous condensers.
- **Curtailment of variable renewable energy plants** creates risks for investors and decreases the financial attractivity of renewable energy generation. Currently, variable RES mainly consists of wind power plants, but soon solar PV generation will also become one important source of generation. These generators are curtailed due to dispatching rules and lack of flexibility of the grid, providing priority to thermal power plants and hydro and geothermal generation as those can provide a more stable generation and system services. This situation is improving due to the installation of battery storage systems in all the islands, allowing to change the operation rules and thus permitting for further integration of RES.
- **Power cuts** happen mainly **due to weather conditions**, like thunderstorms. Due to climate change, extreme weather conditions are expected to become more frequent, putting the accent on measures needed to adapt the electricity systems of the islands to these expected changes (ensuring back-up, remote control, and automation of operation).
- **Lack of interest of private investors in BESS tenders on the small islands**. These island systems require more flexibility in order to continue the decarbonisation and specifically the needed integration of more variable renewable energy generation. The difficulty in attracting contractors to develop small-scale projects in remote areas and the high cost of implementation are also issues for small islands. Hence, there is a greater need to obtain funding to make them viable.
- **An enabling regulatory framework for flexibility services or demand response is still missing**. Pilot projects are implemented to test various opportunities and services that different flexible assets (EVs, BESS) can provide, but the regulatory framework is still to be developed.

Réunion, France

Governance

The Department of Réunion (Réunion) is a non-interconnected island and an outermost region of France. Réunion is inhabited by 863,000 permanent residents according to a 2020 census. It is located in the Southern Hemisphere, in the Indian Ocean, to the east of Madagascar. Its climate is tropical. It is prone to cyclones.

Réunion is a volcanic island centred around two craters: the Fournaise Peak in the southeast and the Snow Peak in the centre. There is a mountain road passing between them. As is shown on Figure 12 below, activities are concentrated around the island's coastal areas, particularly in the northwestern quarter.

Réunion is one of the 15 regions of France with the status of non-interconnected zone, zone non interconnectée (ZNI). EU and French law apply to Réunion unless specifically stated otherwise.

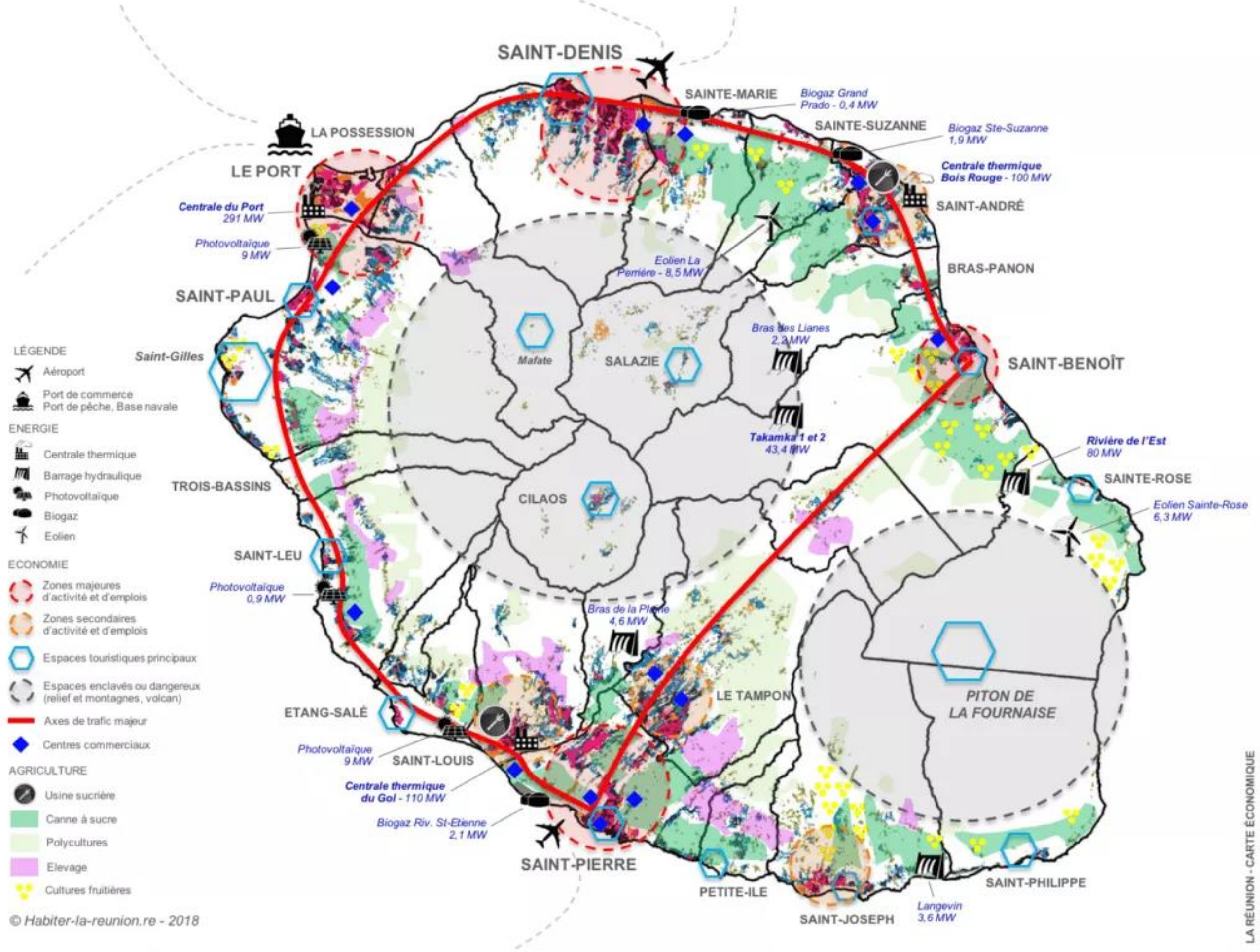

Figure 12 Map of economic activities in Réunion, 2018[73]

[73] Habiter la Réunion, Cartes de la Réunion, (link)

Relevant key actors

The French state is represented in Réunion through the prefect, who is nominated by the French Prime Minister. The regional council is the highest instance of local government, above the municipal authorities.

Laws published for Réunion must always come from the French legislative bodies: the parliament for laws, or the government for decrees. The Ministry for Ecological Transition is responsible for the validation of the ten-year energy plan of the region - the **Programmation pluriannuelle de l'énergie** (PPE), the organisation of tenders for renewable energy, and feed-in tariffs for small scale renewable energy. It is accompanied by two state related bodies: the Superior Energy Council and the Agency for Ecological Transition.

The NRA for mainland France, Commission de Régulation de l'Energie (CRE), is also the regulator in Réunion. The CRE regulates the gas and electricity networks in mainland France and in the outermost regions. The CRE implements certain support measures for storage through calls for tenders.[74]

Local actors include the regional council and particularly its Directorate for the environment, urbanism, and housing, who conduct works for ten-year energy plans (the PPE) and other texts. This includes the public consultation around the draft text and the integration of comments into a final text along with a summary of the consultation.[75]

The Syndicat intercommunal d'électricité de La Réunion (SIDELEC) is a public body that owns, and delegates the operation of, the energy distribution networks on the island.[76] It is an energy syndicate with 20 years of existence, originally only in charge of electrification.

SIDELEC has delegated the management and operation of the grid to Electricité de France, Systèmes Energétiques Insulaires (EDF SEI). EDF SEI is a subsidiary of Electricité de France (EDF). EDF SEI is the operator for both the transmission and distribution of electricity, the single buyer for electricity production on the island, and the monopoly energy supplier, based on regulated tariffs. EDF SEI publishes key statistics on its open data platform.[77]

On the production side in Réunion, key actors are EDF SEI, in particular with respect to hydro generation, EDF Production d'Énergies, which handles the operation of the former diesel power plants, now retrofitted to run on biodiesel, and Albioma, which operates the former coal and bagasse (sugar cane residue) power plants, now retrofitted to run on solid biomass and bagasse. The development of distributed energy (solar and wind) is highly fragmented with numerous actors involved, in particular with the development of solar production supported by feed-in tariffs.

[74] CRE, "Présentation générale de la CRE" (link)

[75] La Réunion Government, Bilan et Synthèse PPE, (link)

[76] Under French law, this body is identified as an Organising Authority for the Distribution of Electricity (Autorité Organisatrice de la Distribution d'Électricité (AODE)) (link).

[77] EDF SEI (link)

French regulatory niche for islands

The EU's Third Energy Package of 2009 established a specific framework for "small, isolated networks". EU Member States may request a derogation from system operator unbundling rules to integrated electricity companies supplying such networks. French legislation has transposed in the national legislation the notion of a "small, isolated network" and "small, connected network" notably through the notion of non-interconnected zones (ZNI) to the continental electricity grid.

The incumbent operators in the ZNIs, including EDF SEI in Réunion and all other regions represented in red in Figure 13 below, are thus allowed to act as vertically integrated utilities: producer, market operator, DSO, and energy supplier.

The Observatory of Energy in Réunion (OER), is a public agency responsible for the analysis and aggregation of data. Since 2006, they publish a **yearly report of the energy system on the island** and maintain a detailed, real-time dashboard for energy and weather data.[78]

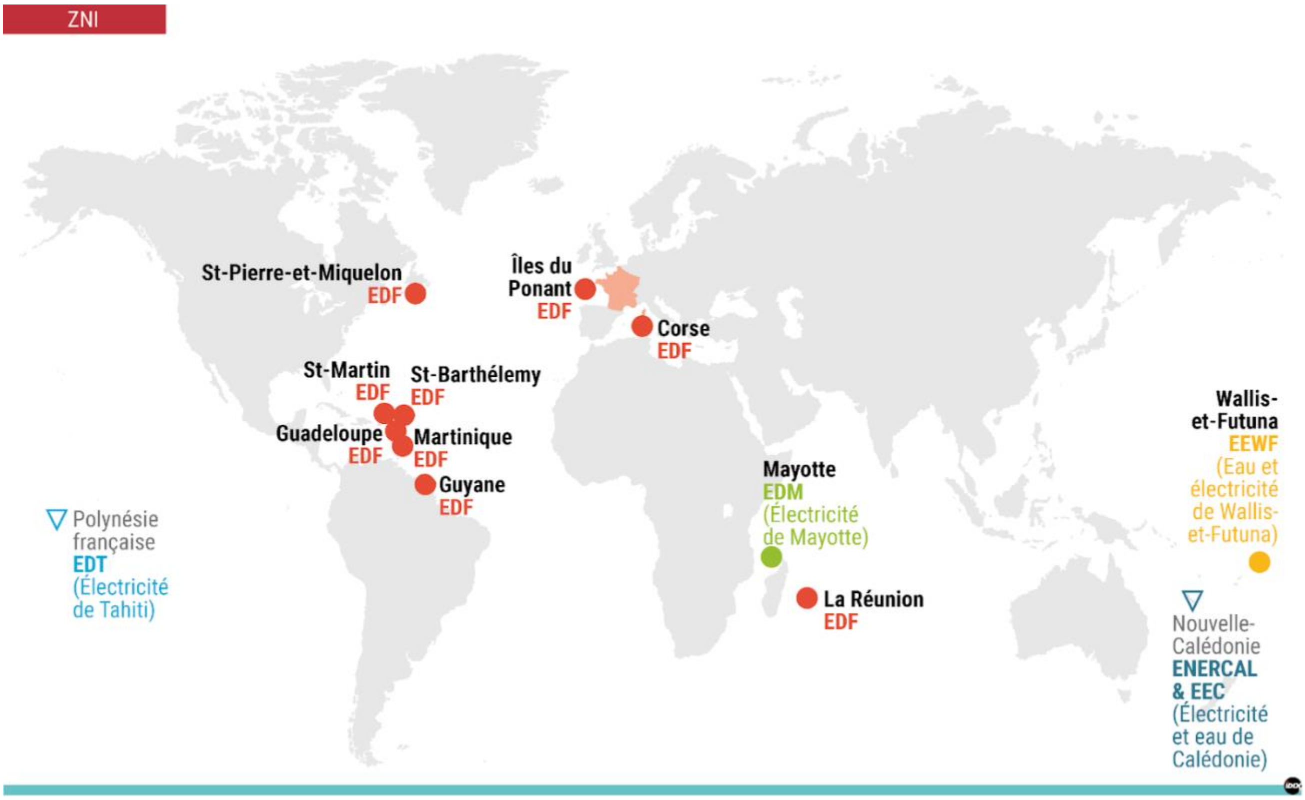

Figure 13 Overview of the main French islands, including in red the ZNIs that fall under the management of EDF SEI

[78] OER, Observatoire Energie la Réunion, (link)

Energy system

Réunion's energy consumption is relatively stable throughout the year, as shown in Figure 14 below. The peak demand is typically in January-February, during the summertime, with increased air-conditioning demand.

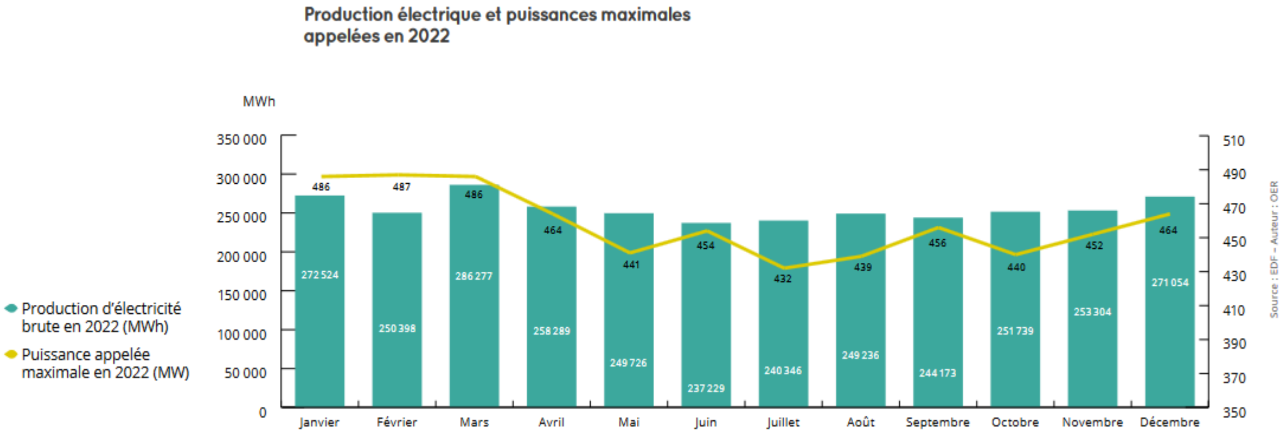

Figure 14 Réunion's monthly electricity production (teal) and monthly maximal demand (yellow), OER, 2023

In Réunion, peak and off-peak tariff hours have been put in place. When applicable, peak hours are in the evening, between 18:00 and 22:00. Off-peak hours are between 22:00 and 06:00. The basic tariff applies during the daytime between 06:00 and 18:00. EDF SEI is working on adapting the peak and off-peak tariffs' time slots.[79] The aim is to more accurately reflect the actual consumption and emit more accurate price signals to the end-users in relation to the risks of tension on the network. Moreover, a compensation framework is applicable in Réunion for standardised small-scale electricity curtailment.

In Réunion, as in other French islands, electricity consumers are eligible for the French regulated electricity tariffs calculated by the CRE and validated by the French government. This enables electricity consumers to have access to electricity tariffs reflecting the costs of the continental markets rather than the much higher costs of the island. In order to compensate for this difference between the actual production costs in the island and the revenue associated in the regulated tariff, the CRE conducts annual accounting audits to evaluate the financial compensation to be redeemed to EDF SEI which is included in the State budget. Figure 15 below showcases the varying costs of electricity production across some of the French islands.

[79] CRE, Proposition des tarifs règlementés de vente d'électricité, 2023, (link)

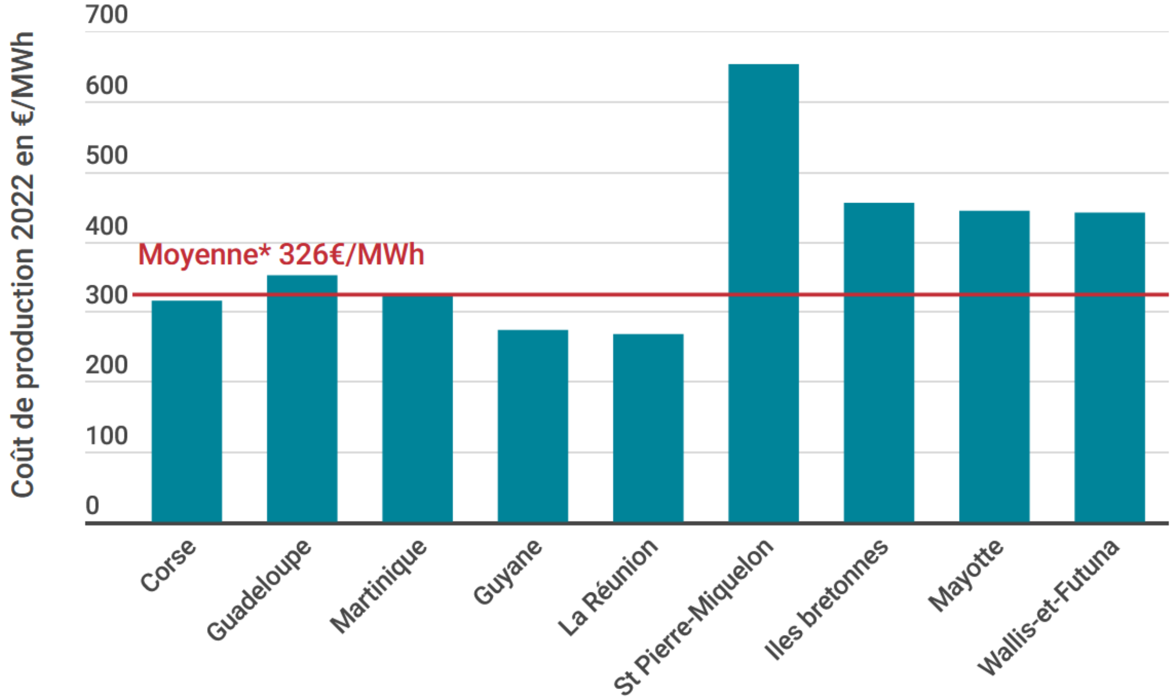

Figure 15 Average electricity production costs on French islands, CRE, 2022[80]

Generation

In 2023, the renewable energy share in Réunion was 54%. Figure 16 below, from the OER's interactive data visualisation, depicts Réunion's electricity mix in 2022 (inner ring) as compared to 2019 (outer ring).[81] In 2022, renewable electricity represented 37.7% of electricity generation and 14.2% of the total primary energy mix. It is based on data from the active energy producers on the island, mostly EDF and Albioma. It does not take into account the self-consumption of solar electricity, which is counted as energy savings.

[80] CRE, Transition Energétique dans les ZNI, (link)
[81] OER, Production d'électricité la Réunion, (link)

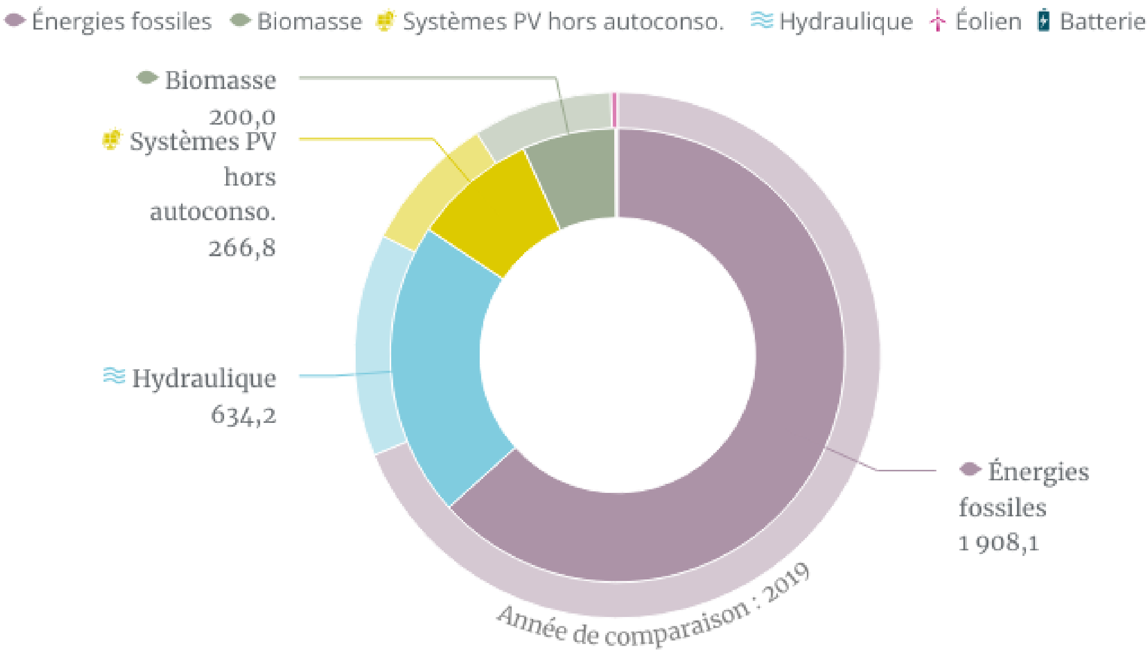

Figure 16 Réunion's electricity mix in 2022 compared to 2021, OER, 2023

Figure 17 below depicts a map of the electricity generation plants in Réunion at the end of 2022. Not pictured are the PV power plants, including the "centrale des Cèdres", with 9 MW_p of PV panels on top of fields and fish basins. It also contains 9 MW, 9 MWh of battery storage.

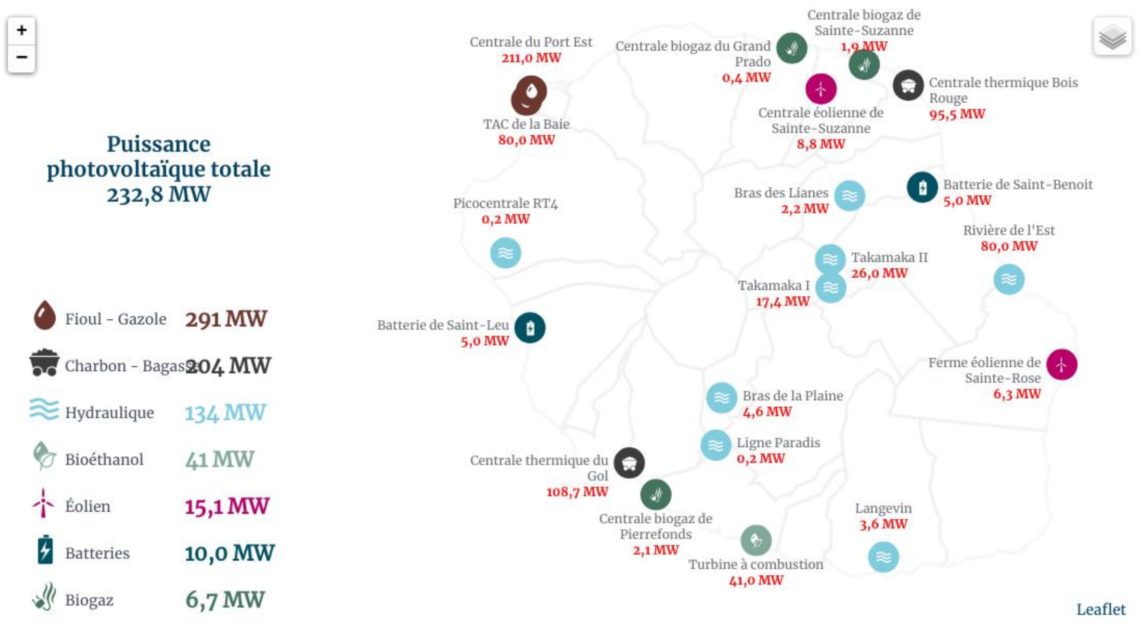

Figure 17: Generation capacities in Réunion in December 2022, Observatoire de l'Energie de Réunion

Réunion's energy generation landscape is diverse, with solar PV, thermal power plants, hydro dams, BESS, biomass, and wind assets. All thermal units have been retrofitted in 2023 to switch to biomass: solid biomass from sugarcane residue (bagasse) and wood pellets for coal plants, and biofuel for diesel plants.

Grid status and management

Réunion electricity grid consists of high-voltage lines of 63 kV, a medium-voltage network at 15 kV, and a low-voltage distribution grid at 230 V.

EDF SEI's presence on many French islands, including Réunion, allows them to share best practices and treat challenges in a systematic way. This is made evident when it comes to increasing RES penetrations on islands' grids.[82] A recent study by EDF SEI researchers lists the following common challenges and possible solutions:

- Voltage drops on the high voltage grid: low voltage ride through (LVRT) cannot in principle be managed by the utility, but it can require that new installations match certain expectations. EDF SEI's approach has been to focus on RES installations above 10 MVA since 2008. Since 2018, finer rules have been in place for those same installations featuring power electronics.

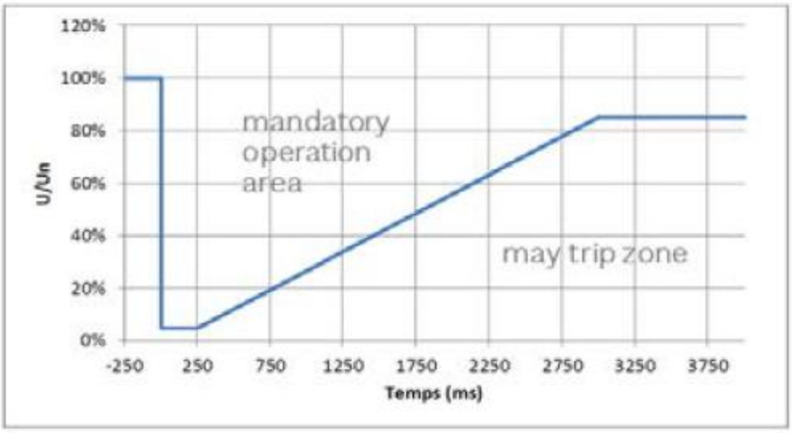

Figure 18 Voltage limit to allow generators' disconnection, EDF R&D

- Variability balancing: EDF R&D is looking to define specific reserve requirements to deal with intra-hour drops in renewable energy production.
- Lack of inertia to maintain frequency: inertia requirements have been set, forcing the operation of critical high-inertia assets (thermal power plants, synchronous condensers). EDF SEI sees stand-alone batteries[83] as part of the solution; in Réunion, two 5 MW, 5 MWh li-ion battery systems were installed by EDF SEI and CorsicaSole to reinforce the grid. These batteries are not yet operated in grid-forming mode, thus do not produce synthetic inertia. However, the response time of these installations (<250 ms) allows them to support the frequency of the grid with ultra-fast reserve services.

Réunion's grid is managed in accordance with **France's Energy code.**[84] Article L. 141-9 of the **French Energy Code** allows non-interconnected islands' DSOs to disconnect wind and/or solar electricity installations when the active power they inject into the grid reaches a threshold. This threshold depends on the territory and is regularly reviewed. For Réunion, this limit is set at 45% for 2023 in its

[82] G. Prime & J. Witkowski, *Toward high levels of renewables in the French insular systems*, 7th International Hybrid Power Plants & Systems Workshop (HYB 2023), 2023 p. 9 – 18, doi: 10.1049/icp.2023.1428
[83] EDF SEI Guadeloupe, projet KISS (link)
[84] French Government, Code de l'énergie (link)

PPE.[85] It is planned to be raised to 55% of the active power on the grid by 2028. To that end, the DSO is to assess and publish, with approval from public powers, the technical grid conditions necessary to sustain non-curtailable variable power up to that threshold. The PPE also states a goal to curtail at most 5% of renewable energy assets by 2028.

EDF SEI is responsible for the grid's balance between supply and demand. One of the instruments to that end is the French generalised five-year plan prediction of supply and demand balance, which is the basis for the network development plan.

In 2019, the French Ministry of Ecology accepted **EDF SEI's plan for future connections to the grid up to 2028**,[86] namely the 162 MW outlined in the PPE. It concluded that the transmission grid was mostly fit for that task and only required the addition of a transformer for a value of 3.4 million euros.

Renewable energy policy

Réunion is planning to get to 100% renewable electricity by 2030. This 100% renewable electricity transition does include imported biomass in the form of wood pellets and liquid biomass. The vision is highlighted in the PPE and in its appendix, the regional biomass plan. Ideas to make this RES transition locally contained exist, summarised by the French Agency for Ecological Transition in its 2030 vision for 100% autonomous renewable energy in Réunion.[87]

The solar sector in Réunion was developed through feed-in tariffs, public tenders for large plants, and CRE's islands tendering storage installations scheme:

- Feed-in tariff projects for around 200 MW
- Around 40 projects won auctions for PV + batteries for around 50 MW
- 13 projects won auctions for self-consumed PV for around 4.5 MW
- 2 projects won auctions for stand-alone, transmission grid-connected battery storage, with the first auction for a 5 MW centralised storage installation going out in 2017.

CRE launched a tender for stand-alone battery storage in May 2023 for ZNIs, including Réunion.[88] Local public tenders first mandated 1-hour batteries on each utility-scale solar plant, and are now shifting to centralised, longer-duration storage via the CRE tenders. CRE also supports the conversion of fossil fuel plants to biomass.

Réunion has a small off-grid site in Mafate.[89] It is part of an electrification programme for a few hundred off-grid homes. EDF SEI estimates that microgrids may be fit for very high variable renewable energy penetration rates. The site is 40% complete. It is composed of a solar microgrid and batteries. It is subsidised by the state fund for rural electrification.

Renewable energy connection policy

RES connection policies are set in **EDF SEI's technical requirements**, which function as a grid code for the island.

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[85] La Réunion Government, PPE, 2022 (link)
[86] EDF SEI, S2RENR, 2019 (link)
[87] ADEME, Rapport Autonomie Energétique ZNI 2030, (link)
[88] CRE, Appels d'offres aux ZNI, (link)
[89] Johann Francou, Cédric Abbezzot, Paulisimone Rasoavonjy, Didier Calogine. An Islanded Microgrid Design: A Case Study. *6th Hybrid Power Systems Workshop*, Apr 2022, Madeira, Portugal. p.6. (link)

In Réunion like in mainland France, the first step to connecting RES assets is to obtain a construction permit, under the French Urbanism Code.[90] For rooftop PV, a preliminary construction declaration is necessary as part of the urbanism authorisation, subject to approval by the municipalities, which in practice have authorisation durations of up to six months.

The main connection policy in place for RES is the **Schéma de Raccordement au Reseau des Energies Renouvelables de Réunion (S2RENR)**,[91] a 10-year plan for the connection of RES assets above 100 kVA in capacity. While led by EDF SEI and the regional government, the process of its preparation includes many other key actors on the island.

The installation of new grid assets specifically for RES connection is to be paid by RES developers above 250kVA. In order to ensure fair cost distribution, the **S2RENR** splits the provisional costs associated to the development of new grid assets through a uniform cost per MW that all new RES projects above 250kVA should finance. The applicable **S2RENR** in Réunion dates back to 2019 and is under revision. It concluded that only one new grid asset was needed, a MV/HV transformer costing 3.4 M€, leading to a 20,900€/MW connection cost for future new RES projects (considering 162 MW of foreseen projects to be connected by 2028). In the future, during the counting period of future **S2RENR,** non-declared or allocated projects above a certain threshold (several MW) will not be able to benefit from this connection policy.

Finally, feed-in tariffs are available for PV installations up to 500 kWp for total resale, and 100 kWp for collective self-consumption. EDF SEI complies with this obligation by using bilateral contracts for grid connections to the electricity generators. PV installations larger than 500 kWp are not subsidised via feed-in tariffs but can be developed through auctions or, for some specific projects, if they respond to the ambitions of the region PPE in terms of RES development and are approved by CRE.

Key challenges

Based on the above analysis, the key challenges facing the electricity system of Réunion, relevant for the increased integration of variable renewable energy generation, are:

- **Variable RES increase grid instability,** specifically frequency variation in case of generation loss and the relative drop in inertia in the system.
- **Power cuts** happen due to weather conditions. New grid lines are built underground to decrease risks related to weather conditions. However, there is still a need to upgrade other grid assets to ensure the resilience of the grid.
- **DSO human capacity and long-term planning** is dependent on the staff availability. With a relatively small industrial sector and high ambitions for the energy transition, it is not always possible to get the appropriate skilled staff.
- **Partly adequate price signals for energy efficiency and demand-side management.** Currently, some industrial and tertiary companies use electricity tariffs that provide price-based signals to end-users reflecting the constraints on the electric system.
- **Decentralised rooftop PV long permitting procedure.** Rooftop PV generation currently requires a building permit for installation which is long and complex, which does not foster installation of rooftop PV.

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[90] French government, Code de l’urbanisme, (link)

[91] La Réunion Government, S2RENR, (link)

Rhodes and Chalki islands, Greece

Governance

Rhodes (1,400 km^2) and Chalki (27 km^2) are part of Dodecanese islands and located in the Aegean Islands archipelago. Their electrical networks are connected and together form the autonomous electrical power system of Rhodes. The population of the two islands is 1.2% of the total population of Greece and the 8.7% of all the Greek islands' population.[92]

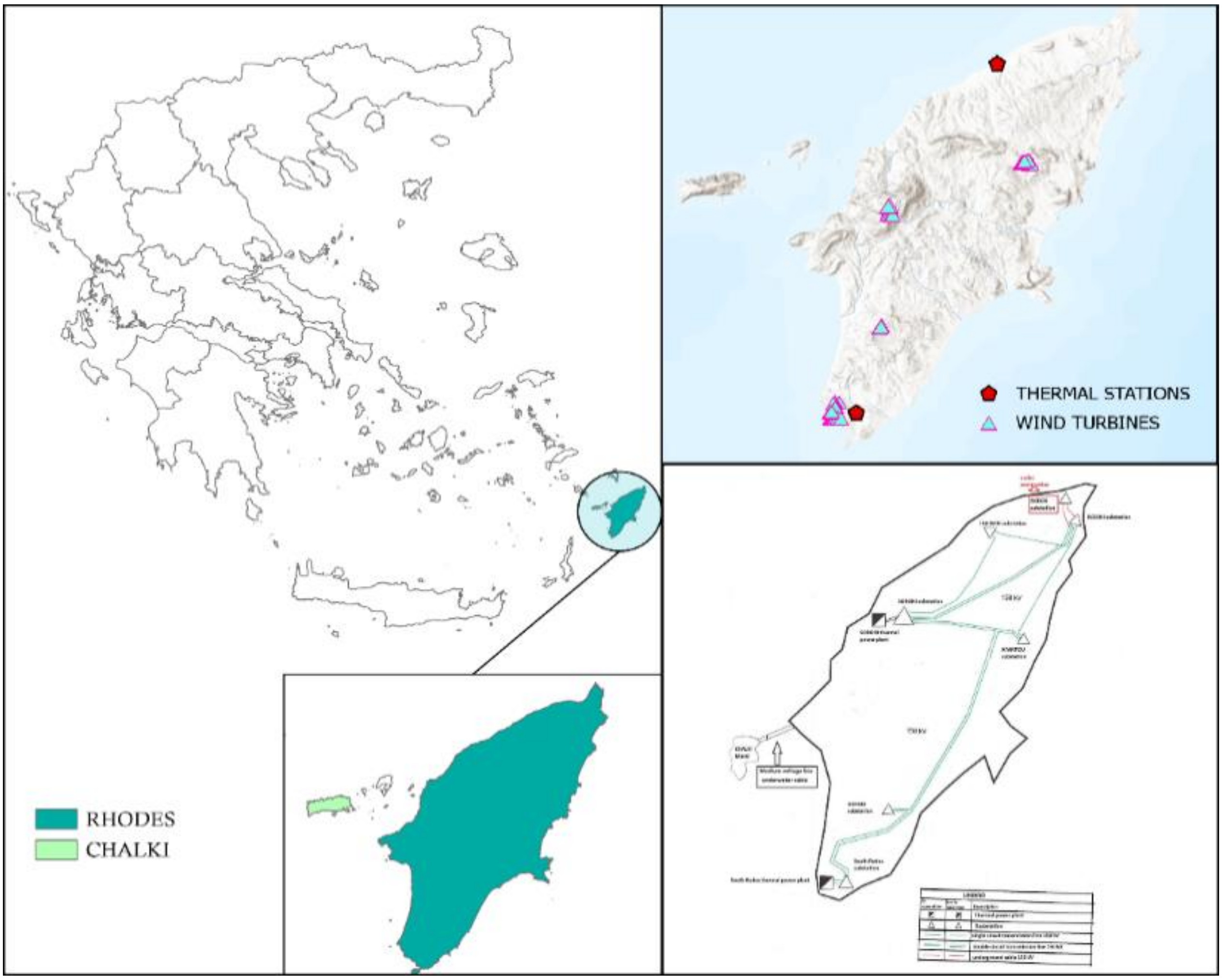

Figure 19 The map of Rhodes and Chalki islands, location of generation plants and 150 kV transmission grid (Source: HEDNO)

The islands fall under Greek national energy legislation. However, there are two lower levels of governance: the municipality of Rhodes, is responsible for waste and water management projects, and the Regional Authority of South Aegean is responsible for the implementation of development projects at the regional level including road infrastructure. The island of Rhodes is governed by the municipality of Rhodes and the island of Chalki is governed by the municipality of Chalki. Both municipalities fall under the regional authority of South Aegean.

[92] ELSAT, Greece Census 2021, (Link)

Relevant key actors

Energy policy in Greece, and in the islands of Rhodes and Chalki, falls under the Ministry of Environment and Energy.

The NRA is the Regulatory Authority for Energy, Waste and Water (RAEWW).[93]

The DSO is the Hellenic Electricity Distribution Network Operator S.A. (HEDNO), responsible for the electricity system in Greece, including the two islands of Rhodes and Chalki. The electricity transmission system of mainland Greece is owned and operated the Independent Power Transmission Operator (IPTO). IPTO does not operate on non-interconnected islands. There are however projects to connect non-interconnected islands to the mainland grid. The island of Rhodes is one of those islands. IPTO oversees the interconnection projects on those non-interconnected islands that are set to be completed by 2029.

PPC is an electric power company in Greece that owns thermal power stations in non-interconnected islands. PPC Renewables, Ellaktor A.E., Wind Park Rhodes A.E., EUROWIND A.E., and Enel Green Power Hellas A.E., are the owners of the wind parks in Greece.

Energy system

Generation

The autonomous electricity system of Rhodes includes the electricity grids of the islands of Rhodes and Chalki. In 2023, the electricity system of Rhodes consisted of the following installed generation units:

- 2 thermal power plants located on Rhodes island with an installed power of 306.5 MW;
- 5 wind power plants located on Rhodes with an installed power of 48.5 MW;
- 216 photovoltaic (PV) power plants with a total installed power of 18.2 MW;
- 154 PV rooftop PV plants installed by autonomous producers with an installed power of 2.9 MW; [94]
- 248 PV rooftop producers with an installed capacity of 1.2 MW.

The Rhodes electricity system had a 17% share of renewable energy in electricity production in 2021.

The annual electricity consumption of Rhodes in 2022 was 846 GWh, with a load factor of 44.3%. The average power load on this electricity system was 97 MW, while the peak load was 218 MW. Low winter loads can be as low as 30 MW (0.5 to 1.2 MW for Chalki island).

Most electricity demand is in the northern part of the island, while a new thermal power plant (TPP) and wind generation plant is located in the southern part of the island, as indicated in Figure 19 above.

[93] Regulatory Authority for Energy, Waste and Water (link)

[94] The concept of autonomous producer bears many similarities with the notion of prosumer. The net-metering scheme can be used by the autonomous producers that use following technologies: PV, small wind turbines, biogas, biomass/bioliquids, CHP, and small hydroelectric stations. Moreover, all RES technologies used by autonomous producers for self-consumption can receive subsidies.

Grid status and management

The Rhodes electricity system connects the island of Rhodes with the island of Chalki via two submarine cables and a power transmission capacity at a rated voltage 13.2 MVA.

The Rhodes electricity system consists of a 150 kV transmission system operated by HEDNO. The installation of a new TPP in the south of Rhodes led to transition of the grid from 66 kV to 150 kV.

The Dodecanese interconnection project aims to interconnect the national electricity transmission system with six electricity systems of the Southeastern Aegean Islands, including the Rhodes electricity system. The project is set to be completed in 2029. Rhodes will be connected with Kos by means of three underwater cables. Kos is projected to be connected with a future substation in Corinth.[95]

In the meantime, HEDNO estimates that excessive variable renewable energy deployment could further strain the grid. HEDNO proposes caps on additional capacity for each technology introduced to the Greek electricity system. The proposed caps are reviewed by RAEWW and published as margins for each autonomous electricity system. The margins for different technologies for Rhodes electricity system are described below.

Renewable energy policy

Hybrid power plants are foreseen as the solution to maximise renewable energy share in non-interconnected islands while contributing to their energy autonomy and the security of supply. Several projects in the Rhodes and Chalki focus on renewable energy. For instance, the GR-Eco project in Chalki focuses on the electrification of transport.[96] Additionally, the local energy community ChalkiON has installed a 1 MW PV-plant to provide electricity to Chalki's inhabitants

Hybrid power plants

Hybrid power plants are systems that consist of renewable energy generation integrated with another generation or storage system.

Renewable energy connection policy

The Rhodes electricity system follows the national renewable energy connection policies. At the national level, the licencing procedure for RES and storage installations has been simplified under **Law 4951/2022**. The simplification applies among others, to generation plants with installed capacity smaller than 1 MW. These plants are excluded from the obligation to obtain permits regarding production, installation, and operation.

Hybrid stations and wind stations of non-interconnected islands are granted a trial operational period prior to permanent connection to the grid. After the electrification of the station, the hybrid or wind energy station enters in the phase of trial operation. The test is successful when there are 15 consecutive days without any problems. After the trial operational period, the DSO issues a certificate

[95] Three AC 150 kV submarine cable, with a capacity of 250 MVA each, between Kos and Rhodes, with a length of about 100 km.

[96] United Nations SDGs, GR-Eco Initiative, (link)

of completion of trial operation, certifying that the operational testing phase of the station has been completed.

The connection policy regarding net-metering installations is also simplified.[97] Financial incentives are provided with frequent programmes for subsiding PV and storage net-metering installations for prosumers with installations smaller than 10 kW.

Renewable energy communities, as defined by **Law 5037/2023**, are given priority in issuing permits regarding RES installations and are also excluded the obligation to pay fees for their installed stations. Renewable energy communities are also given the possibility to install RES installations with virtual net-metering schemes.

For the autonomous electrical systems of non-interconnected islands, all RES installations are restricted to follow the margin for future installations. These margins are provided by HEDNO and most recently approved by RAEWW's **decision No. E-74/2023** (**GOG B' 4668/21.07.2023**).

For Rhodes' electricity system, the following approved RES installation margins are set as follows:[98]

- Power margins for **wind turbine** stations: 48.55 MW based on the approved margins after RAEWW's decision;
- Power margins of **photovoltaic** stations: 31 MW based on the approved margins after RAEWW's decision;
- Power margins for **hybrid** stations: 20 MW based on the approved margins after RAEWW's decision;
- Power margins for **controlled biomass/ biogas** stations: 5 MW based on the approved margins after RAEWW's decision;
- Power margins for **small wind turbine** stations: 1 MW based on the approved margins after RAEWW's decision;
- Power margins for **uncontrolled biomass/biogas** stations: 0 MW based on the approved margins after RAEWW's decision.

In addition to the planned interconnection activities, there is a list of total capacities of renewable energy projects which have submitted their applications for connection, but are not granted terms of connection to the grid, to Rhodes' electricity system in the future:

- Wind power plants – 2929.8 MW (of which 2596.8 MW are part of bigger applications which include Rhodes, Crete, and Kasos);
- Controlled biomass-biogas stations – 247 MW;
- Hybrid stations – 217.6 MW (production licence) and 173.6 MW (under evaluation);
- Combined Heat and Power - 22 MW_e and 38 MW_{th}; and
- PV power plants – 9.7 MW.

It should be noted that the production licence is granted separately from a connection, at an early stage of the licencing procedure, and has the status of a "feasibility licence." Financial, sustainability, and spatial factors are not taken into account when granting this licence. In consequence, a

[97] Net-metering – billing mechanism where locally generated electricity is accounted for and cancels out the consumed electricity.

[98] The remaining available power margins for RES, according to RAEWW's decision No. E-74/2023, can be found at (link)

connection to the electricity grid is not guaranteed once a production licence is obtained when applying for a renewable energy connection.

Key challenges

Based on the above analysis, the key challenges facing the Rhodes' electricity system relevant for increased integration of variable renewable energy generation are:

- **High curtailment of wind** reduces the profitability of wind power plants. There is high-RES penetration in the summer and very low-RES penetration in the winter. Wind power plants injection to the grid is significantly reduced in the winter to protect the electricity grid due to instabilities.
  - In the winter island system's low demand, only must-run stations are operated. As TPPs provide system services, they are must-run stations. Due to low demand, even they are operated at their allowed technical minimum, or sometimes below their allowed minimum.
  - Throughout the year, wind power plants are provided with set-point power limitations. These limitations are defined so that technical and dynamic limitations are met. The technical limitation is defined as the technical minima of the TPPs. The <u>dynamic limitation for wind power plants is 30% of the electricity system load at a specific moment</u>. Hence, all wind power plants together are not allowed to exceed more than 30 % of the total system electricity load at any moment.
- **Power-cuts** typically happen three to four times per year. A main cause for the power-cuts has been the management of reactive power, especially in low-demand periods, which cannot be achieved by TPPs alone, but with compensation coils. A mitigating measure to tackle the challenge of power-cuts has been the installation of compensation coils, together with other generators and a lines operation mode.
- **Unfavourable typology of the existing grid**
  - The new TPP which is easier to manage is located in the south of Rhodes, while the old TPP that has significant challenges in the operation and electricity demand is located in the north of Rhodes. The electricity grid lines connecting the north and south of Rhodes are above ground and go through the area most affected by thunderstorms, causing issues in supply. In the past years, there have been several efforts and actions to reduce the issues in supply, as the installation of lightning conductors.
  - A major challenge has also been the transition in capacity from 66 kV to 150 kV due to the new TPP. The increased voltage required significant upgrades to the existing infrastructure, including substations, transformers, and transmission lines, which require significant resources and time. This may involve disruptions to the existing system during the upgrade process. Furthermore, the transition of voltage affects the stability of the electrical grid also increasing the complexity of managing variable generation from RES units.

Kos-Kalymnos group of islands, Greece

Governance

Nine islands in the Dodecanese archipelago make up the Kos-Kalymnos electrical power system:

- Kos (287 km^2), governed by municipality Kos;
- Kalymnos (110 km^2), Pserimos (14.62 km^2), Telendos (5 km^2) and Gyali (5 km^2) governed by municipality Kalymnos;
- Tilos (61 km^2), governed by municipality Tilos;
- Leros (54 km^2), governed by municipality Leros;
- Nisyros (41 km^2), governed by municipality Nisyros; and
- Leipsoi (16 km^2), governed by municipality Leipsoi.

The population of the islands of the electrical system is 0.6% of the total population of Greece and 4% of all Greek islands' population.[99]

Figure 20 Kos-Kalymnos electrically interconnected archipelago of 9 islands[100]

The Kos-Kalymnos islands fall under Greek national energy legislation. There are two lower governance levels. The islands are locally administered by the municipalities listed above, which are responsible for waste and water management projects. The municipalities belonging to the Kos-Kalymnos electricity system are part of the regional authority of the South Aegean region, that is responsible for the implementation of development projects at the regional level, including road infrastructure.

[99] ELSAT, Greece Census 2021 (link)

[100] Kavadias, Kosmas & Alexopoulos, Panagiotis & Charis, George & Kaldellis, John. (2019). Sizing of a solar–geothermal hybrid power plant in remote island electrical network. Energy Procedia. 157. 901-908. 10.1016/j.egypro.2018.11.256. (link)

Relevant key actors

The Kos-Kalymnos electricity system is non-interconnected. Energy policy falls under the Ministry of Environment and Energy. The NRA is the Regulatory Authority for Energy, Waste and Water (RAEWW).[101]

The DSO is the Hellenic Electricity Distribution Network Operator S.A. (HEDNO), responsible for the electricity system in Greece, including the Kos-Kalymnos islands. The electricity transmission system of mainland Greece is owned and operated the Independent Power Transmission Operator (IPTO). IPTO does not operate on non-interconnected islands. IPTO oversees the interconnection projects on those islands that are set to be completed by 2029.[102]

PPC is a large electric power company in Greece and is also the owner of the thermal power stations in non-interconnected islands. EUNICE is the owner and operator of the hybrid station on Tilos island, which was installed under the TILOS Horizon 2020 project.[103] PPC Renewables, Ellaktor and Dodecanese Wind Energy Company are the owners of the four wind parks on the electricity system.

Energy system

Generation

The electricity system of Kos-Kalymnos includes the following installed generation units:

- 2 thermal power plants with a total installed power of 168.2 MW (Figure 21):
  - 1 located on Kos island and
  - 1 located on Kalymnos island;
- 4 wind power plants with installed power of 15.2 MW:
  - 3 located on Kos and
  - 1 located on Leros island;
- 283 PV power plants with a total installed power of 10.2 MW (including independent producers with 8.7 MW, PV rooftop generation with 0.7 MW and autonomous consumers with 0.8 MW);
- 1 hybrid station located on Tilos with an installed power of 0.4 MW. The hybrid station, developed under the TILOS project, includes a wind turbine station of 800 kW (1 wind turbine), a PV station of 160 kW, and a storage system (batteries) of 2.4 MWh/400 kW guaranteed power.

In addition, during high demand in the summer periods, two emergency diesel generators are operational on the islands.

The Kos-Kalymnos electricity system had a 16% share of renewable energy in the overall electricity production in 2021. However, in the summer, when renewable energy generation is higher, the share of renewable energy can reach up to 35%.

[101] Regulatory Authority for Energy, Waste and Water (link)
[102] Kos-Kalymnos electricity system is foreseen to be interconnected.
[103] Tilos Horizon 2020 project (link)

Figure 21 Location of thermal power station of Kalymnos (above) and Kos (below) (Google maps)

Grid status and management

Kos-Kalymnos is one electricity system consisting of nine interconnected islands operating at a voltage of 20 kV.

The annual electricity consumption of the Kos-Kalymnos system in 2022 was 400 GWh, with a load factor of 46.9%. The average power load on this electricity system was 46 MW, while peak load was 98 MW (and can typically reach up to 110 MW during the summer season). During the winter period, where power loads are lower, renewable energy generation can cause instabilities in the electricity system, especially in case of system failure.

The electricity system operation follows a day-ahead scheduling process. The day-ahead scheduling process is not automated and requires constant communication between the grid operator and the power producers.

The Dodecanese interconnection project aims to interconnect the national electricity transmission system with six electricity systems of the Southeastern Aegean Islands, including the Kos-Kalymnos electricity system. [104] The project is set to be completed in 2029. Kos will be connected with the future

[104] The Kos-Kalymnos interconnection project includes:
- Four submarine cables: two with power transmission capacity at rated voltage 10.4 MVA each, and two wit power transmission capacity at rated voltage 12.1 MVA each
- Interconnection of Kalymnoss island with Telendos island, via two submarine cables with power transmission capacity at rated voltage 5 MVA each
- Interconnection of Kalymnoss island with Leros island, via two submarine cables with power transmission capacity at rated voltage 10.4 MVA each
- Interconnection of Leros island with Leipsoi island, via two submarine cables with power transmission capacity at rated voltage 5 MVA each

Corinth substation, an interconnector cable, with a capacity of 900 MW between Kos and mainland Greece.[105] The island of Kos is foreseen to be interconnected at high voltage with Samos, Rhodes, and Karpathos and at medium voltage with the other islands of the Kos-Kalymnos electricity system, thus making Kos an important interconnection hub for the electricity system.

The operation of the Tilos hybrid station with the Kos-Kalymnos electricity grid is being implemented through the **Grid Code for the Non-Interconnected islands**[106], coupled with specific algorithms for the pricing and determination of energy deviations of the Hybrid Station.

Renewable energy policy

The island of Kos completed its **Clean Energy Transition Agenda** (CETA) in 2022.[107] The CETA analyses the current energy situation and identifies priority projects for implementation in order to achieve the energy transition on the island. The CETA adheres to the main national policies regarding the energy transition and deployment of renewable energy.

The island of Nisyros has the second largest confirmed high enthalpy geothermal field in Greece, in terms of geothermal potential. The field is 3.5 km^2 with a geothermal fluid temperature over 350°C and a wellhead pressure that exceeds 40 bar[108]. It has been determined that the confirmed geothermal potential is approximately 50 MW. However, due to the environmental risks, the influence on the local landscape, and the negative example of a geothermal power plant on Milos island, the local community is strongly against the installation of a medium-high to high enthalpy geothermal power plant. Interesting alternatives propose the solution of plants that could make use of the small geothermal fields of low enthalpy scattered throughout the territory of the island, which are characterised by temperatures of 25-95°C, that could provide heating, cooling, hot water, and clean water for the island, while having the minimum environmental effect on the island.

RES connection policy

The Kos–Kalymnos electricity system follows the national renewable energy connection policies. At the national level, the licencing procedure for RES and storage installations has been simplified under **Law 4951/2022**. The simplification applies among others, to generation plants with installed capacity smaller than 1 MW. These plants are excluded from the obligation to obtain permits regarding production, installation, and operation.

Hybrid stations and wind stations of non-interconnected islands are granted a trial operational period prior to permanent connection to the grid. After the electrification of the station, the hybrid or wind energy station enters in the phase of trial operation. The test is successful when there are 15

- Interconnection of Kos island with Pserimos island, via two submarine cables with power transmission capacity at rated voltage 5 MVA each
- Interconnection of Kos island with Gyali island, via two submarine cables with power transmission capacity at rated voltage 6.6 MVA each
- Interconnection of Gyali island with Nisiros island, via two submarine cables with power transmission capacity at rated voltage 6.6 MVA each and
- Interconnection of Nisiros island with Tilos island, via two submarine cables with power transmission capacity at rated voltage 6.6 MVA each.

[105] Dodecanese Interconnection Phase A: Corinthos (2024) - Kos Interconnector (link).
[106] Operation Code for non-interconnected islands – 4th version - March 2022 (link)
[107] Kos Clean Energy Transition Agenda (link)

consecutive days without any problems. After the trial operational period the DSO issues a certificate of completion of trial operation, certifying that the operational testing phase of the station has been completed.

The connection policy regarding net-metering installations is also simplified.[109] Financial incentives are provided with frequent programmes for subsiding PV and storage net-metering installations for prosumers with installations smaller than 10 kW.

Renewable energy communities, as defined by **Law 5037/2023**, are given priority in issuing permits regarding RES installations and are also excluded the obligation to pay fees for their installed stations. Renewable energy communities are also given the possibility to install RES installations with virtual net-metering schemes.

For the autonomous electrical systems of non-interconnected islands, all RES installations are restricted to follow the margin for future installations. These margins are provided by HEDNO and most recently approved by RAEWW's **decision No. E-74/2023** (**GOG B' 4668/21.07.2023**).

For the Kos-Kalymnos electricity system, taking into account the installed systems and applications and RAEWW's **decision No. E-74/2023** issued after a last public consultation, the following approved power capacity margins are set as of January 2024:[110]

- Power margins for **wind turbine** stations: 26 MW based on the approved margins provided by HEDNO and RAEWW's decision;
- Power margins of **photovoltaic** stations: 16.2 MW based on the approved margins provided by HEDNO and RAEWW's decision;
- Power margins for **hybrid** stations: 11 MW based on the approved margins provided by HEDNO and RAEWW's decision;
- Power margins for **controlled biomass/biogas** stations: 5 MW (including a geothermal station) based on the approved margins by HEDNO and RAEWW's decision;
- Power margins for **small wind turbine** stations: 0.9 MW based on the approved margins provided by HEDNO and RAEWW's decision;
- Power margins for **uncontrolled biomass/biogas** stations: 0.9 MW based on the approved margins provided by HEDNO and RAEWW's decision.

In addition to the planned interconnection activities, there is a list of total capacities of RES projects which have submitted their applications, but are not granted terms of connection to the grid to the Kos-Kalymnos electricity system:

- Wind power plants – 12.6 MW, of which 1.8 MW is for small wind turbine projects;
- Hybrid stations – 12.1 MW;
- Biomass-biogas stations – 5.3 MW, of which 3.5 MW is controlled biomass/biogas stations and 1.8 MW non-controlled biomass/biogas stations;
- PV power plants – 4.6 MW.

[109] Net-metering – billing mechanism where locally generated electricity is accounted for and cancels out the consumed electricity.
[110] The remaining available power margins for RES, according to RAEWW's decision No. E-74/2023, can be found at (link)

Key challenges

Based on the above analysis, the key challenges facing the Kos-Kalymnos electricity system relevant for increased integration of variable renewable generation are:

- **High wind energy curtailment** (20% and approximately 8.3 GWh per year) is mainly caused by seasonal island demand, technical minima of TPPs and inability to control small capacity PV plants due to regulatory restrictions. In 2023, in order to tackle the problem of high wind curtailment, some wind power plants have been granted the permit to produce energy at the maximum of their installed capacity, thus not being subject to previous restrictions in power injections to the grid.
    - Existing wind installations, all with different technical capabilities, make it difficult to operate the system and seemingly impossible to operate as a virtual power plant, due to several turbines with outdated technology. Some wind power plants have technologies that are outdated and need to be replaced.
- The distributed **small-capacity PV systems are not controllable by the system operator** and hence cannot be used for the benefit of the system when needed.
- **Power-cuts** (blackouts) occur as a result of accidents or grid failures on each island, especially during the summer peak loads resulting in insufficiency in meeting the consumption needs for electricity and water (desalination units). The main reason for power cuts has to do with the fact that energy generation assets are not present in all islands. In consequence, they are not able to meet their energy needs autonomously in case of cable faults or frequency/voltage instabilities.
- **Issues with stability of the grid occur due to variable renewable energy** generation. For instance, PV plants' inverters are disconnected in case of voltage dips during the winter periods when demand is low. Currently, there is a **lack of reactive or active current injection or low voltage ride through requirements for renewable energy plants**.
- Hybrid power stations can bring the needed stability to the system. However, if the **hybrid station does not have the ability for a black start of the system,** a thermal generator must be installed to help. This has been a challenge on the Tilos island.
- It is **challenging to operate the multiple islands' electricity system**. The Leros and Leipsi islands have **voltage drop problems** as they are located at the ends of the system without generation plants on the islands. While the planned interconnection of the Kos-Kalymnos system with the mainland will provide flexibility to the system, islands should still ensure the safe operation of their systems. Installation of battery energy storage systems could provide flexibility and stability in these end-of-the-system situations. However, the Greek legislation currently only allows storage within hybrid power plants, and not as a stand-alone option.[111]
- Despite the technical availability of the Kos-Kalymnos autonomous electrical system to integrate renewable energy installations, there is a relatively **small number of applications for future renewable energy installations**. This is expected to be due to among others, long licencing procedures (in case of large capacity renewable energy installations), high installation costs, and the high curtailment of existing wind power installations.

[111] Law 4951/2022 (link)

Aeolian Islands, Italy

Governance

The Aeolian Islands are an Italian volcanic archipelago located in the Tyrrhenian Sea, off the northeast coast of Sicily. They consist of seven inhabited islands:

- Lipari (38 km2, approx. 9,000 inhabitants), Vulcano (21 km2, approx. 450 inhabitants), Stromboli (13 km2, approx. 500 inhabitants), Filicudi (9 km2), Alicudi (5 km2, approx. 235 inhabitants), and Panarea (3 km2, approx. 280 inhabitants), all governed by Lipari municipality; and
- Salina (26 km2, approx. 2,300 inhabitants), governed by three municipalities: Santa Marina, Leni, and Malfa.

All municipalities are part of the Messina Province in the Sicily Region. The Sicily Region is an autonomous region of Italy, which has additional responsibilities in comparison to other regions in Italy. Energy is a subject on which regional and national competencies are integrated. Regions are responsible for the authorisation of generation plants up to limited sizes, and the central government is responsible for the authorisation of medium and large plants. When it comes to environmental constraints, regions are often, but not always, responsible for the identification of areas of special attention or natural protection. The role of municipalities is mostly to provide essential public services, maintenance of local roads and public works of small and medium size. Municipalities are asked for their advice when it comes to the authorisation of infrastructures falling within their territories.

All Aeolian Islands are classified as a UNESCO World Heritage site, because of their volcanic landforms and active volcanism. All the islands are affected by constraints in terms of regional natural reserves, and other environmental and landscape protection areas, making particularly challenging the installation of renewable energy plants.[112]

Relevant key actors

National energy policy and security of supply in Italy are the responsibility of the Ministry of the Environment and Energy Security (MASE).[113] The public company Gestore Servici Energetici is responsible for the promotion of renewable energy and energy efficiency and is fully owned by the Ministry of Economy and Finance. [114]

The NRA is the Regulatory Authority for Energy, Networks and Environment, L'Autorità di Regolazione per Energia Reti e Ambiente (ARERA). ARERA carries out the regulation and controls activities in the fields of electricity, natural gas, water services, and waste management.

The electricity systems of the Aeolian Islands are managed by the following companies:

- The electricity system of Lipari island, the largest and most inhabited of the archipelago, is operated by Società Elettrica Liparese S.r.l., which is a small vertically integrated company. The company operates exclusively on Lipari, where it manages production, balancing, distribution and supply. The company is also part of the Unione Nazionale Imprese Elettriche

[112] CNR and Legambiente, The challenge of ecological transition in the small islands, 2023, (link)
[113] Ministry of the Environment and Energy Security (link)
[114] GSE (link)

Minori (UNIEM), the association of small vertically integrated companies operating on Italian non-interconnected islands.

- The other six islands: Salina, Stromboli, Vulcano, Alicudi, Filicudi and Panarea, are operated by e-distribuzione S.p.A. (distribution) and ENEL Produzione S.p.A. (production and balancing). Electricity supply is open to all operators, as in the rest of the country.

Energy system

The distribution grids of the Aeolian Islands are mostly not mutually interconnected and represent seven independent electricity systems. The only interconnection is represented by a backup cable between Salina and Vulcano power plants. The cable, which goes through Lipari without connecting to the local distribution grid, is only used in emergency situation and is opened during normal operation. No transmission network is present on any of the Aeolian islands, nor on any of the non-interconnected Italian islands.

The annual electricity generation on the two largest Aeolian islands is approximately 35 GWh for Lipari, and 26 GWh for Salina. The power systems of all the islands, affected by large touristic fluxes, are characterised by a high seasonal variability of the power demand. Notably, Lipari has a maximum peak load of 10.6 MW (evening hours around the 15th of August) and a baseload of 2 MW (nigh time in winter) (Figure 22). All the islands are characterised by summer peak loads between five and seven times higher than the autumn/winter peak loads (Figure 23). Such variability of the demand strongly impacts the production and distribution systems.

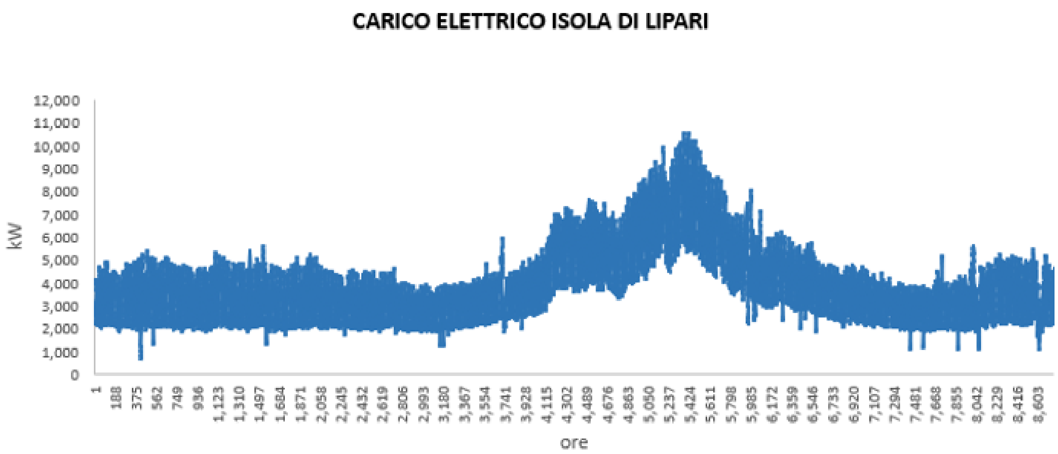

Figure 22 Typical yearly power load of Lipari. Source: SEL (from the presentation: "La transizione energetica nelle isole minori: il caso dell'isola di Lipari Stato attuale, prospettive, problematiche" at the in-person workshop in Palermo, Jan 2024).

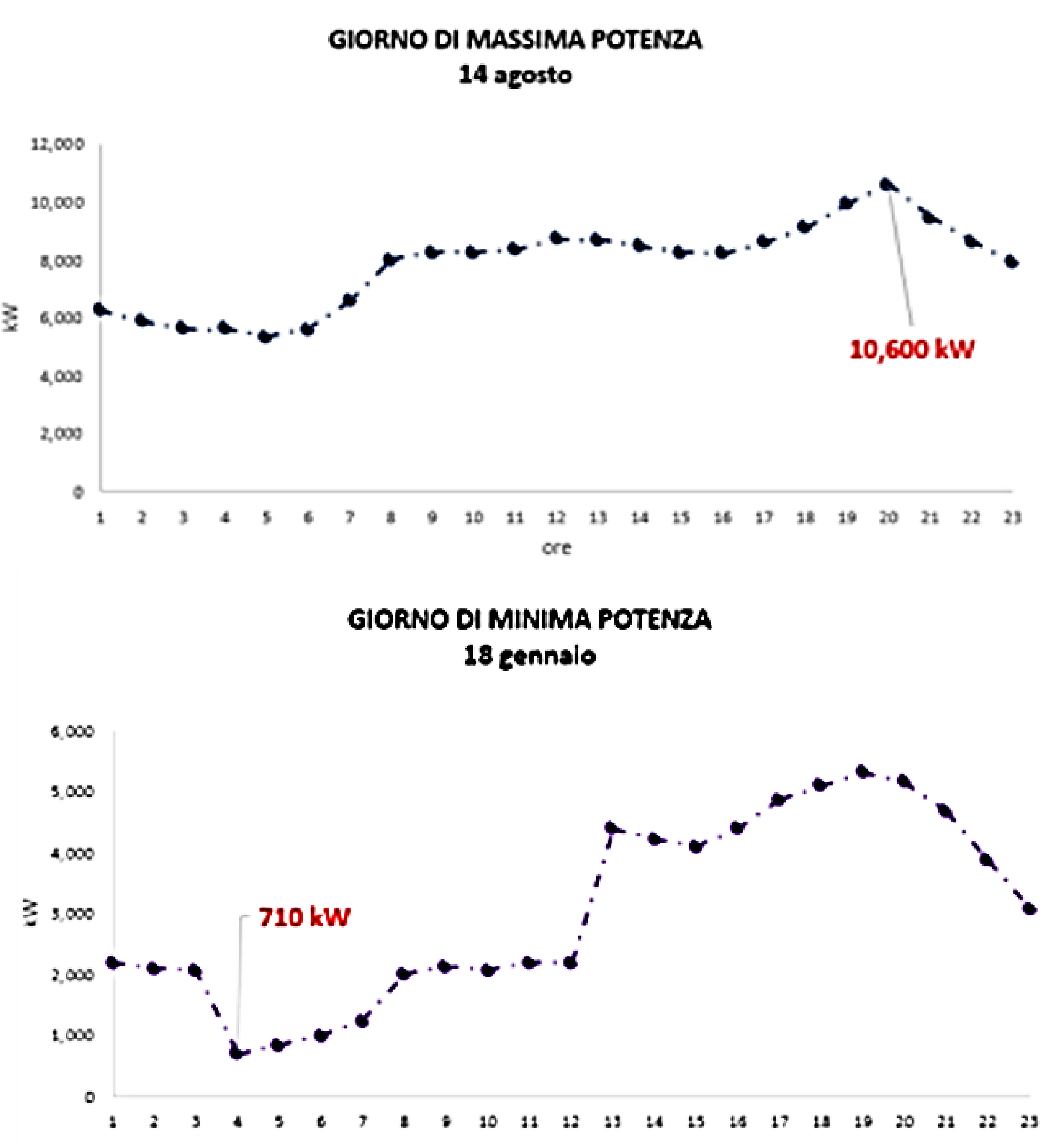

Figure 23 Maximum (top) and minimum (bottom) loads in Lipari. Source: SEL (from the presentation: "La transizione energetica nelle isole minori: il caso dell'isola di Lipari Stato attuale, prospettive, problematiche" at the in-person workshop in Palermo, Jan 2024).

Generation

Each of the Aeolian Islands has diesel-fuelled thermal power plants to provide electricity to the grid and match the demand in a flexible manner. To ensure the security of the supply and comply with maintenance needs, the total installed capacity on each island is around twice the peak demand. Details of generation plants for the two largest islands, Lipari and Salina are provided below.

Salina has the following generation plants:

- 2 diesel thermal power plants: 5.1 MW in Santa Maria Salina and 3.1 MW in Malfa;[115] and
- approximately 400 kW of distributed rooftop PV.

[115] Agenda di transizione energetica dell'isola di Salina (Link)

The Lipari generation plants include:

- 1 diesel thermal power plant with 13 generators, for a total installed capacity of 24 MW;[116] and
- approximately 300 kW of distributed rooftop PV.

In Lipari, in the area of Monte Sant'Angelo, there is also a 999-kW ground-mounted PV plant that was designed to feed the desalination system, with no connection to the local distribution grid. The plant, although constructed, has never entered operation due to administrative reasons, and is currently abandoned. The desalination system is operated in an off-grid mode, with its own diesel generators and is not connected to the island grid.

Currently, the Aeolian Islands' electricity systems are characterised by an average share of RES production lower than or around 5%.

There is a need for adequate environmental protection, preservation of biodiversity and landscape, but overlapping regional and national environmental regulations and spatial plans create a barrier to install wind and PV power plants in the Aeolian Islands.

Grid status and management

On Lipari, the MV distribution network managed by Società Elettrica Liparese S.r.l. is structured on two voltage levels: 3.3 kV and 10 kV. Generation from the diesel thermal power plant is performed at 3.3 kV. There are three MV lines at 3.3 kV, that serve the areas nearby the power plant, and three MV lines at 10 kV (Figure 24).

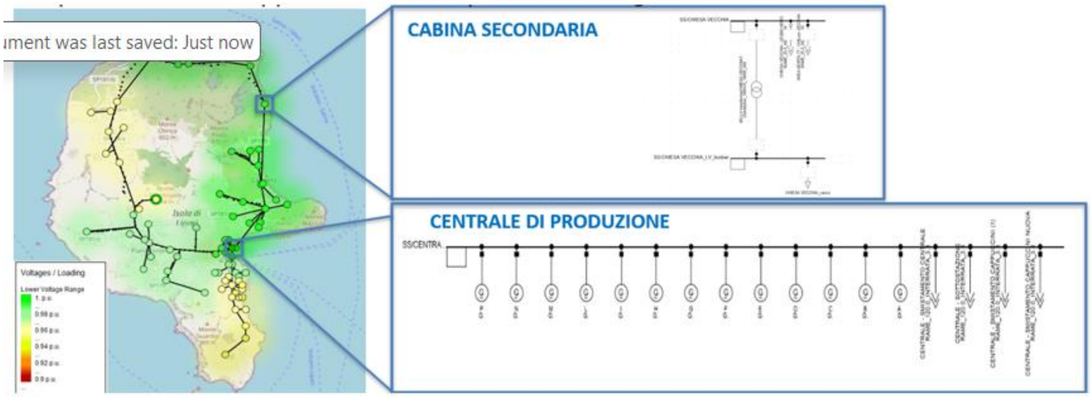

Figure 24 Map of Lipari power grid. Source: SEL (from the slides presented at the in-person workshop in Palermo, Jan 2024).

On the other Aeolian Islands, distribution is performed at a voltage of 20 kV, in line with the rest of the distribution grids managed by e-distribuzione S.p.A. in the peninsula.

Dispatch of electricity on the non-interconnected Italian islands is regulated by **Resolution ARG/elt 89/09**[117] of ARERA. Because of the small size and remoteness of the affected islands, support mechanisms for electricity companies operating on the small non-interconnected islands have been put in place. These schemes allow the companies to supply electricity to end-users at the same price as that guaranteed to mainland users (protected price). Two main cases can be distinguished among the Italian islands:

[116] M. Spiller et.al., Impact of BESS Frequency Control on Microgrids: the Case Study of the Small Island Lipari, 2023 (link)

[117] ARERA, Resolution ARG/elt 89/09, (link)

- 9 islands (including all the Aeolian Islands, except Lipari) have separate entities that manage the distribution activities (e-distribuzione S.p.A., the largest Italian DSO) and production activities (mainly Enel Produzione S.p.A.). Production and distribution are successfully unbundled on these islands.
    - For these islands, the reimbursement of costs for production activities is carried out through the national mechanism remunerating the generation plants that are essential for the security of the electricity system according to **AEEG Resolution 111/06.[118]**.
- 11 islands (including Lipari) are operated by electricity companies that were not transferred to Enel pursuant to **Law No. 1643/1962.[119]**. Production and distribution are not unbundled and are carried out by small vertically integrated companies on each island (Imprese Elettriche Minori).
    - Vertical integration occurs pursuant to Article 7 of **Law No. 10/1991.[120],** which establishes the coverage of costs of small insular electricity companies through tariff integration.

The abovementioned supporting mechanisms enable the retail price of electricity on the non-interconnected grids to be the same as in the rest of Italy. Currently, users on the islands whose grids are operated by e-distribuzione S.p.A. can access the open electricity market and choose their electricity supplier. On the other hand, users on the islands operated by the small vertically integrated companies can only buy electricity from the producer/DSO, at a nationally regulated price. ARERA intends to take regulatory measures to overcome this situation and enable users from all islands to access the open electricity market.

It is challenging to achieve the decarbonisation targets set at different governmental levels, and particularly those set for 2026 by **Law No. 34/2022**.[121] The investments needed to prepare electricity grids for integration of a high share of renewable energy and secure operation of the systems are very high. Only the costs of increasing grid flexibility with the inclusion of storage are already significant. Such investments typically require high up-front investments which are not feasible for the operators of small vertically integrated electricity companies. In addition, there is a need for a dedicated regulatory framework for electricity systems of non-interconnected islands.

There are, however, some specific financing mechanisms for innovative interventions on island grids, namely the MASE "Call for Innovative Integrated Projects for the Small Non-Interconnected Islands"[122] and the "Green Islands" measure within the National Resilience and Recovery Plan.[123] These measures have for instance led to a 4 MW – 4.9 MWh Li-ion BESS connected to the diesel-PV hybrid plant in Pantelleria. However, possible replicability of this project is not yet certain. Furthermore, investment plans are not regularly prepared by DSOs and hence not approved by ARERA prior to implementation, as foreseen by legislation. Therefore, investments from DSOs are currently mostly approved after they happen. This practice creates high uncertainties for investments.

[118] AEEG Resolution 111/06 (link)
[119] Law No. 1643/1962 (link)
[120] Law No. 10/1991 (link)
[121] Law No. 34/2022 (link)
[122] MASE „Call for Innovative Integrated Projects for the Small Non-Interconnected Islands" (Link)
[123] „Green Islands" measure of the Italian National Resilience and Recovery Plan (Link)

Renewable energy policy

In view of the high economic and environmental impact of electricity supply on small islands, the **Ministerial Decree of 14 February 2017**[124] introduced new incentive modalities for renewable energy in non-interconnected small islands, in the form of dedicated feed-in tariffs depending on the geographical location and remoteness of the islands. The decree also introduced targets for renewable energy plants by 2020 for each island. Article 39, paragraphs 1-ter and 1-quater of **Law No. 34/2022**[125] also stipulates the conversion of fossil-fuel plants and the achievement of a fully renewable energy mix by 2026 on the Italian small islands. While the incentive system has somewhat boosted renewable energy production on the small islands, the targets have not been met nor are they expected to be met by 2026.

The municipalities of the smaller islands are beneficiaries for a total amount of 200 M€ to be spent by 2026, within the framework of the **National Recovery and Resilience Plan** (PNRR), Mission 2 - Green Revolution and Ecological Transition, of the "Isole Verdi" programme. Investments are organised along five thematic areas: (i) Urban waste; (ii) Sustainable mobility; (iii) Water Efficiency; (iv) Energy efficiency; and (v) Renewable energy. At the national level, Type V interventions amount to 77.7 M€, of which 49.5 M€ for the construction of renewable energy plants (also in combination with storage systems), and 28.2 M€ for interventions on the electricity grid and related infrastructures (to favour the integration of energy produced from renewable sources).

Within the **PNRR**, the municipality of Lipari has planned two medium-sized PV plants (1 MW and 420 kW respectively), in addition to 430 kW of distributed PV on rooftops of households affected by energy poverty.

The municipalities of Salina are also implementing rooftop PV installations on public and private buildings. This initiative, after the approval of the Court of Auditors (Corte dei Conti), is reinforced with the publication of the **CER Decree 199/2021** which came into force on the 24th of January 2024.

Renewable energy connection policy

The Aeolian Islands, as the rest of the Italian small non-interconnected islands, do not have a dedicated grid code. The connection of renewable plants to the distribution grids of the islands therefore generally follows the same requirements as on the mainland.

The process for the connection of renewable power plants to distribution grids is presented in the integrated text of active connections (**Testo Integrato delle Connessioni attive**).[126] In summary, this involves:

- A request for a connection, indicating the technical characteristics of the plants, the project documentation of the intervention, the foreseen date for the construction and the foreseen date for the starting of the operation phase. This request can come at a cost depending on the capacity of the plant.
- The DSO develops a quotation for the minimum technical solution for the requested connection of the plant, to be eventually accepted by the proponent.
- A signed agreement with the DSO presented to the public bodies including potential environmental and technical evaluations, and the characteristics of the specific plant.

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[124] Ministerial Decree of 14 February 2017 (link)
[125] Law No. 34/2022 (link)
[126] ARERA, TICA, (link)

Installations connected to low voltage (LV) and MV should comply with the Italian technical norms for the connection of active users to the grids managed by the DSOs[127] and additional technical norms of specific DSOs.[128]

DSOs of non-interconnected islands also have the role of evaluating effect of proposed non-dispatchable plants of large size on distribution grid stability. DSOs can justify the rejection of the application for the connection of the plants or require additional technical measures within the minimum technical requirements.

Finally, e-Distribuzione is currently engaged in negotiations with the relevant authorities to become the operator of electricity dispatching in the small non-interconnected islands it manages, with the possibility of operating the BESS plants connected to the distribution network.

Key challenges

Based on the above analysis, the key challenges facing the Aeolian Islands' electricity systems relevant for an increased integration of variable renewable energy generation are:

- **Environmental regulations and spatial planning block the realisation of renewable energy plants on small islands**. Small Sicilian islands have many environmental and land use constraints which makes it difficult or even almost impossible to implement wind power plants or ground PV systems of any size. This blocks the energy transition as it stops exploitation of renewable energy sources available to the Italy's small islands.
- **Economic sustainability of energy production and distribution, and tariff regulation is not certain.** Article 28 of **Decree-Law No. 91/2014**[129] called for a revision of the regulation of integrated island electricity systems that should be based on efficient cost criteria and stimulate energy efficiency as well as the economic and environmental sustainability of the service. Nevertheless, a revision of tariff regulation to guarantee economic sustainability and incentivise investments has not yet been occurred.
- **Integration of distributed renewable energy generation can create instabilities in the island grid operation.** Selectivity of grid protections and the potential over frequency, with the risk of shutdown of power plants make it challenging for DSOs to connect additional RES to their island systems. The current regulation does not incentivise the inclusion of flexibility, the integration of renewable energy with storage capacity in the system, the use of RES for self-consumption, or demand-side management.
- **Inability of small island utility companies to cover high grid investments** needed for the energy transition. Regulation and legislation in Italy do not recognise small island electricity systems as different from the mainland system for investment and operation. However, small island DSOs do not have same human or financial capacity to achieve the same investments as mainland DSOs.
- While some small Italian island systems are operated by vertically integrated utility companies, Italy has not asked for their derogation from the **IMED** and in particular Articles 4, 5, 6, 7 and 8 as well as Chapters IV, V and VI. From the perspective of the government the derogation is not necessary as management of the energy systems on islands should occur in a uniform manner. As a result of vertically integrated electricity companies, **customers on small islands do not have access to the market**. On the other hand, the absence of a

[127] Norm CEI: 0-16 for MV grids (link) and Norm CEI 0-21 for LV grids (link)
[128] e-distribuzione S.p.A, Regole techniche, (link). No integrations are required by Società Elettrica Liparese S.r.l.
[129] Decree-Law No. 91/2014 (link)

derogation from the relevant **IMED** articles means that the vertically integrated electricity companies on the small non-interconnected islands do not have the (administrative) capacity to meet the national requirements. The **vertically integrated companies** on small non-interconnected islands face **difficulties in meeting the nationally standardised procedure** for dispatching applicable for the rest of Italy.

Aruba, Netherlands

Governance

Aruba is an island of 180 km^2 and 107,151 inhabitants (2022) in the Caribbean.[130] Aruba is one of four countries in the Kingdom of the Netherlands. The king of the Netherlands is the head of state. The governor of Aruba is appointed for six years, may be reappointed once. The governor's role consists of heading the Government of Aruba and representing the interests of the Kingdom of the Netherlands.

Daily operations of the Government of Aruba are carried out by its ministers who together form the Council of Ministers, chaired by the Prime Minister of Aruba. Energy matters are governed by the Minister of Labour, Energy, and Integration via Utilities Aruba NV (UA). Utilities Aruba is held by the Aruban Government, and oversees the works of the power generation, distribution, and supply companies, on behalf of the Aruban Government. Additionally, the Minister of Economic Affairs, Communication, and Sustainable Development has competencies regarding policy on the energy transition on the island.

The Government of the Netherlands is responsible for foreign affairs, defence, and the Dutch nationality in Aruba. The Government of the Netherlands additionally provides financial support to the islands through various investment programmes. For instance, the Netherlands has reserved a sum of up to € 200 million from the National Growth Fund to invest in the economic development of, and the energy transition in Curaçao, Aruba, and Sint Maarten.[131]

Relevant key actors

Water-en Energiebedrijf (WEB) Aruba is the power generation company on the island and N.V. Electriciteit-Maatschappij Aruba (N.V. ELMAR) is the sole electricity distribution company and supplier on the island. Both companies are owned by the holding company Utilities Aruba but are independently managed.

There is no official market regulator to supervise these companies; WEB Aruba and N.V. ELMAR are self-regulated through the supervision of Utilities Aruba. This has as benefit that the island has a high degree of price stability but may lack incentives to invest in the grid beyond commercial interests.

Energy system

The main energy source for Aruba comes from imported heavy fuel oil. Aruba uses thermal power plants for its electricity generation. The main sources of renewable energy are solar and wind:[132]

- Windpark Vader Piet NV was established in 2009 and generates 17% of Aruba's wind energy. A new wind park at Rincon aims to increase the renewable energy generation on the island to 35% of total electricity production. This wind park is currently in an initial project development phase.
- Sunrise Solar Park was commissioned in 2018 and has a total estimated capacity of 7.5 MW and a peak capacity of 6 MW per day. Another solar park of 3.6 MW is installed at the airport owned and operated by N.V. ELMAR.

[130] Central Bureau of Statistics Aruba, " Population, population change and population density"(link)
[131] Government of the Netherlands, NGF support to islands, (link)
[132] WEB Aruba, Technologies Used, (link)

- The island's climate plans also look at deploying natural gas as a substitute for heavy fuel oil in 2025. With regards to transport, an EV pilot project is being set up to obtain charging points for energy customers.

The electricity grid operates at 120 Volt/60 hertz. In 2023 the country's peak demand was 155 MW. WEB Aruba publishes its power production figures on its website:

EQUIPMENT	INSTALLED CAPACITY
RECIP Phase 1+2 (6 Engines)	46.8 MW
RECIP Phase 3 (4 Engines)	45.2 MW
RECIP Phase 4 (6 Engines Dual Fuel)	102 MW
GAS TURBINES	22.00 MW
WIND TURBINES	30.00 MW
SOLAR PV	6.5 MW
ENERGY STORAGE	1 MW
AVERAGE ARUBA DEMAND	**108 MW**
MAX DEMAND PEAK	**155 MW**

Figure 25 Web Aruba power production figures (WEB Aruba)

In addition to the data above, rooftop PV generation was estimated at around 14 MW end of 2022.[133] In 2019 the RES consumption was 7.8%.[134] According to the WEB Aruba's energy dashboard, currently **around 19% of Aruba's electricity generation comes from renewable sources**.[135]

Grid status and management

Aruba is not interconnected to the mainland and neither does it have any interconnections with other islands. Studies in the past have analysed the potential of optimising energy systems via interconnections.[136] These studies remain theoretical and have not led to concrete steps for interconnections in the Caribbean region. There are additionally long-term ideas for multi-sectoral collaborations between Aruba, Curaçao, and Sint Maarten, but there are no concrete plans yet.

There are storage projects on the island. The Flywheel project consists of 20 Flywheels with an energy storage capacity of 5 MW for 12 minutes. As this technology is relatively new, the flywheel park at WEB Aruba is still in a phase of optimisation. Other storage projects include a BESS pilot study by WEB Aruba.

[133] Aruban Government, Energy Report, (link)
[134] World Bank, Energy Consumption Aruba, (link)
[135] WEB Aruba, Energy Dashboard, (link)
[136] World Bank, Caribbean Regional Electricity Generation, Interconnection, and Fuels Supply Strategy (link)

Finally, WEB Aruba's Intelligent Generation Management System and the Intelligent Load Shedding System were introduced in 2021. These systems automatically regulate energy supply and power outages.

Renewable energy policy

Aruba has its own legislation that falls under the Constitution of the Netherlands. Relevant legislation on energy matters is:

- **Ordinance on electricity concessions (1005GT91.082)**[137]
  - Decision on the execution of the ordinance (1005GT89.088)[138]
  - Decision on electrical cables and pipelines (1005GT90.053)[139]
  - Decision on electrical installation regulations (1005GT96.005)[140]
- **Decision on the establishment of Utilities Aruba N.V. (1005AB90.041)**[141]

A national strategic plan for Aruba was published in 2020 which included strategic objectives for energy efficiency and diversification on the island.[142] Some of these actions were also mentioned in the Master Plan Repositioning our Sails.[143]

In 2020 the Minister of Labour, Energy and Integration published its national energy policy.[144] The main targets for 2030 for Aruba are:

- A CO_2 reduction of at least 45% compared to 2010;
- Increased energy efficiency in households and companies with 15% compared to 2020;
- Increased renewable energy generation to 50% of total production;
- Reduced daily consumption of heavy fuel in electricity production by 27% compared to 2020;
- Increased share of EV to minimum 15% of all passenger cars.

The Aruban policies on the energy transition were evaluated by the Social Economic Council Aruba, Sociaal Economische Raad (SER) Aruba in 2023.[145] On grids, the SER concluded that N.V. ELMAR as the sole electricity supplier and DSO on the island, does not have the capacity to achieve the goals for the energy transition, in terms of infrastructure. The SER was however not able to reach key stakeholders for this study, which limited the weight of their conclusions.

During the Caribbean Climate and Energy Conference, the Netherlands (Minister for Climate and Energy, Rob Jetten) signed a **Memorandum of Understanding with Sint Maarten** (Prime Minister of Sint Maarten, Silveria Jacobs) **and Aruba** (Prime Minister of Aruba, Evelyn Wever-Croes).[146] The Memorandum of Understanding consists of a cooperation agreement that focuses on various renewable energy technologies, such as wind energy, green hydrogen, solar energy, and energy storage. It includes agreements on the exchange of personnel, scientific and technological knowledge, and the organisation of, for example, joint working groups and research projects.

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[137] Aruban Government, (link)
[138] Aruban Government, (link)
[139] Aruban Government, (link)
[140] Aruban Government, (link)
[141] Aruban Government, (link)
[142] Aruban Government, "Nos Plan, Nos Futuro – National Strategic Plan 2020-2022" (link)
[143] Aruban Government, "Masterplan Reposition our Sails", July 2020, (link)
[144] Utilities Aruba, National Energy Policy, (link)
[145] SER Aruba, Advice Energy Transition, (link)
[146] Government of the Netherlands, Memorandum of Understanding, (link)

Renewable energy connection policy

Concerning the new connections for renewable energy generation, the legislation on electricity connections in Aruba dates from 1997 and has not been updated for new connection procedures. In practice, solar and wind generation is made possible on a case-by-case basis.

Private production of solar energy on existing connections is facilitated by N.V. ELMAR via the "**ELMAR Solar Policy**."[147] This policy allows net-metering for customers who install solar panels with a maximum of 10 kW for domestic use and 100 kW for business use. The policy was introduced in 2012 but due to limitations on the grid, grid expansions are necessary to allow more customers to make use of the programme.

Key challenges

Based on the above analysis, the key challenges facing the Aruba electricity system relevant to achieving an increased integration of variable renewable energy generation are:

- Aruba remains **dependent on imported fossil fuels** and materials, despite existing investments in solar and wind renewable energy, and storage. The Caribbean islands physically do not have access to the technical parts needed for the upgrade and development of distribution lines and transformer houses necessary to integrate renewable energy. This also creates an issue with the timing of projects. Investments in BESS mostly consist of private individuals investing in their own off-grid use.
- The supply chain in Aruba is vertically integrated, with one generation company and one DSO/supplier that fall under the same government-owned holding. **Administrative barriers** hinder the development of renewable energy on the island. One of the main issues has to do with the **power structures**. Investments in the grid are executed on a needs-basis and less on long-term strategies. On the one hand, there is a political will to go for the energy transition; on the other hand, there is no commercial/social incentive from the side of the utilities.
- Social aspects play a large role. **Investments in RES can lead to fewer jobs in the refineries**, meaning employees working in thermal power plants risk losing their jobs.
- There is **no policy** to dictate how much profit the companies can make; the companies can get recommendations from the government level, for instance, but nothing is binding. In consequence, there is a need for an independent regulator and a legislative mandate for the utilities. With a regulatory framework, tariff regulation can incentivise DSOs to invest in energy efficiency and renewable energy.

[147] ELMAR, Solar Policy, (link)

Bonaire, Netherlands

Governance

Bonaire is a Dutch island of 294 km^2 located in the Caribbean.[148] Bonaire's population has been steadily increasing in the past decade and especially since 2020, when the population began growing from 20,915 to 24,090 inhabitants in 2023.[149] Since 2010, Bonaire is a public body of the Netherlands (similar to municipalities), and it is governed by an island authority. The Public Entity of Bonaire, Openbaar Lichaam Bonaire (OLB), runs its internal affairs through the elected Legislative Council, the Advisory Council, and the Executive Council. The Executive Council is responsible for ordinary governance, and it implements the decisions of the Island Council.[150]

Bonaire falls under the former Netherlands Antilles legislation, which will be gradually replaced by new legislation.

Relevant key actors

The utility company is the Water and Energy Company Bonaire, Water- en Energiebedrijf (WEB) Bonaire. WEB Bonaire is owned by the OLB. As a public limited company, WEB Bonaire is directly accountable to the OLB. WEB Bonaire is the sole supplier and is responsible for the sustainable, reliable, and affordable supply of drinking water and electricity on Bonaire.[151]

WEB Bonaire falls under the regulation of the Dutch NRA the Netherlands Authority for Consumers and Markets (ACM). Customers in the Caribbean Netherlands cannot negotiate the price of electricity, nor are they free to choose the company from which they can purchase their electricity. Therefore, the ACM sets the maximum distribution tariffs that WEB Bonaire may charge for the distribution of electricity since 1 January 2023.[152]

ContourGlobal is a private company that is the sole power generation company on Bonaire. In 2013 ContourGlobal acquired all the energy production facilities on the island. These were previously owned by WEB Bonaire and Ecopower.[153] Today, ContourGlobal owns the diesel thermal power plant, and several renewable generation plants on the island.

Energy System

Bonaire is not interconnected to the mainland and does not have any interconnections with other islands. Bonaire currently uses codes similar to the **Dutch mainland Grid code** for the operation of the island's electricity system.

The relevant legislation for electricity is the **Electricity and Drinking Water Act BES**.[154] The act provides a clear framework for the ACM to regulate and supervise WEB Bonaire in the aspect of electricity tariffs.

Bonaire's electricity system has seasonality in demand, with higher peaks in the weekends and tourist seasons. The average load between August and October 2023 was 24.2 MW, while this was 20 MW

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148 Energy Snapshot of Bonaire, prepared by the National Renewable Energy Laboratory (NREL) (link)
149 Statista, Bonaire population increase from 2011-2023 (link)
150 Governance of Bonaire, St Eustatius and Saba (link)
151 Water- en Energiebedrijf Bonaire N.V. (WEB) (link)
152 Decision setting the maximum distribution rates of electricity as of January 1st 2023 for WEB Bonaire (link)
153 CG Acquires generation companies Bonaire (link)
154 Electricity and Drinking Water Act BES (link)

during the remainder of the year. The demand for electricity is higher during the low-wind periods, with higher air-conditioning demand.

Generation

The current energy system of Bonaire consists of 34.5 MW of total installed capacity. **The share of the renewable energy in electricity generation is 33%**.

Bonaire currently operates with a Geospatial Energy Mapper system. The island energy system consists of a diesel thermal power plant of 24 MW, 14 MW battery system, 12 MW wind, 5 MW solar, and a 6 MW battery.[155]

Grid status and management

Bonaire is a non-interconnected island system with a total peak load of 24.5 MW (2023). ContourGlobal is connected to WEB Bonaire with a 30 kV cable. The transmission grid operates at 12 kV.[156]

WEB Bonaire operates and manages the grid. In November 2007, WEB Bonaire entered into a Power Purchase Agreement (PPA) with Ecopower, whose plants are now owned by ContourGlobal. The PPA contains the exclusive right to supply electricity up to the predicted peak load and predicted demand. WEB Bonaire forecasts those two years in advance. The PPA includes a right of first refusal to supply any excess demand. ContourGlobal will have the opportunity to establish a commercial offer for supply of excess demand which WEB Bonaire then evaluates. This gives WEB Bonaire the opportunity to seek alternative solutions, such as setting up its own production facilities or contracting other independent power producers.[157] ContourGlobal provides grid services to WEB Bonaire as defined in the PPA.

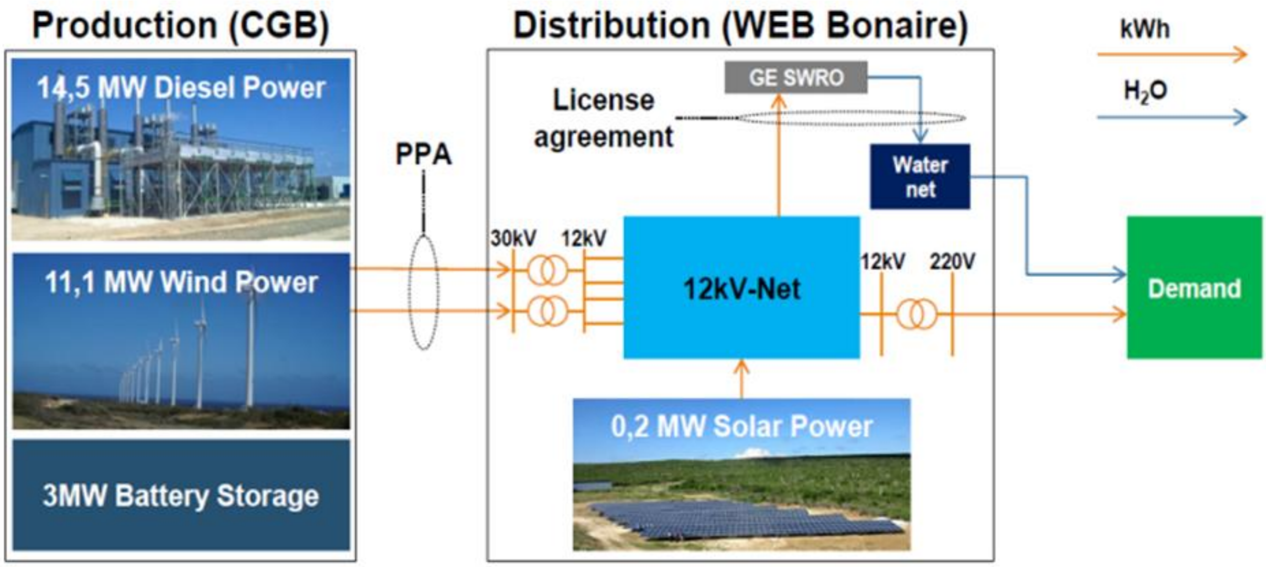

Figure 26 Electricity production system of Bonaire (2016)[158]

[155] WEB Bonaire, interview 28-06-2023
[156] Dynamic Study of Bonaire Island Power System: Model Validation and Project Experience (link)
[157] Renewable Energy Future for the Dutch Caribbean Islands Bonaire, St. Eustatius and Saba (link)
[158] Renewable Energy Future for the Dutch Caribbean Islands Bonaire, St. Eustatius and Saba (link)

Distributed PV generation creates challenges for the grid operation, as is also the case for the island of Bonaire. The main reason is that the distributed generation feeds additional electricity into the grid, which is not locally used. This creates fluctuation and instability.[159] Distributed PV generation is not controllable.

In 2020, transmission and distribution grid losses accounted for 16.5% of the generated electricity.[160] In 2023, however, losses accounted for only 10.13 % of the generated electricity in Bonaire.

Renewable energy policy

Bonaire has set the goal to achieve a 70% share of renewable energy by 2025. Bonaire invests in energy from renewable sources, such as wind, sun, and algae. WEB Bonaire has also extended the goals to include the collection and treatment of wastewater, and the distribution of irrigation water.

The electricity producer ContourGlobal and WEB Bonaire will realise the expansion of the wind farm and a central solar park at Karpata. New generators were installed in 2019 to facilitate the expansion of renewable energy generation at Karpata. Since March 2015, WEB Bonaire has had a test set-up of 792 solar panels (0.2 MW) at Barcadera that provide energy for around 60 households. With the Solar Pilot Barcadera, WEB Bonaire examines the returns and future opportunities of solar energy.[161]

While Bonaire aims to achieve high shares of RES, the biggest challenge for the grid is including distributed variable PV generation. The targeted increase of up to 60 or 70% is technically possible in Bonaire, though it will require additional flexibility of the grid (through BESS), which is financially demanding.

Renewable energy connection policy

Since Bonaire lacks specific legislation, access to the grid for the new generation is limited and kept under control by WEB Bonaire. Currently, there is no formal procedure in place for the connection of small, distributed generation. Only ContourGlobal is allowed to produce energy up to the predicted peak load and predicted demand. Any excess demand is subject to approval by WEB Bonaire. Additionally, new producers will have to apply to the Dutch government to receive a production licence.

Key challenges

Based on the above analysis, the key challenges facing the Bonaire electricity system, relevant for the increased integration of variable renewable energy generation, are:

- **The Dutch mainland grid code is used in Bonaire without accounting for the specifics** of the electricity system on the island of Bonaire. Many of the grid services are regulated through a PPA between WEB Bonaire and ContourGlobal, not making it easy or transparent for other investors or smaller generators to become part of the system.
- **Necessary investments in the grid are expensive**. While Bonaire is able to use European funds for pilot projects or testing and collect learnings for further development, **WEB Bonaire is still primarily dependent on private investment** for future-proofing its grid as needed for the energy transition.

[159] Sustainable Energy, WEB Bonaire (link)

[160] Energy Snapshot of Bonaire, prepared by the National Renewable Energy Laboratory (NREL) (link)

[161] Sustainable Energy, WEB Bonaire (link)

- **Storage or other grid flexibility options are needed to integrate additional variable renewable energy.** Currently, wind power generation is low during times of high electricity demand. Therefore, there is a need for daily balancing but also for seasonal storage.
- **Distributed PV generation is not controllable** and creates disturbances on the grid. Additional distributed PV generation, while requested by the local stakeholders is not easily integrated into the grid.
- **Power cuts** happen due to high demand or disturbances caused by distributed PV generation and low flexibility of the grid. The population of Bonaire is increasing, and the grid needs to be developed to follow this demand and to provide quality service while decarbonising.

French Polynesia archipelago, France

Governance

French Polynesia is a widespread archipelago located in the South Pacific Ocean and covering an area of 2.5 million km². It consists of 118 islands, the total land surface of which represents an area of just 3,521 km².

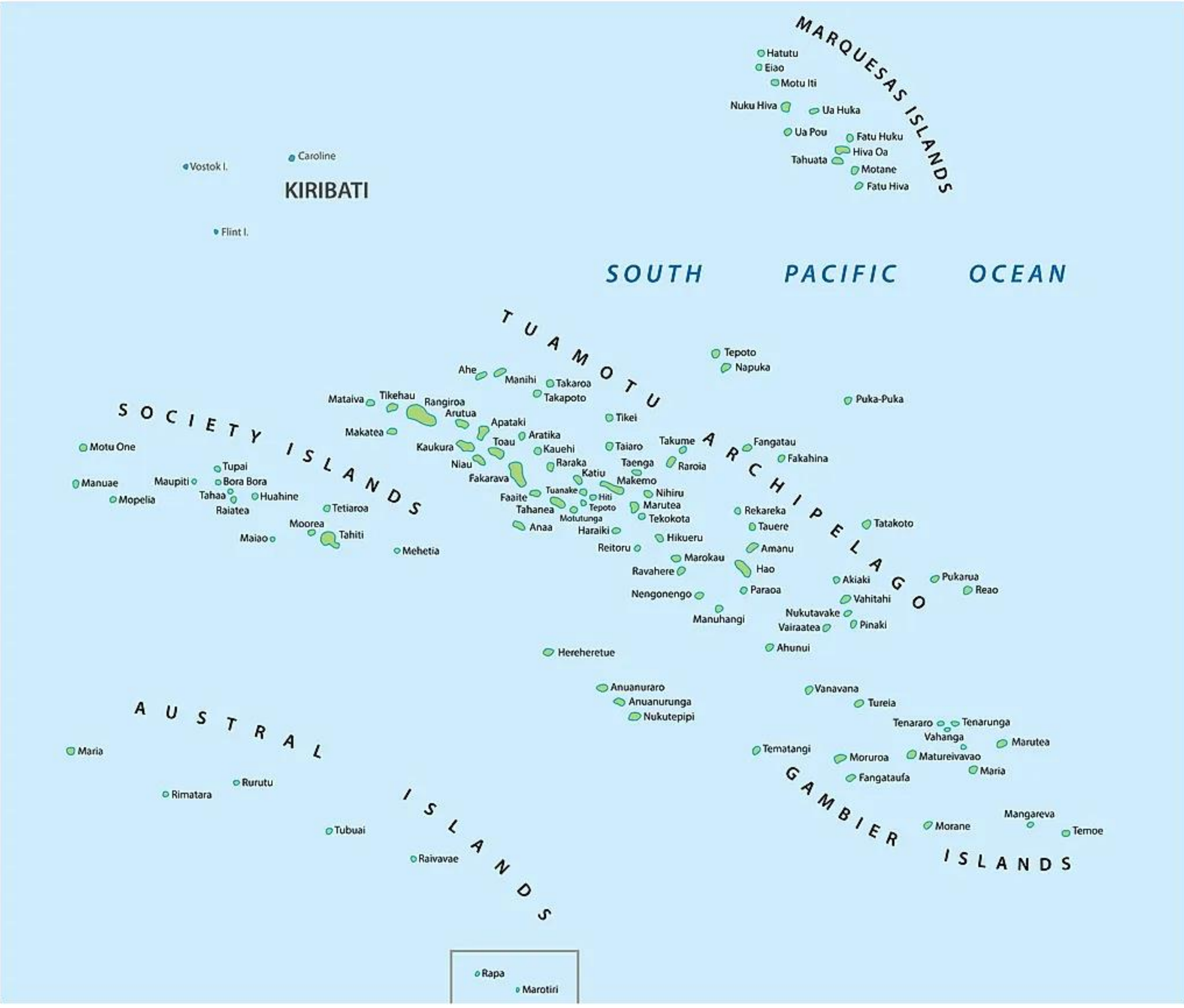

Figure 27 Map of French Polynesian archipelagos, worldatlas.com

In 2022, 278,786 inhabitants lived across 76 islands and atolls grouped into five archipelagos: the Society Islands, the Tuamotu Archipelago, the Gambier Islands, the Marquesas Islands, and the Austral Islands.[162] Of these five, the Society archipelago is by far the most populated one, grouping 245,987 inhabitants in 14 islands or atolls. It is situated in the centre-west of Polynesia and its islands make up close to half of Polynesia's total emerged surface area (1,608 km^2). Tahiti is the largest island in terms of population, area, and energy consumption. Moorea and Bora-Bora, two other island groups from Society Islands, are the next most populated islands, each about 10 times less populated than Tahiti. A breakdown of the main islands' electricity mixes is presented in Figure 28 below.

[162] ISPF, Population (link)

French Polynesia is an overseas collectivity of France. It has partial autonomy, which since 2019 includes authority over its own production and distribution of electricity.[163]

Relevant key actors

Polynesian governance levels include its President and government, elected Assembly, and local governments. The Polynesian Assembly has a legislative role and oversight responsibilities, including a dedicated Energy Commission.

The Polynesian Direction of Energy, Direction polynésienne de l'énergie (DPE) is responsible for energy matters in French Polynesia. It is a sub-unit of the Ministry of Economy, Budget and Finances. The DPE is the licencing authority for the TSO, the DSO and energy producers, while also acting as the regulator and political decision-maker. The DPE also handles the Polynesian Energy Observatory, which publishes annual statistics. The DPE handles energy matters in Tahiti Nord and is a regulator on all islands. Municipalities are competent on energy matters in Tahiti Sud and other islands.

Since French Polynesia has partial autonomy from France, the electricity system is not regulated by the French national regulator, CRE. CRE does have a partnership with the French Polynesian government and provides support for the development of the electricity system and expertise on electricity pricing.[164]

Other French national stakeholders active in Polynesia are the French Agency for Ecological Transition, the Cour des Comptes, the French Development Agency, and the Banque des Territoires.

French Polynesia has many distribution system operators. The largest DSO is Energie de Tahiti (EdT) Engie. It used to be vertically integrated utility handling the production, distribution and balancing of energy on the major islands. EdT Engie's subsidiary Maramu Nui operates hydro power plants on French Polynesia.

The TSO is the société de Transport d'Énergie électrique en Polynésie (TEP). EdT Engie used to be a minority shareholder of TEP, owning 39% of the shares with the Polynesian government owning the rest. In 2021, following the Polynesian government's decision, EdT Engie sold its shares in TEP to a subsidiary of the national French TSO, the Réseau de Transport d'Électricité International. The French Polynesian government and the Réseau de Transport d'Électricité International are the only two shareholders of TEP.

Energy system

Polynesia's energy transition governance is published in two documents that were first developed 2015 and have since been updated:

- The **energy transition plan**[165] presents a strategic vision with concrete actions but has not reach the scale of other French Islands' PPE. It is to be repealed by the **Polynesian Multi-Year Energy Plan**, the PPE 2022-2030. That document being finalised; preparatory works included a 2022 conference of energy transition to engage the wider public.[166]

[163] French Polynesian government, loi organique n° 2004-192 du 27 février 2004 and loi organique n° 2019-706 du 5 juillet 2019

[164] CRE, "La Commission de régulation de l'énergie et la Polynésie française renouvellent leur partenariat" (link)

[165] Polynesian Government PTE 2015-2030, (link)

[166] Polynesian Government, Assises de la Transition Energétique, 2022, (link)

- The **Climate Plan,**[167] which had set ambitious goals that were not reached and for which a full ex-post evaluation[168] has been published. It has since been replaced by the **Climate Plan 2022-2030**, with the even more ambitious objective to halve GHG emissions by 2030 from 11tons/person.[169] This report also features a stakeholder engagement mechanism: its implementation features a 20-person citizen's committee.

Through these documents, French Polynesia sets a target of 75% renewable energy by 2030 for the whole archipelago. This target has however been deemed unrealistic by the French Cour des Comptes in 2023 due to the impossibility of realising the necessary capacity additions in time.[170]

An important source of subsidy is the French National Energy Transition Fund of 7 billion XPF (around 60 million euros). It is distributed yearly, with 1.8 billion XPF in 2024. It is managed by the Polynesian government, which distributes it to the communes that have control over energy in their territory – except in Tahiti Nord, which is handled by the DPE. All investments made in 2023 have been made outside Tahiti to create a hybrid system of fossil-fired power plants and solar power.

Consumption in Tahiti is stable at around 500 GWh per year. Fuel costs for electricity generation are subsidised by the Polynesian Fund for fuel cost regulation. Fuel costs for electricity are kept constant, meaning there is no variation in electricity prices from hour to hour or day to day within an island.[171] In addition, tariff regulation is applied in the archipelago, leading to uniform prices across the islands. As a result, there is no price variation to encourage the adaptation of consumption or the installation of storage facilities.

Generation

In French Polynesia the renewable energy share in electricity generation was 35.9% in 2022 on all islands.

Energy is produced mostly from fossil fuels (mainly diesel, but also gasoline, liquified petroleum gas). Fossil fuels are used for 38% for electricity generation and for 50 % for local transport. In 2022, electricity generation in French Polynesia came from:

- thermal power plants and diesel generators (270 MW, with 172 MW of it in Tahiti)
- solar (52 MW),
- hydraulic power plants (47 MW), and
- wind.

Renewable energy is also used for heating and cooling applications using solar thermal and seawater air-conditioning. French Polynesia is a pioneer in terms of renewable cooling through seawater air-conditioning systems (SWAC). The largest SWAC installation was commissioned in 2022, designed for air conditioning at the French Polynesian Hospital (CHPF).[172] It subsequently contributed to 6% of the renewable energy production in French Polynesia that year.[173]
In addition, copra oil, a locally exploited energy source derived from coconuts is also used.

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[167] Polynesian Government, PCE 2015-2020, (link)
[168] Polynesian Government, PCE Evaluation Finale (link)
[169] Polynesian Government, PPE 2022-2030, (link)
[170] Cour des Comptes, PFR 2023, (link)
[171] French Polynesian government, Bilan Energetique 2022, (link)
[172] EIB, Tahiti Centre Hospitalier SWAC, (link)
[173] French Polynesian Government, BEPF 2022, (link)

	Production thermique nette (GWh)	Production hydraulique nette (GWh)	Production PV Total (GWh)	Production d'électricité (GWh)	Taux d'EnR (%)	Consommation électrique (GWh)	Consommation par habitant (kWh/hab)
Tahiti	281,3	192,8	41,0	515,1	45,4%	489,7	2 553
Bora Bora	42,1	0	1,9	44,0	4,3%	42,4	3 941
Moorea	34,9	0	1,9	36,7	5,2%	34,4	1 926
Archipel de la société (hors Tahiti, Bora Bora et Moorea)	39,5	0	2,7	42,2	6,5%	38,7	1 514
Archipel des Tuamotu-Gambier	19,1	0	1,8	20,9	8,8%	19,0	1 138
Archipel des Marquises	12,0	1,6	0,3	14,0	14,3%	12,2	1 287
Archipel des Australes	7,2	0	0,2	7,4	2,8%	6,8	1 032
Total	436,0	194,4	49,9	680,3	35,9%	643,3	2 307

Figure 28 Polynesian generation and consumption breakdown per island or archipelago for 2022, Observatoire Polynésien de l'Energie[174]

Decentralised solar in French Polynesia has been successful, with 52 MW_p of solar installed; Figure 29 below shows its evolution. This data may be updated as the DPE has been carrying out checks to ensure the accuracy of the registered PV.

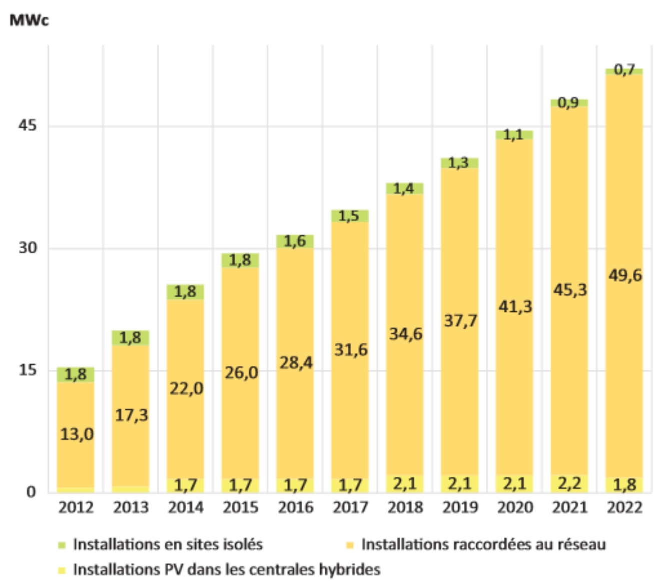

Figure 29 Total solar PV capacity in Polynesia in MW_p, 2012-2022, OPE[174]

In Tahiti, solar energy is currently mainly decentralised. The largest PV plant at present has a nominal capacity of 1.28 MW_p.

[174] French Polynesian Government, BEPF 2022, (link)

Tahiti has significant hydro power potential. Hydro power plants on French Polynesia are operated by EdT Engie's subsidiary Maramu Nui. Installed and operating hydroelectric capacity is 48 MW in Tahiti and 1.2 MW in the Marquesas Islands. There are several types of hydro power plants in Tahiti:

- five valleys featuring dams;
- two run-of-the-river grid-connected installations; and
- isolated micro-hydro turbines.

The European-funded research and development project IANOS is currently being conducted on Bora-Bora.[175] There, it will install 2 MW_p of agrivoltaics, 2 MW_p of fish-farm PV, and battery and/or hydrogen storage.

Grid status and management

French Polynesia's electricity grid consists of 63 public electricity systems. Of them, 12 are managed by EdT Engie through a public mandate, while the other islands are operated by local system operators. None of the islands are interconnected with each other. All islands outside of Tahiti feature an electrical system of a few MW at most. They are managed by EdT Engie or by publicly owned companies which take various forms (e.g., EPIC Moorea-Maiao or SPL Te uira api no te mau motu).

Electrification is underway on some islands, such as Maiao, near Moorea. 17 inhabited islands do not possess an electricity grid. Their total population of 1,088 inhabitants is serviced by diesel generators and/or isolated PV installations.

Tahiti features two different distribution grid sections, Tahiti Nord and Tahiti Sud. Tahiti Nord has been operated by EdT Engie since 1960, and Tahiti Sud has been operated by a subsidiary of EdT Engie since 2017. The transmission grid is managed by the TSO TEP in both regions.

French Polynesia has its own **energy code, adopted in 2019 by the French Polynesian Assembly**.[176]

Pertes	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Transport et distribution (ktep)	4,6	4,6	4,1	4,1	4,2	3,4	3,4	3,2	3,4	3,3	**3,2**
GWh	53,3	53,3	47,7	47,9	48,7	39,7	39,3	37,5	39,0	38,7	**37,0**
%	7,9%	8,1%	7,3%	7,3%	7,2%	6,0%	6,0%	5,6%	6,1%	6,0%	**5,7%**
Transformation (ktep)	68,4	67,8	64,3	64,7	65,5	64,6	63,9	65,9	63,9	65,2	**61,8**

Figure 30 Losses in energy production (bottom, in ktoe) and energy transport and distribution (top, in ktoe, GWh and % of primary energy used for electricity)

In 2022, expected electricity transmission and distribution losses for the entirety of French Polynesia amounted to 37.0 GWh, or 3.2 ktoe. This represents 5.7% of all electricity generated in the French overseas territories. Nonetheless, Figure 30 shows that both the grid and the generation units are getting more efficient.

[175] European Commission, IntegrAted SolutioNs for the DecarbOnization and Smartification of Islands (IANOS), (link)
[176] LOI DU PAYS n° 2019-27 du 26 août 2019 instituant un code de l'énergie de la Polynésie française et précisant le contenu de ses titres 1er et II (link)

A challenge for Tahiti's grid management is handling variable PV generation. Balancing is especially challenging when there is low demand,for example on Sundays, when the peak demand is around 50 MW (compared to 90 MW during weekdays).[177]

Polynesian islands are prone to sudden weather changes and suffer from a lack of reliable weather forecasts. Consequently, EdT Engie has developed tools to facilitate solar power prediction at different time intervals.

In Tahiti, hydroelectric installations have historically been required to supply a certain amount of power during the day, in accordance with the **Modulated Guaranteed Hydraulic Power policy**. However, the daytime power obligation conflicts with generation from PV. In consequence, the obligation has been abolished in order to facilitate PV generation during the day and keep hydraulic production at night, thus reducing the load on fossil fuel generation.

Tahiti's grid is helped by the Putu Uira Virtual Generator, owned and operated by EdT Engie, since 2022. It is made up of transmission grid-connected stand-alone batteries. The virtual generator aims to reduce the runtime of the Punaruu thermal plant, allowing one of its two generator units to be turned off, which can save up to 3,000 tons of diesel per year. Its power is 15 MW, and its capacity is 10 MWh.[178]

Putu Uira constitutes an enhancement of a thermal plant: it eliminates the Punaruu thermal plant's spinning reserve requirement, thereby improving its efficiency. The plant does not enhance renewable energy valorisation directly. The battery is typically kept at a state of charge of 80-85%, which has the added benefit of allowing for the absorption of the solar production peak during abrupt thunderstorms. Putu Uira tests have allowed for one hour of 100% renewable electricity on the grid.[179]

French Polynesia's tariff system

As French Polynesia has autonomy on the energy sector, the country does not fall under the French regulated electricity tariffs. As of 1 January 2022, a new legislation loi du pays n° 2021-5 du 28 janvier 2021 introduced a scheme to compensate for the varying production costs of system operators in French Polynesia. Electricity tariffs are partly regulated, with a reference price set each year by the Council of Ministers. A levy is added to the electricity cost in cheaper islands.

In order to receive their financial compensation, DSOs must meet a certain number of obligations. In particular, the average price of electricity sold for each network must comply with the reference price. DSOs are expected to stay within a 20% deviation from this reference price. (French Polynesian government, Bilan Energetique 2022, (link)).

A recent document by the French Environmental, Social and Energy Council does however recommend extending the mainland French tariff regulation to French Polynesia and other excluded territories. (CESE, Transition Energétique, (link)).

[177] Polynesian Government, Assises de la Transition Energétique, 2022, (link)

[178] EdT Engie, "Concession de Distribution Publique d'Energie Electrique De Tahiti Nord", December 2022

[179] French Polynesian Government, BEPF 2022, (link)

Renewable energy policy

French Polynesia has the most potential in solar, hydraulic, and marine energy.[180] The French Polynesian government not only looks at investing in renewable energy but also at how to address technical challenges such as variable PV production and land-use competition between energy, housing and agriculture. This includes the implementation of storage solutions (decentralised and centralised), giving priority to solar energy during the day and hydroelectricity at night, as well as deploying smart meters. The French Polynesian government also would like to explore more flexible thermal production facilities, giving way to renewable energies.[181]

In 2022 the first PV tender auctioned 30 MW (or 7% of Tahiti's electrical capacity), with three winners for around 10 MW each, two of which are to be connected to the transmission grid. The second PV tender for a further 30 MW was expected to be issued in 2024, but it was retracted. The second tender is shifted from 2024 to 2026.

On small islands, PV generation is mostly centralised and hybridised with fossil fuel power plants. For these smaller islands, the government's vision emphasises solar power and diesel. Future power plants should reach an 80-85% of solar renewable energy with batteries.

Hybrid power plants are preferred for small- and medium-sized islands. Their purpose is to combine renewable energies, limited storage, and thermal power, to meet demand. Their priorities are to reduce the cost of electricity, cut GHG emissions, and guarantee the security of supply. Such plants are planned by a medium-sized island utility, SPL Te uira api no te mau motu, which operates the grid on four islands and whose master plans aim to achieve a 50% renewable energy share in the territory they operate on by 2030. The plan aims for a 1.2 billion XPF hybrid project on Huahine, where the SPL has control of the land: 3 MW of solar power, 5 MWh of batteries (power to be determined) to be hybridised with the existing diesel power plant.

Renewable energy connection policy

The **Energy Code** stipulates that renewable energy should be given priority access to the electricity grid.

Key challenges

Based on the above analysis, the key challenges facing the French Polynesian electricity systems when increasing integration of variable renewable energy generation are:

- **Lengthy unbundling process between EdT Engie and TEP**, which creates a lack of clarity on the division of the tasks and responsibilities of the two parties.
- **End-of-life handling of batteries** demonstrates a reliance on external stakeholders and imports to be able to carry out necessary works. Due to a **lack of expertise** on small islands, many renewable and/or storage installations are not sufficiently maintained. Capacity and knowledge building of relevant experts on the islands is necessary.
- The **regulatory framework remains to be completed**. The Energy Code chapters authorising PPAs are not yet published, despite strong investor interest, and solar PV electricity purchase tariffs have not been revised in ten years.

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[180] Polynesian Government, Assises de la Transition Energétique, 2022, (link)

[181] Polynesian Government, Assises de la Transition Energétique, 2022, (link)

- **Lack of adequate weather forecasts** makes solar power generation hard to predict and manage. Qualitative forecasts, adapted for the specifics of the islands, are needed to ensure the balancing of the system with high shares of variable renewable energy.
- **Lack of control over distributed PV.** Distributed generation cannot be aggregated or controlled, and it can cause severe frequency disturbances to the system. Regulation is in place, but enforcement capacities are currently missing.

Main challenges and recommendations

The Clean energy for EU islands Secretariat analysed case studies, interviewed relevant stakeholders, and assessed challenges and possible solutions in a set of online and in-person workshops.[182] In each of the case studies the secretariat identified **key challenges** for the increased integration of variable renewable energy. This chapter presents these challenges grouped into five main horizontal challenges. The chapter further presents recommendations that can be used to overcome them. The challenges and recommendations are not presented based on their priority.

It is important to note that each of non-interconnect island electricity systems is specific. Each system requires unique analysis, including electricity grid, security of supply and generation adequacy studies to be able to provide system specific recommendations on grid code and requirements for connection and operation of RE generation. The recommendations in this study are broader guidance on the technical and regulatory solutions that can be applied to all non-interconnected and even interconnected island electricity systems.

Main challenges

The challenges identified for ten case studies, and presented above, are grouped into the following **five main horizontal challenges**:

1. Power interruptions and outages due to multiple grid instabilities and system vulnerability to extreme weather conditions.

Islands face power cuts (black-outs or load shedding) due to two main reasons:

- Instabilities in the electricity system are often caused by the operation of variable renewable energy generation plants during periods of low demand. Power cuts occur due to the lack of electricity system flexibility in both generation and demand, or lack of reactive power compensation.
- Islands are more vulnerable in the face of climate change, not only due to their remoteness but also as a result of increasing extreme weather conditions (storms, high temperatures causing fires). Extreme weather conditions impact the operation of electricity infrastructure, causing disruptions.

2. High curtailment of variable renewable energy power plants to ensure system reliability.

Islands are seeing high curtailment of variable renewable energy generation, ranging from 10% to completely shutting down variable renewable energy generation during periods of low demand. To quantify all variable renewable energy that is being curtailed, a forecast of the possible generation is needed. There are two main causes for the curtailment of variable renewable energy on the islands:

- Electricity grid services, such as system inertia and frequency and voltage regulation, are provided by existing TPP. Historically, these TPP are designed to have a high capacity to be able to answer to demand peaks. In addition, aged TPP have high technical limitations for modularity in operation. TPP, as well as geothermal power plants, thus lack generation flexibility and in consequence do not enable the integration of renewable energy generation. Plants that offer grid services have priority of operation. Therefore, in case of

[182] For more information on the workshops please see the chapter earlier in the report: Workshops.

low demand, variable renewable energy generation is the only generation that can be curtailed, and in some cases completely shut down.

- Integrated variable renewable energy generation causes instabilities in the electricity system in case of low demand, or other disturbances that cause voltage or frequency variations.

Most of the islands do not have any regulation defining remuneration of curtailed electricity. This leads to uncertainty with regards to curtailment of variable renewable energy and creates a significant risk for any investor in renewable energy.

3. Limited resources to support the formulation of targeted regulatory frameworks to enable the transition from thermal to renewable-based systems.

Integration of variable renewable energy creates instabilities in the electricity system that are difficult for system operators to balance. With increasing grid congestion, certain Member States have placed limits on the amount of electricity renewable energy plants are allowed to generate. This helps protect security and quality of supply, but also affects the permitting procedures for new renewable energy connections.

Demand-side management can offer a solution to such capacity constraints. However, smaller grids on non-interconnected islands often do not have the technical or physical capacity for such flexibility services. Additionally, where demand-side management is possible, the relevant actors do not have sufficient resources to make use of it. Also, in terms of grid planning, DSOs on islands are sometimes missing capacity to implement new solutions. They rely on external investments, external support, and imported materials and resources, which are not always available.

Finally, unbundling requirements for vertically integrated small island electricity companies create significant administrative burdens, slowing down the already limited capacity of the electricity companies.

4. Lack of sufficient controllability of existing systems' assets and slow uptake of smartening initiatives.

Islands can have very high integration of distributed PV generation on rooftops. To incentivise the uptake of distributed renewable energy generation, distributed PV generation is often treated with a net-metering scheme or an incentive price for the injected electricity. While these developments are beneficial and ensure engagement of local stakeholders and involvement of private capital, existing small scale and distributed PV generation is very often not controllable, due to requirements for connection of small capacity PV.

Solar power is weather sensitive, meaning electricity generation is subject to fluctuations, which can lead to grid instabilities. In periods of high-production, excess electricity is injected into the grid, which system operators have to balance. The island electricity grids require upgrades and are not built for two-way electricity flows. As a result, increased distributed PV generation can create congestion on the existing grids, requiring additional grid investments.

Such developments can cause social inequality, as the residents which can afford to install distributed PV are becoming independent from electricity costs, while using the grid as a large energy storage. Moreover, the rest of consumers, not having distributed PV, could end up paying for the grid investments needed.

5. Complex and fragmented permitting and connection policies for renewable energy power plants.

Due to national, regional, and local environmental and spatial constraints, it is very difficult, and sometimes not possible, to install renewable energy generation plants on small islands. On non-interconnected islands, permitting procedures for generation plants are complex and not designed to enable specific types of renewable energy generation and by extension, do not foster the energy transition. For instance, in some Member States grid codes define connection requirements designed for the safe installation of TPPs. In consequence, renewable energy generation plants need to fulfil requirements that they cannot meet, and as such in extreme situations cannot install their plants.

Connection procedures tend to be complex and not suited to the circumstances of the islands. Often, high-level strategic plans are designed at the national level and do not always incorporate specific characteristics relevant to grid planning on the islands. Connection procedures also tend to be non-transparent for local stakeholders, disincentivising the installation of renewable energy plants. For instance, on some small islands, grid codes do not exist. In those cases, the historical context makes so that it is very common to have only a few stakeholders involved with electricity system. This results in a lack of transparent information to other interested stakeholders, making it difficult to install and connect a renewable energy generation, or participate in the electricity system at all.

Recommendations

In the following section of this chapter the secretariat proposes a set of recommendations to tackle the abovementioned challenges. While the analysis in this study focuses on non-interconnected islands, the recommendations can also be applied to electrically interconnected islands or even remote areas on the mainland. Moreover, each of the recommendations can be implemented at the EU, national or local level. In this chapter, each recommendation indicates the applicable level of implementation, the applicable type of islands, and, if available, existing publications providing guidelines on the topic and examples of best practice.

All recommendations are aimed at improving the electricity grid planning, operation, and management in order to optimise the integration of variable renewable energy generation and ensure security and reliability of supply on the islands. The recommendations are grouped into two categories:

- the first set of recommendations addresses operational and management aspects of the island grids;
- the second set of recommendations addresses grid planning, enabling policy and regulatory framework.

The table below provides an overview of the recommendations, grouped into two sets, and indicating the number of horizontal challenges that it addresses. Each recommendation is described in further detail below.

Recommendations	Challenges addressed
1 Operation and management	
1.1 Foster renewable energy resource diversification and complementarity	1,2
1.2 Foster the use of hybrid power systems	1,2
1.3 Enable the use of centralised storage systems	1,2
1.4 Support the use of long duration energy storage systems	1,2

1.5 Optimise technical and operational requirements of renewable energy generation	1,2,4
1.6 Encourage and support sector coupling	1,2
1.7 Require monitoring and support of the development of smart grids	2,3,4
1.8 Support improvements in generation forecasting tools	2,3,4
2 Planning, enabling policy and regulatory framework	
2.1 Foster thorough electricity system planning and resilience	1,5
2.2 Loosen ownership rules for electricity storage and unbundling requirements for small island electricity companies	3,5
2.3 Allow aggregated control of distributed renewable energy	1,3,4
2.4 Enable joint management of multiple plants – virtual power plants	1,2
2.5 Define a clear regulatory framework on curtailment and its remuneration	2
2.6 Simplify and align grid planning and renewable energy permitting procedures	3,5
2.7 Optimise tender design	4,5
2.8 Create an enabling framework for demand-side management	2,3
2.9 Ensure security of supply for sustainable economic development	2,3,5
2.10 Sensitise national regulation for grids to specific cases of islands	1,2,4
2.11 Provide capacity building opportunities for island system operators	3,5

Table 3: Overview of challenges and recommendations

1. Operation and management recommendations

Recommendation 1.1: Foster renewable energy resource diversification and complementarity

Diversification and complementarity of renewable energy sources can help mitigate island electricity systems reaching maximum capacity of integrated renewable energy. An optimal mix of renewable energy generation includes a diversity of energy sources as well as in the geographical location generation plants.

Complementarity is typically found between wind and PV, since PV is available during the daytime and wind is mostly available during the night-time. Complementarity can also be found between variable and non-variable renewable energy such as wind or PV and geothermal or hydropower.

Complementarity and diversification can help provide a baseload production capacity using renewable energy generation. When analysing the optimal mix, it is important to follow the effect on levelised cost of electricity.

Resource diversification and complementarity should be encouraged with policy, allowing for the optimal use of local resources and energy security. Governments are recommended to analyse resource complementarity and diversification in strategic planning and support of different technologies. It is also recommended to consider diversification and complementarity in the design of tendering processes (Recommendation 2.7).

LEVEL OF IMPLEMENTATION	
⊖	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Recommendation 1.2: Foster the use of hybrid power systems

Hybrid power systems, combined technology power plants, are systems that consist of renewable energy generation integrated with other renewable energy generation or energy storage systems. Hybrid systems have multiple benefits for isolated electricity systems.[183] Some of the benefits of the hybrid power systems include:

- Optimised use of the existing electricity grid to integrate variable renewable energy generation, decreasing the need for additional infrastructure investments and providing system services;
- Optimised use of space/land which is important for islands considering spatial and environmental constraints;
- Increased share of variable renewable energy generation by maximising the use of local renewable energy resources, decreasing curtailment, and thereby increasing security of supply and resilience of the system;
- Improved economics of decarbonisation by diversifying revenue streams (e.g. renewable energy generation and system services) and shared costs (e.g. permitting, siting, equipment).

Hybrid power systems have wide variety of system architectures, thereby responding to a wide variety of system needs. Often, hybrid power systems include one renewable energy generation plant and one storage system (e.g. BESS) to optimise locally generated electricity. Depending on the size of the hybrid power system and electricity system, it can provide local system support or overall system support. If the system operator requests a specific power profile from generation plants, variable renewable energy generation integrated with BESS in a hybrid power system can respond to such request. Additionally, existing renewable energy generation plants can be hybridised by adding different technologies to renewable energy generation or storage systems.

Hybrid systems are not yet defined in regulation and hybridised power plants are therefore treated as separate systems. In 2019, in order to level the playing field for hybrid power plants WindPower identified key policy recommendations in their publication "**Renewable hybrid power plants benefits and market opportunities.**"[184] Using these recommendations, the secretariat recommends a regulatory framework including the elements listed below. National governments, together with regulatory authorities, should develop a regulatory framework defining hybrid systems and including the following points:

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[183] Hybrid power plants are referred to as combined technology power plants in SWD/2022/0149 COMMISSION STAFF WORKING DOCUMENT Guidance to Member States on good practices to speed up permit-granting procedures for renewable energy projects and on facilitating Power Purchase Agreements (Link)
[184] Renewable hybrid power plants benefits and market opportunities, WindEurope, 2019 (Link)

- Hybrid power plants should be allowed **one grid connection point**. Metering should be streamlined which **allows tracing of energy flows** (for which clear monitoring practices should be defined);
- Total **hybrid power plant capacity** of all integrated renewable energy generation and storage systems must be allowed to be **higher than the hybrid power plant's approved grid connection capacity**;
- In case of hybridisation of existing connected power plants, **connection and permitting requirements** should only apply to the **new installation**;
- **Sizing of the storage capacity** should be optimised based market design and opportunities and not should not be defined in regulation; and
- **Double taxation and double grid charges should be avoided**.

LEVEL OF IMPLEMENTATION	
⊖	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Existing publications

European Commission's Recommendation and Guidance to Member States on good practices to speed up permit-granting procedures for renewable energy and related infrastructure projects - C/2024/2660 (link) and SWD/2024/333 (link)-, updating the 2022 **Recommendation and Guidance to Member States on good practices to speed up permit-granting procedures for renewable energy projects and on facilitating Power Purchase Agreements – C/2022/3219 (link) and SWD/2022/0149 (link)**

With the increased share of variable generation in the electricity grids, the hybridisation of power plants offers the following benefits:

- optimising the use of grids and can helping to reduce infrastructure investment costs;
- ensuring more stable power output, thereby mitigating the variability of renewable energy generation;
- adding a storage for the energy that would otherwise need to be curtailed.

To support the use and implementation of hybrid power plants, the regulatory framework needs to:

- clarify the permitting procedures for hybrid power plants and hybridisation of existing plants;
- define rules for monitoring the energy flows between the storage and the grid;
- allow hybrid power plants to apply for grid capacity based on the maximum anticipated generation, instead of the sum of the capacities of the individual complementary technologies;
- allocate connection capacity to the combined hybrid power plant and not as if they were each separate projects.

European Commission's Recommendation on Energy Storage – C/2023/1729 (Link)

Member States should accelerate the deployment of storage facilities and other flexibility tools in islands, remote areas, and the EU's outermost regions areas with insufficient grid capacity and unstable or long-distance connections to the main grid. For example, Member States can implement support schemes for low carbon flexible resources, including storage. Member States should additionally **revise the network connection criteria to promote hybrid energy projects.**

Best Practices:

Greece – support for the development of hybrid power systems

Greek legislation provides strong support for hybrid power systems in non-interconnected islands with **Law 5037/2023 (FEK B' 78/28.03.2023).** Hybrid power systems are supported with a goal to increase the share of renewable energy in non-interconnected islands from the current estimate of 20% to a share of 50% of the electricity generation for each non-interconnected island system. Hybrid power plants are expected to replace the existent TPPs in the future. This is reflected in the large margins given to hybrid power stations by the regulator. Below are two operational example projects on Tilos and Ikaria islands.

Tilos project, Tilos island, Greece

EUNICE LABORATORIES installed the first hybrid power plant in Greece under the Tilos project. The power plant has been in operation since 2018. It consists of a wind turbine (800 kWp), a solar power plant (160 kWp) and an energy storage system with batteries (2.8 MWh/800 kW). The hybrid power plant covers most of the electricity demand on Tilos island and exports surplus renewable energy to Kos.

The Hybrid Plant is equipped with an optimised Energy Management System that can combine various renewable energy sources, such as wind and photovoltaics, with energy storage.

The operation of the hybrid station with the autonomous grid is being implemented through the Grid Code for the Non-Interconnected islands, coupled with specific algorithms for the pricing and determination of energy deviations of the hybrid station.

Naeras, Ikaria island, Greece

PPC Renewables operates the second hybrid power plant in Greece, Naeras. The power plant has been in operation since 2019. It combines wind and hydraulic power. It is one of the first power plants of this kind in Europe and the only one in Greece. It consists of a wind park (2.7 MWp) with 3 wind turbines (900 kW each), 3 hydro turbines (4.15 MWp), a pump station (rated power 3 MW) of 12 pumps (250 kW each) and three reservoirs with a total water capacity of 990.000 m^3. Naeras produces approximately a total net clean energy of 9.8 GWh/year, covering much of the island's annual energy needs, especially during the winter months.

Graciosa, Azores, Portugal – operational hybrid power plant

Graciosa has 4,301 inhabitants and an electricity system with a peak load of 2.5 MW. The electricity system is made up of a diesel run TPP (4.7 MW). The electricity system was expanded with the installation of the Graciolica hybrid power plant. The hybrid power plant consists of a wind power plant (4.5 MW), a solar power plant (1 MW), BESS (7.4 MW, 2.6 MWh), and an energy management system. Now, more than 60% of electricity consumed comes from renewable energy, and the island electricity system has periods where 100% of consumer electricity is from renewable energy sources. The inclusion of the BESS has helped improve quality of service by improving the power quality, stabilising the frequency, and reducing voltage variations. The batteries do have a significant investment cost. However, the increase in renewable energy generation obtained from the presence of the batteries leads to a large reduction of fuel consumption that shows to be quite beneficial to the electricity system of the Azores.

Recommendation 1.3: Enable the use of centralised storage systems

Hybrid power plants allow the coupling of storage systems with renewable energy generation plants on the same location. This can however lead to suboptimal siting of storage systems that is not aligned with grid congestion areas, as well as suboptimal sizing of the storage system from the point of view of the overall electricity system.

Centralised energy storage increases operational flexibility of the grid, provides grid services, and improves economies of scale. Grid forming capabilities of BESS allow for control of the system based on grid needs. This results in a stabilisation and increase in security and quality of supply, while increasing variable renewable energy generation and decreasing curtailment. BESS also provides smoothing electricity generation, frequency and voltage control support, energy shifting and could lead to grid investment deferral.

Centralised storage can be advantageous in non-interconnected islands with multiple stand-alone variable renewable energy systems with different owners. Centralise storage can be used to reduce curtailments with economies of scale instead of potentially adding behind-the-meter storage. As a result, the exploitation of the existing installed systems can be maximised, and the new installation of hybrid power systems can be avoided (especially in cases of limited space availability or conflicts of land).

Centralised storage can be a solution to the need to accelerate the energy transition, to reduce curtailments, and as an alternative to other grid investments. The secretariat recommends, especially for non-interconnected islands, that **system operators assess various techno-economic solutions, including centralised storage, in their grid planning.** Regulatory authorities should guide the system operators in their assessments as part of the evaluation of the grid planning.

The secretariat additionally recommends an **enabling regulatory framework** that recognises the role energy storage can play for the island electricity grid.

LEVEL OF IMPLEMENTATION	
–	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
–	Interconnected islands
–	Remote areas on mainland

Existing publications

European Commission's Recommendation on Energy Storage – C/2023/1729 (Link)

The European Commission's Recommendation on Energy Storage underlines the crucial role energy storage can play in decarbonising the energy system and security of supply. A decarbonised energy system requires significant investments in storage capacity. Energy storage technologies can facilitate the electrification of different economic sectors, notably buildings and transport.

The recommendation refers to the key role energy storage plays for energy systems that are less or not interconnected, such as islands, remote areas, or the EU's outermost regions. Flexibility resources, notably energy storage, can significantly help to move away from imported fossil fuels and manage high levels of short-term and seasonal variability in renewable energy supply.

Therefore, recommendations include:

- National regulatory authorities to ensure that energy system operators further assess the flexibility needs of their energy systems when planning transmission and distribution networks, including the potential of energy storage (short- and long-term duration) and whether energy storage can be a more cost-effective alternative to grid investments;
- Governments to identify potential financing gaps for short-, medium- and long-term energy storage, and if a need for additional flexible resources to achieve security of supply and environmental objectives is identified, consider the potential need for financing instruments that provide visibility and predictability of revenues;
- Governments to accelerate the deployment of storage facilities and other flexibility tools in islands, remote areas, and the EU's outermost regions;
- Governments and national regulatory authorities to publish detailed data on network congestion, renewable energy curtailment, market prices, renewable energy, and greenhouse gas emission content in real time, as well as installed energy storage facilities, to facilitate investment decisions on new energy storage facilities.
- Governments to identify the flexibility needs of their energy systems in the short, medium, and long term, and in their updates of the national energy and climate plans strengthen the objectives and related policies and measures that aim to cost effectively promote the deployment of energy storage, both utility-scale and behind-the-meter storage, demand response and flexibility.

Best Practices:

French islands – electricity grids operated by EDF SEI

Centralised BESS is used on the French islands' electricity systems for the purpose of frequency regulation, voltage control, compensation due to fluctuations caused by renewable energy variability, shifting of renewable energy generated electricity, and grid forming. For French islands such as Réunion, Guadeloupe, and Martinique studies demonstrated that a centralised BESS is the optimal techno-economic solution for the overall electricity grid.

Madeira, Portugal – decreasing curtailment using centralised BESS

The electricity company EEM has installed centralised BESS on the island of Porto Santo in 2020 (4.3 MW /3.3 MWh) and on the island of Madeira in 2022 (15 MW / 16.4 MWh). Both systems have grid following capabilities, providing support for frequency regulation, voltage control and active and reactive power. In addition, the BESS in Porto Santo has grid forming capabilities as well providing inertia to the system. The use of the centralised BESS not only decreased curtailment of renewable energy generation but also improved the quality and security of supply to the customers in these two electricity systems.

Recommendation 1.4: Support the use of long duration energy storage systems

Many EU islands face significant energy demand fluctuations due to tourist seasons. In some islands peak summer demand can be up to six times higher than the winter baseload. In addition, islands can have seasonality in availability of resources, specifically in wind. In consequence, thermal power plants were traditionally overdesigned to meet peak energy demand.

Seasonality in demand and generation can be mitigated with demand side management (recommendation 2.8) and resource diversification (recommendation 1.1). Specifically in non-interconnected systems there is also a need for long duration energy storage. This includes options such as pumped hydro, hydrogen, electrochemical, thermal, or mechanical storage.

For non-interconnected islands it is important to plan system expansions considering all technology solutions, support mechanisms, and availability of resources. The secretariat recommends that **programmes** that support research and innovation in long duration energy storage **focus on the case of non-interconnected island systems**. This should be supported on the EU level. Moreover, financial support and knowledge sharing should be provided to encourage the use of these technologies where it is required.

Similarly to the recommendation concerning hybrid storage, the secretariat also recommends **including long duration energy storage** as one of the considered technologies **within grid planning and investments**.

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
–	Remote areas on mainland

Existing publications

European Commission's Recommendation on Energy Storage – C/2023/1729 (Link)

"Member States are recommended to continue to support research and innovation in energy storage, in particular long-term energy storage and storage solutions integrating electricity with other energy carriers, and to optimise existing solutions (e.g. efficiency, capacity, duration, minimal climate and environmental footprint). Consideration should be given to de-risking instruments, such as technology accelerator programmes and dedicated support schemes that guide innovative energy storage technologies through to the commercialisation stage."

Recommendation 1.5: Optimise technical and operational requirements of renewable energy generation

EU islands' electricity systems are often operated and regulated using national regulations and grid codes which apply to the whole territory of the Member State. Whereas the Requirements for Generators Code exempts non-interconnected islands, the national grid codes often do not distinguish electrical systems of the islands or non-interconnected islands from the mainland systems.

Renewable energy requirements at the national level often do not sufficiently incorporate islands' needs and priorities. Renewable energy generation can provide support to the island grid, which might not be required on the mainland due to existing interconnections and back-up facilities. Non-interconnected islands have very specific electricity systems. They need to provide reliability and security of supply to cover varying and seasonal demand. With the integration of a higher share of variable renewable energy generation, specific requirements are necessary to ensure safe grid operation at an optimal cost.

The secretariat recommends an update of the **national grid codes to require additional/different capabilities from variable renewable energy generation operating in island electricity systems.** Technical requirements are based on the needs of specific island electricity systems (e.g. current integration of variable renewable energy generation, type of grid). Technical grid assessment studies are necessary to define the correct requirements. Grid codes (specifying implementation within island electricity systems) could for instance, require renewable energy generators to have capabilities such as low voltage ride through, bidirectional frequency control, high wind ride through, and high-temperature ride through, or include requirements on power quality, automatic control, or protection.

LEVEL OF IMPLEMENTATION	
⊖	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
⊖	Interconnected islands
⊖	Remote areas on mainland

Existing publications

Transforming small-island power systems, IRENA, 2018 (Link)

This report by IRENA focuses on Small Island Developing States (SIDS) and analyses their non-interconnected electricity systems and their increased integration of variable renewable energy generation. While it is not directly applicable to EU islands, it provides a good overview of the challenges and possible solutions which come through redefinition of grid codes.

The report provides an overview of some technical requirements applicable to variable renewable energy which improve reliability and security of supply of electricity systems depending on the level of penetration of variable renewable energy already present. For example, requirements for protection, power quality and power reduction during over-frequency are defined as always needed, while at low renewable energy penetration communication, adjustable reactive power and active power management are required.

Best practice:

Madeira archipelago Grid Code

The Madeira grid code, **Decreto Regulamentar Regional no. 8/2019/M** (Link), adopted in 2019 has added specific connection requirements for renewable energy generation facilities that improve the integration of variable renewable energy in the electricity grids on Madeira and Porto Santo. The new requirements ensure that the variable renewable energy can help support the system when needed (e.g. during or following grid fault), such as:

- → Low Voltage Ride Through;
- → High Voltage Ride Through;
- → Reactive and Active Current Injection;
- → Rapid recovery of active power; and
- → Frequency sensitivity modes.

System inertia emulation from wind generators has not been included in the Madeira Grid code since the absorption of active power from grid following the initial active power injection was seen as detrimental. However, when grid forming converters are used together, virtual inertia from battery storage systems is used.

Recommendation 1.6: Encourage and support sector coupling

Sector coupling is necessary to incorporate renewable energy and additional variable generation in electricity systems with limited capacity.

Sector coupling in this report refers to the coupling of the energy sector, specifically electricity generation and supply, with various consumption sectors, such as transport, water or waste management, heating/cooling, to ensure more energy efficient and economical operation of multiple sectors.

With increased electrification of the transport and heating/cooling sectors, there are more opportunities for sector coupling that could help increase/improve the flexibility of the system. Namely, many islands have volatile load profiles that are dependent on the residential sector, which in combination with variable renewable energy generation, can cause instabilities in the electricity system. Electric transport, desalination plants, or cooling/heating needs of the tourism/service sector could provide more controllable, or deferable loads that can provide much needed flexibility in the system.

Moreover, some sectors can use electricity when excess renewable energy is available. Electric vehicles can act as storage systems to provide the absorbed electricity later when needed or to provide other system services. Such sector coupling has traditionally been done with industry sector customers but is increasingly expanding to the service, transport, and residential sectors.

The secretariat recommends a **regulatory framework which requires for sector coupling solutions on the islands** and decreases barriers to multipurpose use of resources. Cross-sectoral collaboration can also enable visibility of the various sector plans and regulation, as well as barriers to joint implementation of projects. National governments should establish regulations to achieve this.

The secretariat also recommends **system operators to consider system solutions which result in benefits to other island sectors** aside from energy sector. In the absence of electricity markets on many islands, tariffs can be used to foster sector coupling. National governments should establish this requirement for system operators, supervised by national regulatory authorities.

LEVEL OF IMPLEMENTATION	
⛔	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Existing publications

EU Energy System Integration Strategy (link)

In 2020 EU adopted Energy System Integration Strategy. Within this strategy energy system integration refers to the planning and operating of the energy system "as a whole", across multiple energy carriers, infrastructures, and consumption sectors, by creating stronger links between them with the objective of delivering low-carbon, reliable and resource-efficient energy services, at the least possible cost for society. The strategy identifies six pillars for action:

- A more circular energy system, with 'energy-efficiency-first' at its core;
- Accelerating the electrification of energy demand, building on a largely renewables-based power system;
- Promote renewable and low-carbon fuels, including hydrogen, for hard-to-decarbonise sectors;
- Making energy markets fit for decarbonisation and distributed resources;
- **A more integrated energy infrastructure**; and
- A digitalised energy system and a supportive innovation framework.

A more integrated energy infrastructure pillar calls for a new, holistic approach for both large-scale and local infrastructure planning, including the protection and resilience of critical infrastructures.

Best practice:

Vehicle to grid project in Sao Miguel, Azores, Portugal

This vehicle to grid project was implemented with Galp, Nissan, EDA, Nuvve, MagnumCap and ERSE, Portuguese Directorate for Energy and Geology, and the Azorean Government in Sao Miguel. The project included the use of 10 Nissan vehicles with vehicle to grid capability for a year and a half. The project had three main goals:

- Reduce energy costs for the client (time of use tariffs and peak shaving);
- Provide services to the grid (peak reduction, frequency regulation, voltage control, demand response etc.); and
- Compensate for variable renewable energy fluctuation in generation.

Lessons learned from the project include:

- If not optimised, EV charging can cause additional needs for the operation of the thermal power plant ;
- If optimised, EVs can increase variable renewable energy integration during low demand periods, and thereby decrease curtailment;
- EVs with vehicle to grid can avoid the need for diesel based generation;
- EVs with vehicle to grid can help regulate frequency, provided that the frequency control loops do not face communication delays;
- EVs with vehicle to grid can be used as considerable storage source.

Recommendation 1.7: Require monitoring and support the development of smart grids

Digitising and upgrading electricity infrastructure, and moving to smart grids, are important for the energy transition and electrification of sectors such as transport and heating/cooling. Smart grids and communication are essential for the optimal operation of the grid with integrated renewable energy. Increased observability of the grid helps system operators ensure stability and reliability of the grid, as well as foresee upgrade and flexibility needs or challenges. Improved visibility and monitoring can help system operators leverage data to improve forecasts and integrate more distributed generation. In addition, regulatory authorities can use data to make informed decisions on the future tariff methodologies.

Smart grid implementation, optimised for islands, should ensure that both grid upgrade and maintenance, and automation and observability are given the needed support.

A smart grid can be thought as a modernised grid that enables bidirectional flows of energy and uses two-way communication and control capabilities that can lead to new functionalities and applications.

Joint Research Centre, Smart grids in the European Union

The secretariat recommends that regulations should **ensure that the metering infrastructure installed with the distributed renewable energy generation allows for future applications** and interaction with grid operators. The regulatory authority should monitor that the metering infrastructure for distributed renewable energy is aligned with the grid planning of system operators.

Increased observability of the grid allows for decreasing complexity and costs of operation and maintenance. The secretariat recommends that **digitalisation of the grid infrastructure on the islands should be a requirement for system operators.** Additionally, **move to smart grids on the islands should be financially supported** (installation and training) by national governments, with high priority on non-interconnected systems.

The secretariat also recommends that connection requirements for renewable energy generation plants include monitoring and active power communication with renewable energy generators. Regulation should require communication checks before renewable energy plants are connected. Moreover, it is important to find reliable means of data transfer to enable active monitoring and management of grid assets.[185]

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Existing publications

TEN-E policy (link)

The deployment of smart grids is one of the three priority themes of the European Commission's It aims to help integrate renewable energy, complete the European energy market, and allow consumers to better regulate their energy consumption.

EU Grid Action Plan, European Commission, 2023 (Link)

Two action points provided within the EU Grid Action Plan that relate to the deployment of smart grids include:

- Action 7: ENTSO-E and EU DSO Entity to promote uptake of smart grid, network efficiency and innovative technologies; and
- Action 4: Commission to propose guiding principles identifying conditions under which anticipatory investments in grid projects should be granted.

[185] Commission recommendation on cybersecurity in the energy sector – 2019/553/EU (link)

Best practice:

HEDNO's Central Energy Control Centre for Non-Interconnected Islands

HEDNO has implemented a Supervisory Control and Data Acquisition – Energy Management System (SCADA-EMS) with advanced functionalities. The operation of the new SCADA-EMS is expected to result to an optimal operation of generating units (thermal and renewables) in each of the Greek non-interconnect island system while increasing RES penetration and reducing human intervention to a bare minimum.

The main functionalities of the SCADA-EMS include real-time monitoring of thermal units, feeders, wind power plants and PVs via a graphical interface, real-time data storing in a database, and a runtime environment, which integrates, among other capabilities, several options for wind power plant management.

Non-interconnected islands' electrical systems are considered isolated microgrids. In these systems, fluctuations from wind power plants place increased operational demands on the thermal units, which are responsible for retaining the power balance. Therefore, wind power plants in non-interconnected islands are often curtailed to ensure the electrical systems' stability, power quality and overall, to increase reliability.

On each non-interconnected island, the SCADA-EMS human machine interface provides the operator with a complete overview of the production units (TPP and renewable energy) as well as the ability to manage wind power plants.

In order for the SCADA-EMS to automatically manage wind power plants effectively, an algorithm has been developed that takes into account the limitations and constraints imposed by the dispatched thermal units, the fluctuations of load and the variability of wind resource. Various parameters can be set by the system operator so that the transition from one set point to the next may be implemented with a ramp.

Furthermore, several variables are used as inputs to the wind power plants management algorithm, such as wind direction, wind speed and loss of communication. The output of the algorithm is reassessed every minute based on the conditions and the optimal set-point for each wind power plant is computed.

Recent experience from the SCADA-EMS operation has shown that human intervention in wind power plant management is needed only on special occasions (e.g. grid maintenance, extremely bad weather) since the developed management algorithm along with its parameters efficiently curtails generation from wind power plants whenever required.

Recommendation 1.8: Support improvements in generation forecasting tools

Better forecasting tools for renewable energy generation and operation, communication, monitoring, or control of decentralised generation are necessary. Variable renewable energy can change in minutes or seconds depending on the weather conditions. Generation forecast quality can determine the effectiveness of system operator dispatch to use renewable energy generation to match demand. Accurate, reliable, and timely forecasting is not only important for daily dispatch and balancing, but also for the planning of new generation needs. **Well defined regulation can facilitate implementing better forecasting tools.** For example, clarifying the regulation for curtailment responsibilities (recommendation 2.5) could incentivise stakeholders to invest in better forecasting tools.

The secretariat recommends **collaboration of system operators and knowledge institutions to (continuously) improve their forecasting tools and stay up to date on data availability**. The national regulatory authorities should facilitate this collaboration. Open access to weather data and methods to develop or choose the appropriate forecasting tools should be made available on the EU level with continued efforts from Copernicus.[186]

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Existing publications

Advanced forecasting of variable renewable power generation, IRENA, 2020 (Link)

This report by IRENA maps relevant innovations, identifies synergies, and formulates solutions for integrating high shares of variable renewable energy into power systems. Key factors to enable deployment of advanced forecasting tools for variable renewable energy generation are:

- Regulatory environment incentivizing the use of advanced forecasting tools;
- Open-source systems for weather data collection and sharing; and
- Availability of advanced meteorological devices.

Figure 3 Benefits of weather forecasting to system operators and renewable generators

BENEFITS OF WEATHER FORECASTING	CENTRALISED FORECASTING / DECENTRALISED FORECASTING: For system operators	DECENTRALISED FORECASTING: For renewable generators
Short-term forecasting	Improved network management and system balancing	Advantages for intraday and day-ahead electricity market trading
Long-term forecasting	Reserve planning and operation management	Efficient placement of renewable plants
	Planning for extreme weather events	

Recommended Practice for the Implementation of Renewable Energy Forecasting Solutions, IEA Task 51, 2022 (Link)

186 Copernicus ESMW (link)

The IEA provides best practices and recommendations for among others, forecasting tools and real-time measurements for grid operators and utility-scale generation. The IEA focuses among others, on wind generation and provides webinars for learning more about forecasting tools and data access and validation.

2. Planning, enabling policy and regulatory framework

Recommendation 2.1: Foster thorough electricity system planning and resilience

Islands have competing needs for land use, limiting the availability of locations for electricity system infrastructure and generation plants. In addition, variable renewable energy is highly dependent on the free but variable natural resource of wind and solar radiation. Grid expansion planning based on only demand, and per project-based planning does not take into account the big picture of the overall island decarbonisation and development. Thorough electricity grid planning is needed to consider possible locations for renewable energy plants and related grid infrastructure, weather resources and patterns, geographical constraints related to land-use and storms and necessary grid maintenance.

On the **national level, it should be ensured that grid development plans are aligned with the national, regional and/or local energy and climate plans.** With such alignment, grids can be more optimally developed to allow the integration of planned renewable energy generation plants While the **EU Grid Action Plan** defines the need to align distribution network plans with National Climate and Energy Plans, it also indicates that this responsibility might be omitted for small isolated systems. However, for island systems this aspect is crucial in making sure the grid development and renewable energy planning are aligned and take into account climate change effects.

National Climate and Energy Plans should include objectives, policy and measures targeting the specificities of non-interconnected islands, regardless their size, while in parallel aiming to support those technologies needed to increase the integration of renewable energy generation into the electricity grids of islands (e.g. stand-alone and behind the meter storage, seasonal storage etc.).

Furthermore, decarbonisation of islands and increase in renewable energy generation share are measures to help mitigate climate change. However, actions are needed to prepare electricity systems for, and adapt to, ongoing changes in the climate (high winds, higher chances of fire, flooding) and its effects on the island grids. While this is applicable to the mainland as well, it is more extreme in the case of islands.

Hence, **policy and funding that support the upgrade of electricity systems and grid operations which increase system resilience**, especially in remote and vulnerable areas like those of the non-interconnected islands should be supported. Governments and regulatory energy agencies should oblige and monitor the grid operators to have plans in place for emergency reaction, fast recovery, and back-up of power systems and to implement them. In addition, priority should be placed on digitalisation of the system, improved data management and forecasting, which provide remote visibility and control of the system and improved use of existing system assets (generation and flexibility) to stabilise the system in case of emergency. For example, the deployment of Energy Control Centres allowing the remote dispatching of thermal power plants and renewable energy power plants and the potential reduction of curtailments are measures applied in the right direction by the Greek DSO.

This is even more relevant with the electrification of energy needs, such as transport and heating/cooling, across Europe. These points are analysed and discussed in more detail in the Eurelectric and EPRI publication **The Coming Storm - Building electricity resilience to extreme weather** published in 2022.[187] Below is an extract from the resulting **Policy recommendations**.[188]

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
−	Remote areas on mainland

Existing publications

The Coming Storm - Building electricity resilience to extreme weather, Eurelectric, 2023 Link
Policy recommendations, Eurelectric, 2023 Link

The Eurelectric and EPRI 's policy recommendations are:

For regulators and policy makers:

- Incentivise resilience investments
  - Update the current model for investments in grids
  - Need for Resilience Investment Mechanism to encourage adaptation measures;
- Integrate national climate adaptation plans with grid investment plans.

For system operators and generators:

- Establish emergency management teams;
- Provide multimedia approach to communication with the public;
- Consider redundancy in the design, operation, and maintenance of the power system;
- Adaptation measures should use sound cost-benefit and a consistent impact assessment framework;
- Customer flexibility and DER can support the energy system during extreme weather events.

[187] Eurelectric and EPRI publication *The Coming Storm - Building electricity resilience to extreme weather* with its *Policy Recommendations* published in 2022 (Link)
[188] Policy recommendations, Eurelectric, 2023 *(*Link)

Existing publications

EU Grid Action Plan, European Commission, 2023 (Link)

Two action points provided within the EU Grid Action Plan that are relevant for planning and resilience include:

EU DSO Entity to support DSO grid planning by mapping the existence and characteristics of distribution development plans: The EU DSO Entity is directed to support DSO grid planning by mapping distribution development plans and establishing best practices for coordinated planning with TSOs. By mid-2024, the entity should explore case studies and publish recommendations for improving distribution network planning, and engaging stakeholders transparently. This effort complements National Energy and Climate Plans, and support distribution network development reforms by Member States. It is important to note that small DSOs serving less than 100,000 customers and small isolated systems may be exempted from this duty.

European Commission to propose guiding principles identifying conditions under which anticipatory investments in grid projects should be granted: The Commission will propose guiding principles for anticipatory investments in grid projects, focusing on future-proof infrastructure such as offshore networks, connections to ports, and smart grids supporting EV infrastructure and heat pump rollout.

ACER and CEER – Position on anticipatory investments*, 2024 (Link)

ACER and CEER recommend coordination, including early exchange of information, amongst future network users, network operators and NRAs, as a basis to speed-up the regulatory validation of grid investments which should be deployed. In this regard, consultation of the network planning scenarios (including access to relevant data), the identification of the priorities in addressing reinforcement needs and its means, including wire and non-wire solutions are useful tools.
To accommodate anticipatory investments NRAs recommend following measures:

- Governments (in cooperation with the interested parties) should determine several zones appropriate for RES intake (sometimes labelled as “renewable acceleration areas”), which would feed into the planning of the grid reinforcements needed to accommodate new connection requests.
  - Some related provisions are also foreseen in Article 15(c) of **Directive (EU) 2023/2413**.
- Longer-term network development planning has been useful in facilitating public acceptance and therefore reducing the time for implementation of projects.

*Anticipatory investments refers to investments needed for system integration of renewables, that are risky for society because they may turn out be underused, at least for some years, until developments on the generation side.

Recommendation 2.2: Loosen ownership rules for electricity storage and unbundling requirements for small island electricity companies

Directive 2019/944 on common rules for the internal market for electricity (IMED) dictates rules for system operators including unbundling requirements and rules concerning the ownership of storage facilities. Article 35 of the **IMED** requires unbundling of all vertically integrated electricity companies into transmission and distribution system operators, producers, and suppliers of electricity. The new Network Code on Demand Response will further specify the conditions for system operators to own, develop, manage or operate energy storage facilities pursuant to Articles 36 and 54 of the **Electricity**

Directive. This includes shared ownership and operation of storage assets between system operators and market participants as well as conditions to transfer the ownership.

Outermost regions are exempted from unbundling principles. Small isolated systems and systems with less than 100,000 connected customers may also be exempted from unbundling requirements (Article 35(4) of the **IMED**). Where these exemptions do not apply, for electricity companies on small non-interconnected islands, unbundling brings an additional administrative burden which outweighs potential benefits. Also, with regards to storage, for non-interconnected islands, utility-scale storage system can help stabilise the system.

For those islands, the secretariat recommends requesting a derogation on grounds of Article 66 **IMED**, specifically from Articles 7 and 8, and of Chapters IV, V and VI. National governments and regulatory authorities should analyse their non-interconnected island systems to **assess the advantages and disadvantages of unbundling and rules regarding storage**, in relation to the energy transition of those islands. Where the administrative burden outweighs the benefits of unbundling, the derogation should be requested. System operators of non-interconnected islands and regulatory authorities should also use the guidance from CEER (see existing publications below) in order to allow DSOs to own, manage and operate energy storage in cases where it is necessary.

LEVEL OF IMPLEMENTATION	
⊖	EU
✓	National
⊖	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
⊖	Interconnected islands
⊖	Remote areas on mainland

Existing publications

Short paper on the ownership of Storage Facilities in the Electrical Distribution System, CEER, 2023 Link

"The document provides a stepwise guide on the tendering procedure and the derogation granting process pursuant to paragraph (2) of article 36 of the IMED wherein it is provided under which circumstances are DSOs – otherwise prohibited of doing so – allowed to own, develop, operate or manage electricity storage facilities."

The following steps are further detailed, and guidance is provided:

- **Tender design** – the tender should be designed by the DSO to be open, transparent and non-discriminatory. It should foster competition and efficiency. Demand response should be able to participate in the tender for storage facilities. Finally, tender design should not be more restricting than necessary. The **CEER Paper on DSO Procedures of Procurement of Flexibility** (Link) can be a useful guide in the design of the tender.
- **Ex-ante review by the NRA** – tendering procedure should be reviewed and approved by NRA, especially when there is not much experience already in the procedure.
- **Outcome of the tendering procedure** – the results of the tender procedure should be made public. If bids are received and tender is successful, there is no need to go to derogation procedure.

- **Request for approval of ownership by the DSO** – if tender is unsuccessful and the DSO can justify that the energy storage is necessary and the optimal solution, the request for approval of derogation is sent to the NRA.
- **Ex-post assessment by the NRA** – NRA will assess if the tendering procedure was carried out according to the tender design and if the energy storage justification is valid.
- **Regular public consultation** – the derogation provided by NRAs is time-limited. Hence, at least every 5 years, NRAs should consult the public if there is change in interest to offer the needed service to the DSO. The phase out of the DSO-owned storage can only happen if cost-benefit analysis shows that the phase out with the addition of another service by third party helps increase the total welfare compared to continuing the DSO's storage activity.

Recommendation 2.3: Allow aggregated control of distributed renewable energy

In case of system instability, aggregated control of small, distributed generation systems could provide support to non-interconnected island systems. Aggregated control of distributed energy refers to the collective management of energy sources from different locations and power plants, to provide grid services. Remotely aggregated distributed generation from different physical locations can be used for grid balancing and smoother operation. On small islands with high fluctuations, such aggregated control can be used to manage distributed assets and improve the operation of the grid.

The secretariat recommends that it should be allowed for system operators **to control distributed renewable energy generation, in case of emergencies, and to ensure that the grid infrastructure can support it**. National governments should implement regulation to determine under which circumstances and requirements system operators should be allowed to execute control.

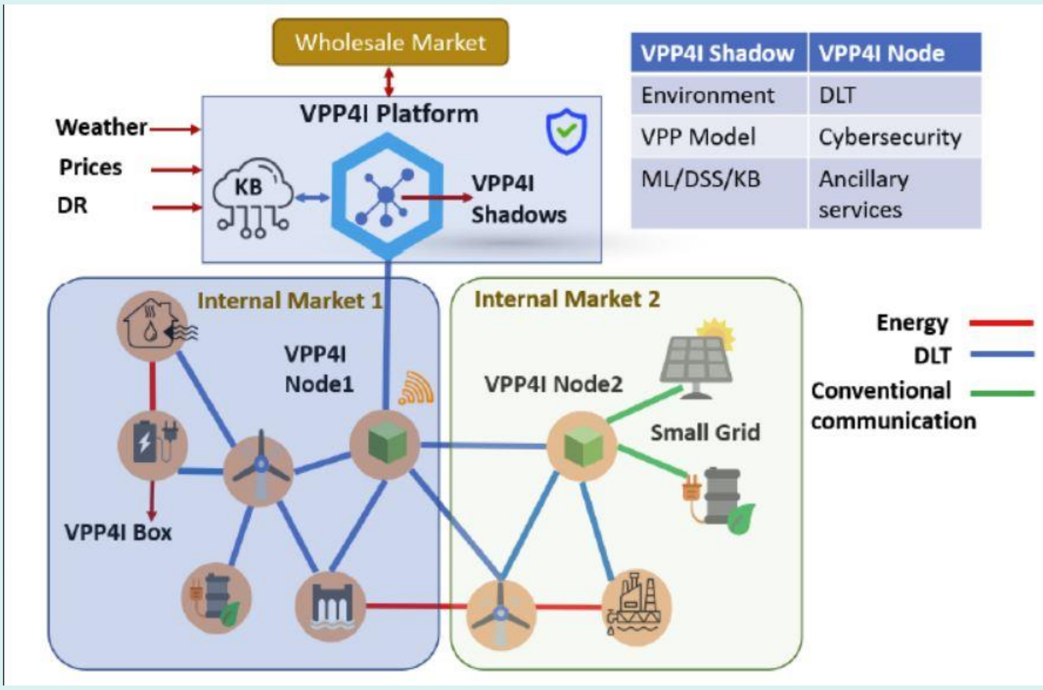
LEVEL OF IMPLEMENTATION	
−	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
−	Interconnected islands
−	Remote areas on mainland

Best practice:

VPP4ISLANDS

The VPP4ISLANDS project is a Horizon 2020 project that is integrating virtual energy storage technology, digital twin, and distributed ledger technology to enable enhanced virtual power plants and the creation of smart energy communities on islands. Here as well, aggregated control of distributed assets is being tested.



Results of the project have not been made public yet, as the project is due to end in April 2024.[189]

[189] European Commission, Horizon 2020 (link)

Recommendation 2.4: Enable joint management of multiple plants – virtual power plants

To maximise the use of electricity produced from renewable energy generation plants, multiple power plants of the same technology can be jointly operated. On islands, specifically due to their topography, wind speed and direction can vary in different areas. Joint management of multiple wind power plants into a single virtual power plant can help minimise curtailment and optimise use of existing generation plants.

A virtual power plant is the aggregation of decentralised generation plants (and storage systems), regardless of their physical location, jointly managed as one power plant.[190] Virtual power plants are used to offer services to the grid or to participate in energy markets.

The secretariat recommends establishing a regulatory framework to allow joint management of multiple renewable energy generation plants, provided that they bear the minimum compatibilities in terms of technical capabilities. **System operators,** especially under conditions of high renewable energy curtailments, **should assess the possibility of enabling a virtual power plant operation to better manage existing plants**. **National governments, in collaboration with regulatory authorities, should establish the legislative and regulatory framework, in line with EU guidelines,** to enable the use of virtual power plants where it can benefit the overall electricity system.

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Best practice:

Madeira wind power plants generation control (Link)

Due to the geography of the island and the technical minimum of the thermal power plants providing system services, the wind power plants' generation in Madeira is curtailed in periods of low demand. In the electricity systems of Madeira and Porto Santo, thermal power plants are used to provide frequency/voltage regulation and system inertia. Pumped hydro and BESS (with grid following and grid forming capability, depending on the grid needs) are installed to help balance the grid, decrease curtailment, and improve frequency control. This has led to a decrease in curtailment of wind power plants generation from 15% to less than 1%.

In addition, EEM has developed an in-house curtailment algorithm. The algorithm aggregates generation from nine wind power plants into one virtual power plant. It provides dependent control to optimise the overall electricity generation from these wind power plants and help decrease curtailment.

[190] ENTSO-E – Technopedia – Virtual power plants (Link)

Recommendation 2.5: Define a clear regulatory framework on curtailment and its remuneration

The integration of variable renewable energy in non-interconnected islands' energy systems often leads to curtailment, especially in periods of low demand. Curtailment, or downward re-dispatch, is a request from the system operator to the renewable energy generation plant to decrease its generation regardless of available renewable energy capacity at that moment.

Curtailment is necessary to maintain system stability and security. Therefore, energy generation plants can obtain a compensation from the system operator in return for the curtailed activity. In some cases, curtailment remuneration schemes and arrangements are included in the power purchase agreements between the system operator and the renewable energy generation plant owner. However, general guidelines and a transparent regulatory approach is necessary. For the system operator it might be more economically and technically feasible to curtail generation than to invest on new grid assets e.g. energy storage systems. For this reason, ensuring full transparency on this matter is an important prerequisite for the efficient operation of the islands' electricity markets.

The secretariat **highly recommends having a solid and transparent regulatory framework in place on curtailment compensation mechanisms and monitoring of amount of curtailed RE electricity**. It should be clear for all parties who bears which (financial) responsibility in which instances. The regulation should **specify the minimum level of curtailment which falls under the responsibility of the energy producer.** Any curtailment above this threshold should then be the financial responsibility of the system operator. The curtailment threshold should be defined based on the island electricity system characteristics. Such regulation decreases investment risk for both power plant owners and system operators.

The Electricity Regulation 2019/943 specifies the framework for re-dispatching in Article 13 and requests market-based compensation as long as certain conditions are not met. There are different means to address grid congestions such as curtailment, re-dispatching, flexible connection agreements and with possible implementation of local flexibility markets on the islands these options can be further specified. Additionally, on the new Network Code on Demand Response will help address local congestion issues and to enable system operators to procure flexibility.

Best practice guidelines could be provided at the EU level, taking into account specifics of operation of island electricity systems and remote areas on mainland.

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
–	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Best practice:

Terceira island, the Azores, Portugal

On the island of Terceira, private investors get compensated for the curtailed electricity from their wind power plants. Wind power plants are often the first plants to be switched off in the event of excess of electricity supply. In power purchase agreements between private investors in wind power plants and system operators, remuneration agreements were signed for electricity-sale-loss in case of curtailment. The agreement defines the generation losses, on the basis of the registered wind speeds and the technical limitations associated with the condition of the wind turbines available from Supervisory Control and Data Acquisition systems of the wind power plant.

Recommendation 2.6: Simplify and align grid planning and renewable energy permitting procedures

In order to increase the deployment of renewable energy, energy planning should be developed by actors on all levels. The secretariat recommends identifying the areas where the installation of renewable energy plants is possible. This should not be done in isolation but should include other sectors which can potentially conflict with renewable energy installations. Such sectors include the environmental, land-use, agricultural, and defence sectors.

Additionally, **grid connection procedures should be simple and transparent**. One possibility is to standardise and digitalise administrative procedures for grid connections through a central online platform. National governments can follow the European Commission's **Recommendation and guidance on speeding up permit-granting for renewable energy and related infrastructure projects**.[191]

The secretariat recommends **that grid development plans and permitting procedures are aligned with the national, regional and/or local energy and climate plans.** Stakeholders at the national, regional, and local levels should be involved so that grid planning and permitting procedures are tailored to suit specific needs as well as contribute to the national objectives for increased renewable energy. To achieve this, one option is to update national grid codes. On the EU level, the **Demand Connection Code** stipulates that harmonised rules for grid connections should be set out in order to, among others, facilitate the integration of renewable energy sources.[192] Not all national codes have yet been updated to reflect this. Alignment of the EU network codes with the national grid codes is necessary for system operators to implement such rules on the ground. **Updating procedures and standards for renewable energy generation plants in the codes will also increase transparency regarding how to install renewable energy plants**. Guidelines can be provided on the European level for policymakers and DSOs to ensure alignment.

LEVEL OF IMPLEMENTATION	
−	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

[191] European Commission, Recommendation and Guideline on permitting procedures, 13 May 2024, (link)
[192] Regulation 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection, preamble 3, (link)

Existing publications

EU Grid Action Plan, European Commission, 2023 (Link)

Two action points provided within the EU Grid Action Plan grid planning and permitting procedures include:

- Action 3: EU DSO Entity to support DSO grid planning by mapping the existence and characteristics of distribution development plans
- Action 8: ACER, in its next tariff report, to recommend best practices in relation to the promotion of smart grids and network efficiency technologies through tariff design, focusing on the consideration of OPEX in addition to CAPEX and benefit sharing.
- Action 11: Commission to support permitting acceleration providing guidance and technical support on how to implement existing legislative tools and Member States to implement acceleration measures

Following the EU Grid Action Plan, CEER and ACER published a **position paper on anticipatory investments**, in which they recommend that NRA's act more leniently in permitting procedures:[193]

"NRAs could consider greenlight to a project to progress permit granting and other pre-construction activities as much as possible, without the regulatory approval of the project construction (which would come later, when the need is confirmed); such an approach would speed up the project implementation, while limiting the risks of "sunk costs" for the society to the (small) pre-construction costs, in case the need will never be confirmed."

Best practice:

Italy

The **Italian Ministerial Decree of 14 February 2017 on Minor Islands** is specifically implemented to promote the modernisation of the electricity networks thereby increasing RES through the use of storage systems, the development of electricity transport, and the integration of the electricity system with the island's water system. Specifically, the Decree introduces dedicated incentive modalities for renewable energy in non-interconnected small islands, in the form of dedicated feed-in tariffs depending on the geographical location and remoteness of the islands. Procedures are thereby tailored to the conditions of non-interconnected minor islands.

Recommendation 2.7: Optimise tender design

Renewable energy generation implementation has been supported in the past through financial incentive schemes such as feed-in tariffs. To reduce the cost of large-scale implementation of renewable energy technologies, the European legislator has implemented tendering procedures. These procedures foster competition and lead to a decreased need for renewable energy incentives. The result is that tendering reduces support costs, enhances the deployment of renewable energy,

[193] ACER and CEER "Position on Anticipatory Investments" (link)

and provides a framework for technological improvements. Moreover, tenders foster competition and best solutions in cases where resources are scarce.[194]

Islands have a scarcity of land resources. Stakeholders in the energy sector need to collaborate with other sectors such as tourism, agriculture, and environmental protection, to ensure an optimal solution for holistic and sustainable island development. Tenders, and specifically auctions,[195] are an optimal way to foster the energy transition while maintaining consideration for other sectors.

Tender design is important to influence an offered technology or solution, the likelihood of implementation of the project, and ease of integration to the grid. For example, **Badela et.al.** propose a tender design specifically for the hybridisation of renewable energy generation plants using BESS.[196] **SolarPower Europe** also provides guidelines for PV and PV with storage tenders.[197] While guidelines are useful, the specifics of the island's electricity system, priorities and land limitations are best known by the local stakeholders.

The secretariat recommends collaboration between national governments, regulatory authorities, system operators, and local and regional stakeholders, in the preparation and design of tenders for the islands. **Relevant stakeholders should be engaged to ensure that the appropriate tender design filters are selected** for optimal solutions for the local situation on islands. The tender preparation process should be transparent and inclusive to ensure that the requested solutions can be implemented smoothly and with little to no delay.

Carefully designed tenders result in an implementation of technologies which can support better integration of renewable energy generation into the grid, leading to less curtailment. Although this recommendation is applicable to all islands, remote areas, and the mainland, it is crucial for non-interconnected islands where resources are scarce and electricity systems are isolated.

LEVEL OF IMPLEMENTATION	
⊖	EU
✔	National
✔	Local

RECOMMENDATION APPLICABLE FOR	
✔	Non-interconnected islands
✔	Interconnected islands
✔	Remote areas on mainland

Recommendation 2.8: Create an enabling framework for demand-side management

Demand-side management incentivises end-users to delay or decrease their consumption (load) in order to help optimise the operation of the electricity system. End-users can be incentivised to use electricity during periods of higher renewable energy generation or lower consumption from other consumers. End-users are typically incentivised either by the electricity price (e.g. providing a lower

[194] Report from the Commission to the European Parliament and the Council on the performance of support for electricity from renewable sources granted by means of tendering procedures in the Union, COM(2022) 638 (Link)
[195] Auction is a form of tender where the main criteria is price of electricity.
[196] Badela et al., How to Efficiently Procure Battery Energy Storage Systems for Hybrid Energy Systems through a Tender Process, Virtual 5th Hybrid Power Systems Workshop, 2021 (Link)
[197] SolarPower Europe, EPC Best PractiCe guidelines v 2.0, 2021 (Link)

price in periods when the electricity should be used) or by remuneration for provided flexibility/capacity on the electricity market.

However, many non-interconnected island electricity systems have vertically integrated system operators, and are not part of the open national electricity markets. Moreover, in many cases non-interconnected islands have subsidised electricity prices. Due to regulated and subsidised tariffs, implicit demand-side management (i.e. consumers acting on price signals via tariffs) is more difficult to implement. On the other hand, if island electricity systems integrate increased shares of variable renewable energy, extensive EV charging infrastructure, and provide quality and security of supply, demand-side management must be implemented.

Demand-side management aims to increase the flexibility of the electricity system by ensuring that not only generation can be managed based on system needs, but also demand. While small demand capacity does not provide much benefit to the system on its own, solutions are developed to aggregate small demand capacity to provide higher benefits to the overall system. The Clean Energy Package and specifically the **IMED** introduce the concepts of demand response, aggregation, and the independent aggregator as an actor. The IMED requests to open all electricity markets (including day-ahead, intraday, balancing, and congestion management) to demand response provided by (independent) aggregators, as well as to incentivize DSOs to procure flexibility services. Based on the mandate given to EU DSO Entity, ENTSO-E and ACER by the **IMER**, a new **Network Code on Demand Response** is being developed. The Network Code on Demand Response is currently at ACER and will be submitted to the European Commission in 2025, aiming for adoption by the end of 2025.[198]

The secretariat recommends **using islands' electricity systems as possible case studies for Member States**. The secretariat recommends national governments to develop their general demand side management frameworks, ensuring this framework is island proof and hence can be implemented on the islands as well. .

The secretariat also recommends that **measures to support demand side management should be adapted for use on island electricity systems.** For example, in the same way that specific time-of-use tariffs could incentivise peak shaving, adjusted time-of-day variation in injection prices could incentivise voluntary curtailment of decentralised renewable energy generation.

	LEVEL OF IMPLEMENTATION
✓	EU
✓	National
✓	Local

	RECOMMENDATION APPLICABLE FOR
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Existing publications

Network Code on Demand Response, EU DSO Entity and ENTSO-E, 2024 Link

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[198] EU DSO entity and ENTSO-E prepared and submitted a joint Network Code on Demand Response (Link)

The overall aim is to provide an EU framework for the integration of technology-agnostic distributed flexibility in transmission and distribution-related services for the overall benefit of consumers and contributing to decarbonization goals, by:

- Simplifying market access requirements such as registration and prequalification procedures, and the definition of aggregation models;
- Establishing principles for the market design for congestion management and voltage control services;
- Facilitating the standardisation of products for these services at national level;
- Enhancing the framework for cooperation between TSOs and DSOs by ensuring access to the necessary data from each other and from grid users to operate the system.

The Network Code will be complemented by national terms, conditions and methodologies.

Recommendation 2.9: Ensure security of supply for sustainable economic development

The energy transition on the islands is an opportunity for sustainable economic development. To support this development, reliability of supply should be ensured. Detailed analysis of the electricity system is necessary, including security of supply and verification of generation adequacy.

Renewable energy generation, while using local resources, is of variable nature due to its dependence on weather conditions. Island electricity systems are smaller in size, and investment or generation choices can influence the larger economic and sustainable development of the island. .

The secretariat recommends **carrying out studies to identify needed investments in grid infrastructure and generation, to allow for needed upgrades and changes in dispatching practices.** Studies should use **advanced models capable of addressing the time variabilities associated with renewable energy generation in different timeframes and include a comprehensive range of annual regimes of renewable energy generation**. Analysis needs consider the load and renewable energy generation profiles, the operation rules, the existence of storage, load flexibility, and the rates of failure of generation units including their repair and maintenance times.

National regulatory authorities should assign **regular security of supply studies for island electricity systems as basis for investment planning by system operators**. Collaboration with knowledge institutes should be fostered and continuity of collaboration enabled, to allow both system operators to increase faculty for such analysis and to encourage new staffing where necessary. System operators and supporting organisations should be pro-active in enabling such collaboration.

LEVEL OF IMPLEMENTATION	
⊖	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Recommendation 2.10: Sensitise national regulation for grids to specific cases of islands

National regulations for grid operation and renewable energy connection policy are often uniform across the Member States, regardless of the islands. Even when islands have a strong electrical interconnection with the mainland, islands face more challenges in the energy transition and use of local resources. Islands typically have more limited resources than the mainland, particularly in terms of land, and in consequence also have stricter environmental protection requirements.

Non-interconnected or weakly interconnected islands[199] in particular face the largest challenge to ensure security of supply and reliability of their electricity grids.

For Member States with **non-interconnected and weakly interconnected islands, the secretariat recommends increasing the analysis of grid regulations and renewable energy connection and operation policies.** Policies can for instance consider insularity, seasonal and variable demand, increased costs for maintenance and operation, higher vulnerability to extreme weather conditions caused by climate change. National governments and regulatory authorities should **ensure that the requirements and grid codes applicable to islands foster energy transition and integration of renewable energy generation**.

LEVEL OF IMPLEMENTATION	
–	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Recommendation 2.11: Provide capacity building opportunities for island system operators

Energy transition and integration of additional variable renewable energy into the islands' grids requires capacity building and trainings for system operators. With the technology and systemic changes that are required for the operation of the grid with the decarbonisation, inclusion of renewable energy and move to smart grids, there is a need for active training of the system operators' staff. Shortage of skilled staff is identified as a challenge with large system operators and is even more so for small island system operators.

The EU **Study on skills needs development, vocational education, and training systems in the challenging electricity sector** identifies digitalisation and technological changes as the greatest challenge and need for occupational upskilling in the electricity sector.[200] The study recommends close collaboration of education and training providers with the sector organisations to upskill and attract additional workforce to the sector.

The secretariat recommends providing **additional opportunities to island system operators through trainings, upskilling programmes and providing opportunities to exchange experiences.** European system operator organisations in collaboration with national associations should facilitate this. The

[199] Weakly interconnected islands in the context of this report are islands whose electricity interconnection has a higher risk of interruptions in comparison to those on the mainland.
[200] Skills needs developments, vocational education and training systems in the changing electricity sector, by industriAll European Trade Union, the European Public Service Union (EPSU) and Eurelectric, with support from the EU, 2018 (Link)

Clean energy for EU islands secretariat also supports exchange in the preparation of this study. The need for continued exchange of experiences and knowledge is extremely important to foster the energy transition of the islands.

Additionally, the secretariat recommends the **exchange of experiences among system operators**, including with island system operators. **National organisations should support exchanges.** Exchanges should ensure that system operators are informed about new regulations and that they also participate in the shaping of the upcoming regulations affecting the islands.

Finally, the secretariat recommends **collaboration of knowledge institutes and local education institutions with system operators, fostered by national governments and regulatory authorities.** Collaborations should allow for upskilling and to attract additional workforce. For example, financial support can be provided for internship programmes.

LEVEL OF IMPLEMENTATION	
✓	EU
✓	National
✓	Local

RECOMMENDATION APPLICABLE FOR	
✓	Non-interconnected islands
✓	Interconnected islands
✓	Remote areas on mainland

Existing publications

EU Grid Action Plan, EC, 2023 Link

"The lack of skilled workers affects the increasing staffing needs of transmission and Distribution System Operators, HVDC cable manufacturers and other power system suppliers. This includes the need to acquire further advanced digital and technological skills, such as automation, controlling, big data and advanced analytics, to detect and control network challenges as well as develop the necessary technologies."

Best practice:

Formal and peer-to-peer exchanges between island grid operators

While each island features its own specific context, most islands can benefit from learning about the experiences of others. Many islands benefit from the experience of experts from the mainland and other islands, typically through formal frameworks:

- Tahiti's TSO TEP is accompanied by French national TSO RTE, through its subsidiary RTE International, which recently acquired 25% of TEP's capital (Link). TEP is also in frequent contact with New Caledonia's TSO Enercal, and TEP itself regularly assists grid operators on smaller Polynesian islands.
- The University of la Reunion's PIMENT laboratory is part of the TwinSolar research project with Fraunhofer Institute and DTU (Link)
- Horizon 2020 project MAESHA tests solutions in Mayotte with the aim to replicate them in Gran Canaria, Gozo, Favignana, Wallis-and-Futuna, and Saint-Barthelemy (Link)

Conclusions

The Clean Energy for EU Islands Secretariat has been analysing the policy and regulatory framework of Member States since 2021 to identify barriers to clean energy transition for islands. The secretariat has been collaborating with relevant stakeholders to design recommendations for overcoming identified barriers. In 2023, the secretariat published the **Study on regulatory barriers and recommendations for clean energy transition on EU islands**, which included a detailed analysis of the regulatory framework relevant for the island energy transition of seven Member States. The study identifies several challenges faced by all analysed Member States. One main barrier is grid constraints and security of supply, which is reflected mainly in the inability of islands' electricity systems to integrate additional variable renewable energy sources. This barrier was observed to stem from renewable energy connection rules and procedures, lack of grid modernisation methodologies, and lack of regulation for the implementation of innovative technologies including energy storage.

This study aimed to further understand and identify concrete challenges non-interconnected island electricity systems face in establishing reliable operation and security of supply while integrating variable renewable generation. Ten case studies, varying in geographical location, governance, and electricity system architecture, were examined to provide tangible examples of non-interconnected island systems, their operating conditions, and ongoing challenges in the operation of these systems.

During the preparation of the study, the Clean Energy for EU Islands Secretariat communicated and brought together electricity system operators, national regulatory authorities, and relevant government bodies of the case studies' islands. The preparatory process included both online and in-person workshops. Online workshops allowed for knowledge and best practices exchange among system operators and national regulatory authorities of case studies. In-person workshops, allowed for discussion among Member State-specific stakeholders on shaping the relevant regulation and operational principles for non-interconnected islands. In this collaborative process, main challenges were discussed, best practices were brought forward, and possible solutions were identified.

The sustainable development of EU islands requires a reliable and secure energy supply using locally available renewable resources. Significant work has already been undertaken by all involved stakeholders and relevant EU bodies. However, to achieve ambitious targets set by islands and Member States in the decarbonisation of EU islands, five main challenges need to be overcome by applying a combination of proposed recommendations. i) Power cuts, ii) high curtailment of existing RE generation, iii) limitation on additional RE generation uptake, iv) uncontrollable distributed RE generation and v) complex and non-transparent permitting and connection procedures for RE generation, hamper the energy transition of the EU islands.

To overcome these challenges, policy, regulatory, and operational actions are recommended on the system operator, national, and EU levels. Recommended actions are aimed at improving the planning and operation of islands' electricity systems, sensitising national grid and renewable energy regulation to characteristics of island electricity systems, preparing island electricity grids for safe and reliable operation through energy transition, and ensuring beneficial increased integration of variable renewable generation. The responsibility for implementation lies with system operators, national regulatory authorities, and national and regional governments. However, the EU can play a significant role by gathering best practices, providing guidelines, and shaping funding programmes to require systemic changes.

The collaborative process of this study showed positive effects on increasing knowledge and improved interactions among involved stakeholders. The secretariat will continue to foster such exchanges and provide opportunities for increased visibility of best practices among stakeholders relevant to EU islands, specifically those involved with islands engaged with the 30 for 2030 initiative. The secretariat will continue its collaboration with EU, national and local bodies, associations, and stakeholders with the goal of supporting EU islands to decarbonise their energy systems.

Annex 1: Extended EU policy framework – exceptions for islands

The EU legislative framework is analysed mainly on the following **6 key issues** that are of **high interest to achieve the decarbonisation** of the EU's islands.

- **Flexibility in distribution**
  Commission Recommendation on energy storage SWD(2023)57[201] shows determination to support remote areas and outermost regions. Consequently, the European Commission recommended Member States to expedite the integration of flexibility tools, namely storage systems, as well as review connection requirements to support hybrid energy projects[202], specifically for EU islands, remote areas, or outermost regions with insufficient grid capacity and unstable or long-distance connections to the main grid.
- **Unbundling**
  The **IMED** contains an option for Member States to apply an exception to the obligation for national DSOs to be unbundled, specifically not to apply the independence and monitoring requirements laid out to those integrated DSOs which serve less than 100,000 connected customers, or that serve small isolated systems.[203] However, for outermost regions that cannot be interconnected with the Union electricity markets, the derogation shall not be limited in time, although it still shall be subject to conditions aimed to ensure that the derogation does not obstruct the Member State's transition towards achieving EU's renewable energy targets.
- **Phasing out non-RES and fossil fuels**
  The **Renewable Energy Directive of 2018 (RED 2018)**[204] foresees the possibility for Member States to apply a derogation to most eligibility criteria concerning outermost regions' access to financial support for the consumption of certain renewable fuels. Amended by the **RED 2023**, this provision has expanded from biomass fuels to also include biofuels and bioliquids.
- **Financial incentives supporting RES integration**
  Under **TFEU**, outermost regions benefit from laxer restrictions for granted State aid. Additionally, **RED 2018** includes a specific exception for financial support schemes when they target outermost regions or small islands. For these cases, this support may be adapted to consider the higher production costs associated with the isolated nature and external dependence of these regions.
  Regulation (EU) 2021/1056 establishing the Just Transition Fund (JTF)[205] implements a fundamental aspect of the EU Just Transition Mechanism under the Sustainable Europe Investment Plan. The JTF is a dedicated financial instrument directly addressing a priority area under the European Green Deal: to mitigate the adverse social, economic, and environmental

[201] European Commission, Commission Recommendation of 14 March 2023 on Energy Storage – Underpinning a decarbonised and secure EU energy system 2023/C 103/01, *OJ C 103, 20.3.2023, p. 1–5,* (link)
[202] Hybrid projects combine two or more generation elements, possibly in combination with storage and/or transmission elements and use the same electricity evacuation infrastructure with a single grid connection point. European Commission, Directorate-General for Energy, Kern, S., Zorn, T., Weichenhain, U. et al., *Hybrid projects – How to reduce costs and space of offshore development – North Seas offshore energy clusters study*, Publications Office, 2019, (link)
[203] Article 35(4) of the IMED.
[204] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, *OJ L 328 21.12.2018, p. 82*, (link)
[205] Regulation (EU) 2021/1056 of the European Parliament and of the Council of 24 June 2021 establishing the Just Transition Fund, *OJ L 231, 30.6.2021, p. 1–20,* (link).

impacts associated with the transition to a climate-neutral and circular economy in the most affected regions, to foster a balanced socio-economic shift. Financial support under JTF is granted to NUTS 3 regions identified as most negatively affected in a just transition plan, with special attention to the particular needs of islands, insular areas and outermost regions.

- **Non-financial support for RES integration**
  Regulation (EU) 2019/941 on risk-preparedness in the electricity sector[206] shows awareness of the particular context of island electricity markets. It emphasises that risk-preparedness plans should include all national situations, including their micro-isolated systems that are not connected to the national grid or their territories that are outermost regions, because these are vulnerable to local electricity crisis scenarios and as such, they need tailored prevention and mitigation measures.
- **Provisions concerning further aspects of grid operation**
  The **IMED** has two additional aspects in regard to exceptions and derogations. Namely, an exception to the obligation for small integrated electricity undertakings to follow and update a transparent ten-year network development plan and a possible derogation to the obligation for Member States to have a single independent regulatory authority for small systems in a geographically separate region of Member States.
  Additionally, the **IMER** provides easier access for capacities (bid sizes of 100 kW or less) from smaller island electricity systems for trading in day-ahead and intraday markets.

Flexibility in distribution

Commission Recommendation on energy storage SWD(2023)57[207] shows determination to support remote areas and outermost regions. Thus, Recital 9 stresses the importance of flexibility resources, notably energy storage, to significantly help to move away from imported fossil fuels and manage high levels of short-term and seasonal variability in renewable energy supply in energy systems that are less or not interconnected, such as islands, remote areas, or the EU's outermost regions. Consequently, the European Commission recommended two actions specifically directed towards EU islands, remote areas, or outermost regions with insufficient grid capacity and unstable or long-distance connections to the main grid. For this, Member States should expedite the integration of flexibility tools, namely storage systems, as well as review connection requirements to support hybrid energy projects.[208]

As renewable energy technologies integrate electricity systems at an increasingly accelerated rate, so grows the need for flexibility solutions to accommodate the new and more unstable energy sources. This was precisely reiterated in the **Commission Staff Working Document**[209] accompanying the Energy Storage Recommendation. The Staff Working Document further explores the need to **increase**

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[206] Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector, *OJ L 158, 14.6.2019, p. 1–21,* (link)
[207] European Commission, Commission Recommendation of 14 March 2023 on Energy Storage – Underpinning a decarbonised and secure EU energy system 2023/C 103/01, *OJ C 103, 20.3.2023, p. 1–5,* (link)
[208] Hybrid projects combine two or more generation elements, possibly in combination with storage and/or transmission elements and use the same electricity evacuation infrastructure with a single grid connection point. European Commission, Directorate-General for Energy, Kern, S., Zorn, T., Weichenhain, U. et al., *Hybrid projects – How to reduce costs and space of offshore development – North Seas offshore energy clusters study*, Publications Office, 2019, (link)
[209] European Commission, Commission Staff Working Document: Energy Storage - Underpinning a decarbonised and secure EU energy system, SWD(2023) 57 final, 2023, (link)

flexibility in the EU electricity system **by introducing both long- and short-term technologies**, namely energy storage, demand response, and supply-side flexibility. In particular, the Staff Working Document identified the relevance of short-duration balancing and non-frequency ancillary services, such as fast frequency response, inertia for local grid stability, black start capability, and island-operation capability. When looking at long-timeframe technologies, long-duration energy storage was highlighted as a highly versatile solution, because transforming renewable energy into, for instance, electricity, helps advance electrification in more isolated areas. This is because storage helps to increase the flexibility and stability of the grid due to variable RES, thanks to its possibility to store electricity during the off-peak generation. Then, storage systems can release energy during peak demand times or when generation from renewables is low. Moreover, it can provide important ancillary services that help maintain the grid's operational integrity and ensure a steadier and more reliable electricity supply.

Unbundling

The **IMED** contains an **exception** to the obligation **for national Distribution System Operators** (DSOs) to be unbundled. Under Article 35(4), Member States may decide not to apply the independence and monitoring requirements laid out to those integrated DSOs **which serve less than 100,000 connected customers, or** that serve **small isolated systems**. The exception is applicable both to vertical and horizontal integration and it mainly concerns organisational and decision-making independence, and reporting or monitoring aspects, any of which could be susceptible of distorting competition.

Likewise, under Article 66 of the **IMED**, Member States can apply for **derogations** from the relevant provisions concerning unbundling of their **Transmission System Operators** (TSOs), in case of demonstrable substantial **problems for the operation of their small connected and/or isolated systems**. The Commission may grant the derogation, provided that it is limited in duration and under conditions pursuing a double aim: to increase competition in, and the integration of the internal market; as well as to ensure that the derogations do not hinder the transition towards the energy transition or any of their elements (renewable energy, increased flexibility, energy storage, electromobility and demand response). However, **for outermost regions** that cannot be interconnected with the Union electricity markets, the derogation shall not be limited in time, although it still shall be subject to conditions aimed to ensure that the derogation does not obstruct the Member State's transition towards achieving EU's renewable energy targets.

Phasing out non-RES and fossil fuels

The Renewable Energy Directive of 2018 (RED 2018)[210] foresees in Article 29(13)(c) the possibility for Member States to apply a **derogation** to most **eligibility criteria** outlined in Article 29 concerning **outermost regions' access to financial support** for the consumption of certain biofuels. This derogation allows Member States to adopt, for a limited period, specific eligibility criteria for outermost regions' installations and the biofuels fuels they consume. For the latter, diverging criteria must be objectively justifiable under the goal of transitioning from fossil fuels to sustainable ones. Amended by the **RED 2023**, this provision has expanded from renewable biomass fuels to also include bioliquids and biofuels. The amending Directive takes into consideration in Recital 86 the challenges faced by outermost regions (namely isolation, limited supply, and fossil-fuel dependency) that resulted in broadening this derogation.

[210] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources, *OJ L 328 21.12.2018, p. 82*, (link)

This view is also reflected in Article 3(d) of the **RED 2018**, which allows Member States to **renew or grant support** to the production of electricity from forest biomass by electricity-only installations in exceptional cases. The exception applies to **NUTS 3**[211] **regions** identified **in a territorial just transition plan** for their reliance on solid fossil fuels (for instance, the Greek Aegean Islands and Crete), and to **outermost regions**. The latter regions can benefit from this exception for a limited time and only if it contributes to ultimately phasing down the use of forest biomass while guaranteeing the safety and security of the energy supply.

In this same sense, the European Commission issued in 2022 the **Communication on Short-Term Energy Market Interventions and Long-Term Improvements to the Electricity Market Design – a course for action**,[212] further addressing European electricity market issues addressed by the European Commission's **2023 Toolbox**[213] and the **2022 REPowerEU Communications**.[214] The Communication proposed short-term intervention measures following an extensive stakeholder outreach process. Concerning Electricity Market Interventions, it introduced a limited possibility for Member States to **temporarily subsidise the cost of gas for power generation** in those regions with very limited interconnection capacity, high influence of gas in price setting and consumers particularly exposed to wholesale electricity prices.

Financial incentives supporting RES integration

Under Article 107(3)(a) **TFEU**, **outermost regions** benefit from **laxer restrictions for granted State aid** susceptible of distorting competition. In this way, aid granted by the State or through State resources to further develop the economy of outermost regions may still be considered compatible with the internal market and thus, allowed.

Another way in which EU legislation supports the deployment of renewable energies in islands is in Article 4.7 of **RED 2018**, which includes a specific exception for **financial support schemes** when they **target outermost regions or small islands**. For these cases, this support may be adapted to consider the higher production costs associated with the isolated nature and external dependence of these regions.

Regulation (EU) 2021/1056 establishing the Just Transition Fund (JTF)[215] implements a fundamental aspect of the EU Just Transition Mechanism under the Sustainable Europe Investment Plan. The JTF is a dedicated financial instrument directly addressing a priority area under the European Green Deal: to mitigate the adverse social, economic, and environmental impacts associated with the transition to a climate-neutral and circular economy in the most affected regions, to foster a balanced socio-economic shift. Financial support under JTF is granted to **NUTS 3 regions identified as most negatively affected in a just transition plan**, with Article 6 and Recital 19 underscoring the need to pay additional attention to the particular needs of islands, insular areas and outermost regions. This

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211211 European Commission, NUTS Overview, (link)

212 European Commission, Commission Communication: Short-Term Energy Market Interventions and Long Term Improvements to the Electricity Market Design – a course for action, *COM/2022/236 final*, (link).

213 European Commission, Commission Communication: Tackling rising energy prices: a toolbox for action and support, *COM/2021/660 final*, (link)

214 European Commission, Commission Communication: REPowerEU: Joint European Action for more affordable, secure and sustainable energy, *COM/2022/108 final,* (link)

215 Regulation (EU) 2021/1056 of the European Parliament and of the Council of 24 June 2021 establishing the Just Transition Fund, *OJ L 231, 30.6.2021, p. 1–20,* (link).

obligation is in line with provisions laid out in Articles 174 and 349 TFEU. Additionally, insular regions benefit from an exception that allows enterprises other than SMEs to receive (conditional) financial support in the shape of productive investments under the JTF, in line with Article 8(2) and Recital 12.

Non-financial support for RES integration

Regulation (EU) 2019/941 on risk-preparedness in the electricity sector[216] shows awareness of the particular context of island electricity markets in Recital 20. There, it is emphasised that risk-preparedness plans should include all national situations, including their micro-isolated systems that are not connected to the national grid or their territories that are outermost regions, because these are vulnerable to local electricity crisis scenarios and as such, they need tailored prevention and mitigation measures.

Additionally, **Regulation (EU) 2022/869 on guidelines for trans-European energy infrastructure (the revised TEN-E Regulation)**[217] lays down rules for cross-border energy infrastructure, primarily focusing on **Projects of Common Interest (PCIs)**[218] implemented under one of the 14 priority energy infrastructures, grouped into priority corridors for electricity, offshore grids, and hydrogen and electrolysers, and 3 priority thematic areas: smart electricity grids, smart gas grids, and a cross-border carbon dioxide network. PCIs shall meet the following essential requirements: to be necessary for the realisation of at least one priority energy infrastructure, to advance sustainability, to keep a positive balance between costs and benefits, and either to have a significant cross-border impact or involve at least two Member States. Moreover, certain energy infrastructures include stricter requirements for islands. Hydrogen interconnections, electrolysers, and smart electricity grids on islands can be considered priority corridors or thematic areas only when, on top of meeting other infrastructure-specific criteria, they help to decrease energy isolation, support innovative solutions involving at least two Member States a significant positive impact on the EU's 2030 targets for energy and climate and 2050 climate neutrality objective, and contribute significantly to the sustainability of the island and EU energy systems. The insular States of Cyprus and Malta benefit from a derogation to apply this paragraph's (except for electrolysers) and a few other provisions concerning, namely, PCI assessment criteria and investments.

Provisions concerning further grid operation aspects

The **IMED** contains an exception to the obligation for small integrated electricity undertakings to follow and update a transparent ten-year network development plan. The transparency obligation concerns medium- and long-term flexibility services, investments, changes to the main distribution infrastructure, and alternative resources to grid expansion. Member States may apply this exception to integrated electricity undertakings which serve less than 100,000 connected customers, or which serve small isolated systems.

The **IMED** also contains a **derogation to the obligation for Member States to have a single independent regulatory authority**. Under Article 57(3), Member States can designate regulatory

[216] Regulation (EU) 2019/941 of the European Parliament and of the Council of 5 June 2019 on risk-preparedness in the electricity sector, *OJ L 158, 14.6.2019, p. 1–21,* (link)

[217] Regulation (EU) 2022/869 of the European Parliament and of the Council of 30 May 2022 on guidelines for trans-European energy infrastructure, *OJ L 152, 3.6.2022, p. 45–102* (link)

[218] Projects of Common Interest are a category of key cross-border infrastructure projects necessary to interconnect the European Union's energy infrastructure, as identified by the European Commission.

authorities for small systems in a geographically separate region whose consumption, in 2008, accounted for less than 3 % of the total consumption of the Member State of which it is part.

Moreover, under **Article 66(1)** of the **IMED**, Member States which can demonstrate substantial problems with the operation of their **small connected and/or isolated systems** may apply to the Commission for **derogations** from the relevant provisions of Articles 7 and 8, and of Chapters IV (distribution system operation) and V (transmission system operation). Additionally, small isolated systems and France -for Corsica- may also apply for an additional derogation from Articles 4, 5 and 6. Derogations granted by the Commission shall, in line with Article 66(2), be limited in time and subject to conditions that aim to foster competition and protect internal market integration, while also avoiding becoming an obstacle for the transition towards renewable energy, increased flexibility, energy storage, electromobility, and demand response. On the other hand, **for outermost regions that cannot be interconnected** with the Union electricity markets, the derogation shall not be limited in time; and will, however, be conditional to the enforcement of a series of specifications designed to ensure that the derogation does not constitute a barrier for the clean energy transition.

The **IMER** provides **easier access for capacities from smaller island electricity systems**. Notably, Article 8(3) states that Nominated Electricity Market Operators shall provide products for trading in day-ahead and intraday markets which are sufficiently small, with bid sizes of 100 kW or less, to allow for the effective participation of demand-side response, energy storage, and small-scale renewables including direct participation by customers. This marks a notable reduction in bid size from the previous 500 kW limit, allowing smaller projects to participate. This provision is, however, **only relevant for those islands that participate in the electricity market** (notable exceptions include the Irish Single Electricity Market: the Aran Islands, Arranmore and Tory Island, Inishbofin, Cape Clear Island and the other West Cork Islands, as well as the Dutch Caribbean islands: Saba, Bonaire, and St. Eustatius).

Moreover, under **Article 64(1)** of the **IMER**, Member States may apply for a **derogation** from certain provisions (Articles 3 and 6, Article 7(1), Article 8(1) and (4), Articles 9, 10 and 11, Articles 14 to 17, Articles 19 to 27, Articles 35 to 47, and Article 51) in cases of impossibility or difficulty of a system's connection to the Union's energy market. To be eligible for the derogation, the Member State shall be able to demonstrate the existence of substantial problems for the operation of their **small isolated and/or connected systems, or** it shall affect one of its **outermost regions**. If granted by the European Commission, a derogation applicable to small systems that do not constitute outermost regions within the meaning of Article 349 **TFEU** will be of limited duration and conditional to a series of requirements aimed at safeguarding competition and integration within the internal market for electricity. On the other hand, an outermost region may benefit from granted derogations to the abovementioned **IMER** provisions indefinitely.

Context of island electricity systems

E.DSO has recently formulated some general recommendations concerning the financial and complex bureaucratic challenges faced especially by small and/or municipal DSOs that could also be relevant for EU islands. In its **2023 DSO Funding Gap Report** (link) E.DSO underscored remarkable issues and formulated recommendations to overcome said challenges based on the views of 54 DSOs:

- Difficulty in Obtaining PCI Status: Respondents expressed frustration over the challenges DSOs have faced in obtaining Projects of Common Interest status in recent years. They noted that the process has become increasingly complex, with applications reportedly facing a lack of transparency in the selection criteria. This complexity makes it difficult for all, and especially small, DSOs to succeed in obtaining PCI status.
- Issues with Connecting Europe Facility Energy Funding: Respondents echoed concerns raised earlier about the allocation of funding through the Connecting Europe Facility Energy programme. They mentioned a perceived change of priorities for the European Commission when distributing funds, which has affected DSOs' ability to secure funding for their projects.
- Challenges with the Innovation Fund: Respondents also discussed this challenge, noting that the application process is highly complex and has stringent requirements. They highlighted fierce competition and a perceived disadvantage for DSOs compared to other stakeholders when applying for funding. While the thematic areas of the Innovation Fund align closely with DSO goals, respondents felt that DSO projects, particularly those led by municipal DSOs, are considered less competitive compared to projects focused on Carbon Capture, Utilisation, and Storage.
- Need for Supportive Funding Rates and Rules: Finally, respondents emphasised the importance of funding mechanisms that are supportive of small and municipal DSOs. They called for more favourable depreciation rules for assets and coverage of operational costs in funding mechanisms. Respondents highlighted that the transition to a decarbonised and decentralised energy system requires additional skilled staff, increased local presence, and deployment of new software, all of which contribute to increased operating costs for DSOs.

Annex 2: List of interviewed stakeholders

Rhodes island and the Kos-Kalymnos islands, Greece

- RAE
- Power Production Company
- Power Production Company Renewables
- IPTO
- HEDNO

Aeolian Islands, Italy

- Regulatory energy agency (ARERA)
- DSO Lipari
- Enel – E-dsitribuzione

Gran Canaria, Fuerteventura, and Lanzarote islands, Canary Islands, Spain

- IDAE
- MITECO, Ministry for energy
- Red electrica, TSO
- Endesa (Enel), DSO
- ITC

Terceira, Faial, Pico, Sao Jorge and Graciosa islands, Azores, and Madeira and Porto Santo islands, Madeira, Portugal

- INESCTEC
- EDA, Electricity company Azores
- EEM, Electricity company Madeira
- Regulatory energy agency, ERSE
- Regional department for energy Azores

Aruba and Bonaire, Netherlands

- National Regulatory Authority, Department of Energy, ACM
- Ministry responsible for Caribbean islands
- WEB Bonaire
- WEB Aruba
- TNO
- University of Aruba
- ASDC Group

Réunion, France

- Regulatory energy agency, CRE
- University of Réunion
- Total Energies
- Temergie, Réunion cluster
- SIDELEC
- Horizon Réunion

French Polynesia, France

- French Polynesian government, Energy ministry
- TSO Transport d'Electricité Polynésie
- Akuo energy
- DSO Electricité de Tahiti – Engie

EU wide association or broader

- IRENA
- Eurelectric

Annex 3: Online workshop series "Future-proofing electricity systems"

The series of online workshops started on 11 October 2023 and lasted until 13 December 2023 with six workshops on the following topics:

- **Workshop 1: Key aspects of grid operation**
- The key aspects of safely operating non-interconnected systems with high share of asynchronous RE generation
- **Workshop 2: RES requirements and rights**
- RES asynchronous generation in non-interconnected island systems
- **Workshop 3: BESS**
  Use of BESS within high-RES non-interconnected system
- **Workshop 4: Demand-side management**
  Use of distributed flexibility to help grid management for non-interconnected islands
- **Workshop 5: The 100% decarbonised systems**
  What is needed to completely turn off thermal power plants for 100% RES secure system operation?
- **Workshop 6: De-risking Investments**
  De-risking investments in RES on the non-interconnected islands

All materials presented at the workshops can be found on our website. Here the secretariat presents the agenda, overview of topics discussed in workshops, and a list of participating stakeholders, per workshop.

Workshop 1: Key aspects of grid operation

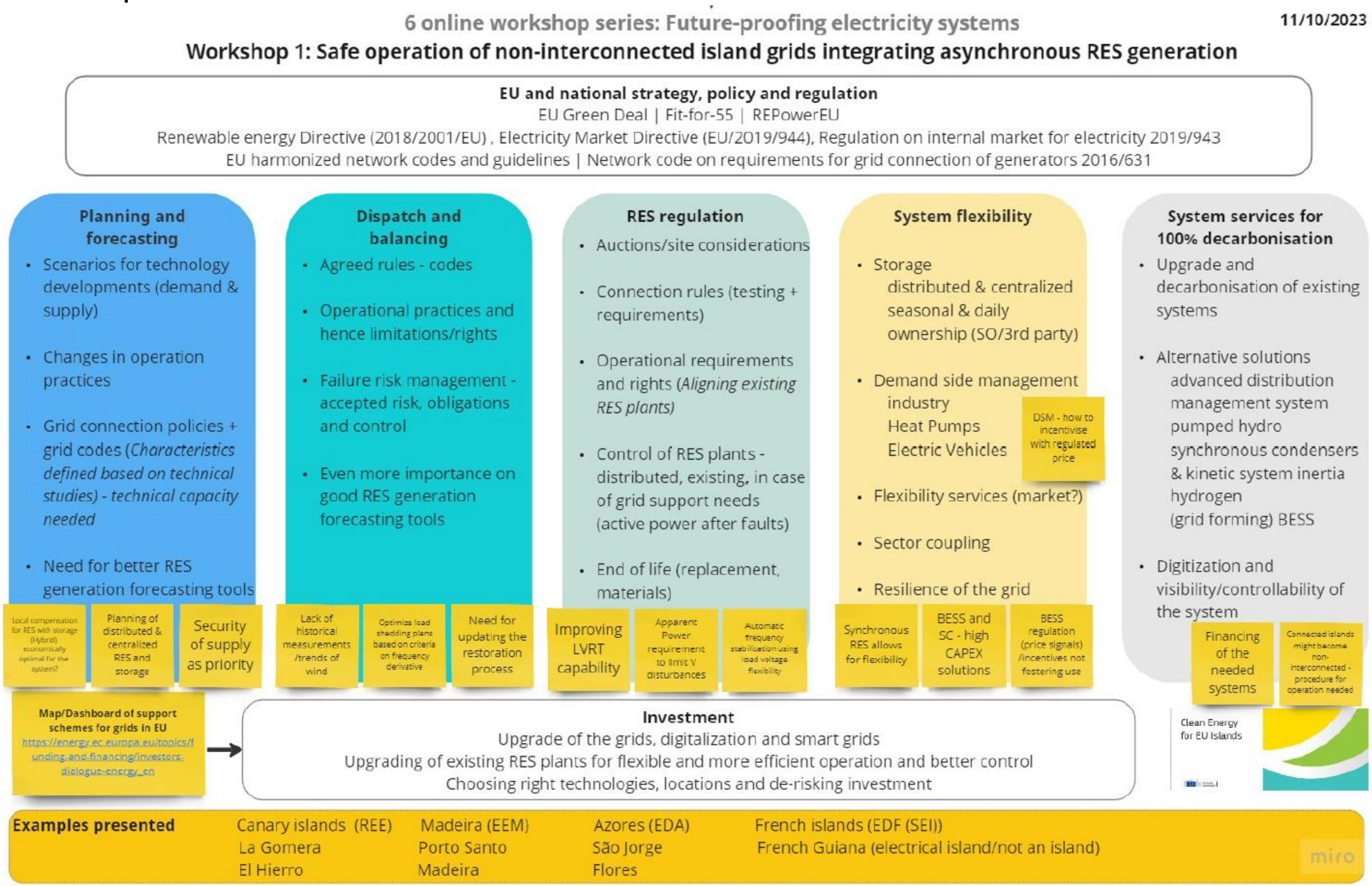
The key aspects of safely operating non-interconnected systems with high share of asynchronous RE generation

Online, 11 October 2023

Agenda:

10.00- 10.05	Welcome	Secretariat
10.05-10.15	Energy transition and decarbonisation of island systems: Focus on electricity grids and non-interconnected islands	Tadhg O'Briain, DG ENER
10.15-10.30	Key challenges of the grids and key aspects (connection, operation, planning and market) of grid codes	Secretariat
10.30-11.00	Examples of low-RES penetration including drivers and challenges	Participating DSOs
11.00-11.05	Break	
11.05-11.35	Examples of high-RES penetration including drivers and challenges	Participating DSOs
11.35-11.50	Presentation on how DSOs will finance upgrades and smart grids	Julien Dieler, DG ENER
11.50-12.15	Breakout sessions: ▪ Requirement and rights for RES asynchronous generation, Martina Cannata, 3E ▪ Use of BESS, Romain Gitton-Riviere, 3E ▪ Demand-side management and flexibility, Kostas Komninos, DAFNI ▪ Last mile - move to 100% RES, Lucija Rakocevic, Th!nk E	All participants
12.15-12.25	Conclusions from the breakout sessions	Moderators of breakout sessions
12.25-12.30	Closure and next steps	Secretariat

Discussed topics



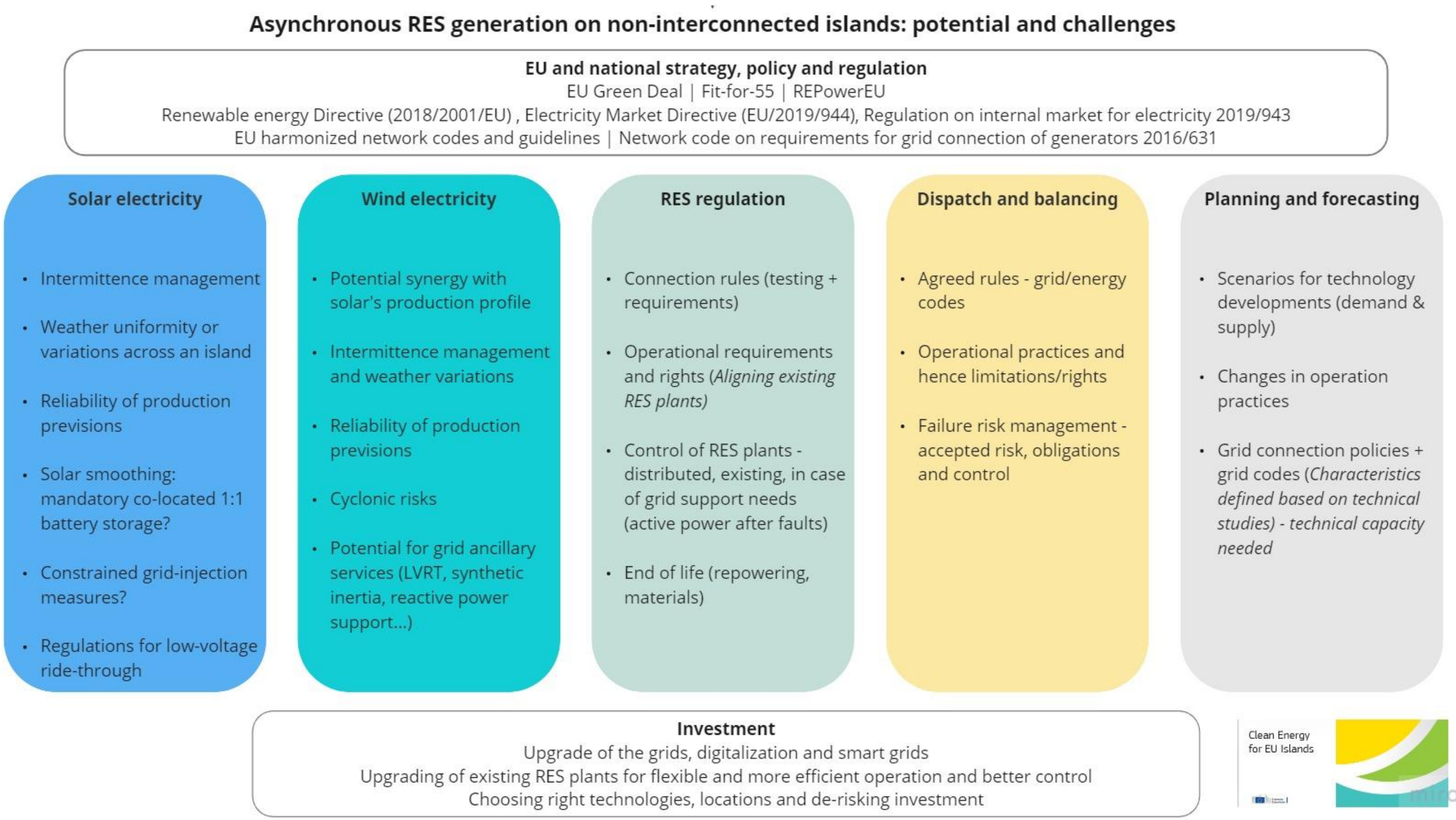
Workshop 2: RES requirements and rights

RES asynchronous generation in non-interconnected island systems
Online, 27 October 2023

Agenda:

10.00 – 10.05	Welcome and setting the scene	Secretariat
10.05 – 10.15	Variations in requirements and rights for wind energy	Nicolas Meerts, 3E
10.15 – 10.20	Clarification questions	All
10.20 - 10.30	Variations in requirements and rights for wind energy – Catarina Augusto & Leo Mauger	Solar Power Europe & Akuo Energy
10.30 – 10.35	Clarification questions	All
10.35 – 11.05	Examples from 3 island systems of RES integration issues solved • Quentin Ferreira, EDF SEI: Low-voltage ride through • Agostinho Figueira, EEM: Reactive power capability for voltage control • Veronica Deniz Perez, REE: Active power management	Grid operators
11.05 – 11.35	Roundtable on injection rules, challenges, and solutions: • Rodriguez Manuel del Castillo, Endesa • Quentin Ferreira, EDF SEI • Despina Koukoula, HEDNO	Grid operators
11.35 – 11.40	Concluding remarks	Secretariat

Discussed topics:



Workshop 3: Battery Energy Storage Systems (BESS)

Use of BESS within high-RES non-interconnected systems

Online, 10 November 2023

Agenda:

10.00 – 10.05	Welcome and workshop overview	Secretariat
10.05 – 10.20	BESS overview in an island context: • Third-party operation vs DSO-operated • Benefits to the grid • Examples	3E
10.20 – 10.25	Questions	All
10.25 – 11.10	Three Examples from island systems: implementation and finance, lessons learned, challenges, and outlook: • Canary and Balearic Islands, Endesa • Tilos, HEDNO • Azores, EDA	DSOs
11.10 – 11.35	Relevant regulatory framework and results: how to finance this development	Regulators
11.35 – 12.00	Grid operator roundtable: vision for batteries	Grid operators
12.00 – 12.05	Concluding remarks	Secretariat

Discussed topics:

November 10th: Use of BESS within high-RES non-interconnected systems

EU and national strategy, policy and regulation
EU Green Deal | Fit-for-55 | REPowerEU
Renewable energy Directive (2018/2001/EU) , Electricity Market Directive (EU/2019/944), Regulation on internal market for electricity 2019/943
EU harmonized network codes and guidelines | Network code on requirements for grid connection of generators 2016/631

Planning and forecasting

- Long-term projections establishing the need for BESS on islands
- Scenarios for technology developments
- Critical design choices regarding storage capacity, duration, ownership and alimentation
- Islands' electricity prices today do not necessarily comport the price signals for batteries

Dispatch and balancing

- Energy/grid codes provide the framework for
- Operational practices and hence limitations/rights
- Failure risk management - accepted risk, obligations and control
- Importance of good RES generation forecasting tools

BESS framework

- Different design options for battery auctions
- Connection and permitting rules (testing + requirements)
- Operational requirements and rights
- Control of battery assets (distributed, existing...)
- End of life (replacement, materials)

System flexibility

- Storage
  Distributed & centralized
  Seasonal & daily
- Intra-day energy smoothing
- Daily or multi-day energy shifts
- Flexibility from consumers/electric vehicles batteries

Grid services for 100% decarbonisation

- Grid services provided by conventional lithium-ion batteries on non-interconnected systems et)
- Grid services that could be provided by BESS connected to grid-forming inverters
- Digitization and visibility/controllability of the system

Investment
Necessary: private investment into third-party batteries, standalone or co-located
Possible: public investment into centralised batteries
Choosing right technologies, locations and de-risking investment

Clean Energy for EU Islands

Workshop 4: Demand side management (DSM)

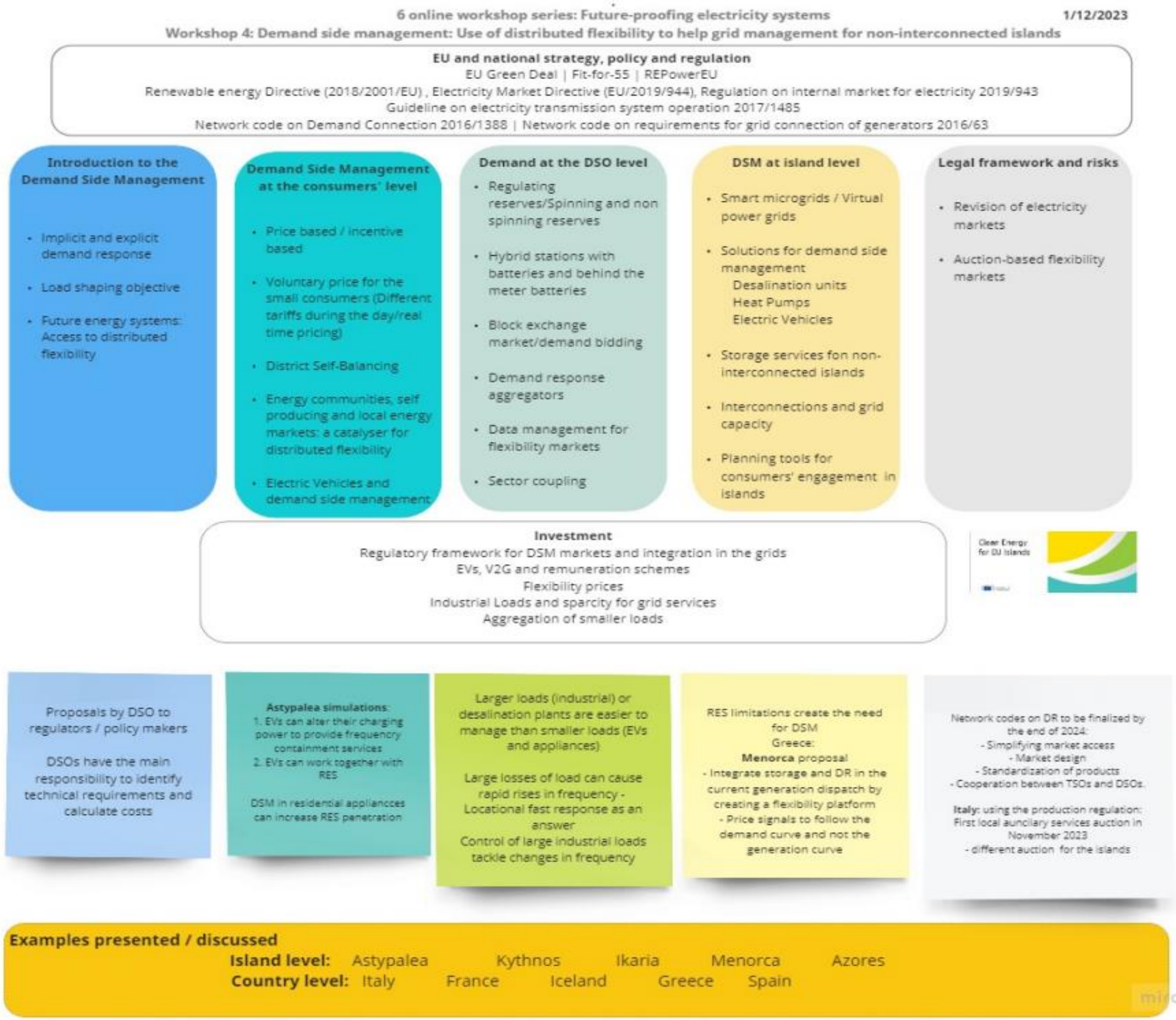
Use of distributed flexibility to help grid management for non-interconnected islands

Online, 1 December 2023

Agenda:

10.00 – 10.05	Welcome and workshop overview	Secretariat
10.05 – 10.20	Development of guidelines for network codes for distributed flexibility	Carlos Castel – EUDSO
10.20 – 10.25	Questions	All
10.25 – 10.35	Use of DSM and to increase flexibility of the grid (electric mobility, HVAC, industry)	Nikos Hatziargyriou – NTUA, ETIP SNET
10.35 – 10.40	Questions	All
10.40 – 11.20	Examples from DSOs / TSOs: • Landsnet • ENDESA • HEDNO • EDF	DSOs /TSOs
11.20 – 11.25	Break	
11.25 – 11.55	Regulator round: • How does the regulatory framework support DSM • How to finance actions • ARERA • RAE	Regulators
11.55 – 12.00	Concluding remarks and next steps	Secretariat

Discussed topics:



Workshop 5: The 100% decarbonised systems

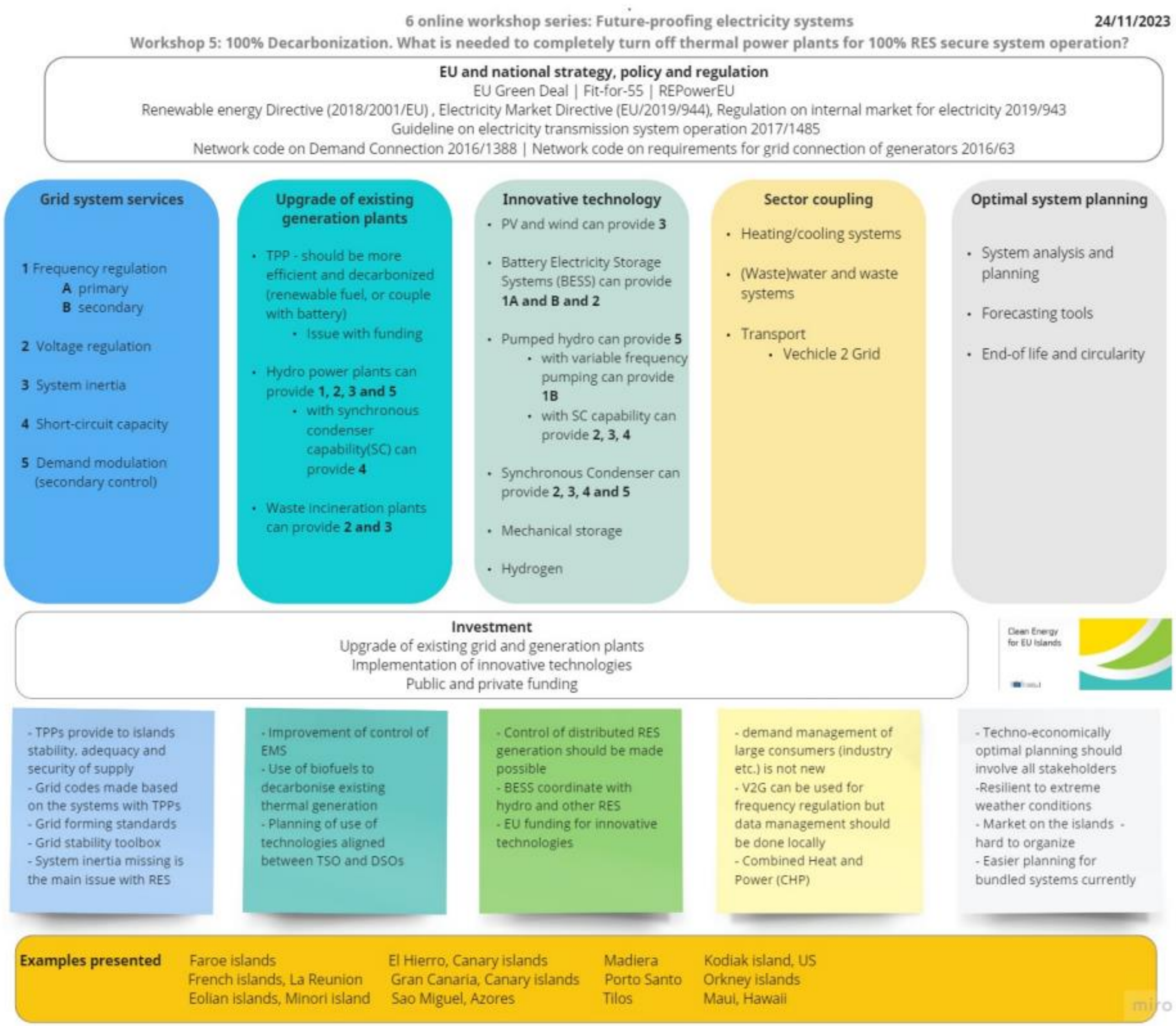
What is needed to achieve 100% decarbonised secure electricity system operation?

Online, 24 November 2023

Agenda:

10.00 – 10.05	Welcome and workshop overview	Secretariat
10.05 – 10.15	Infrastructure planning needed for energy transition	Tom Howes, DG ENER
10.15 – 10.30	Main services for DSOs traditionally offered by TPPs Sustainable alternatives and their benefits to the grid	Konstantinos Kyparissis, Eurelectric
10.30 – 10.40	Questions	Secretariat
10.40 – 11.30	DSO/TSO round: 1-2 examples of the use of various technologies for grid services on non-interconnected islands • Pumped hydro, hydrogen, synchronous condensers, grid forming use of batteries, forecasting tools • Challenges	DSOs / TSOs
11.30 – 11.45	Techno-economic overview of various technologies and examples	Christina Kopitopoulou, DNV
11.45 – 11.55	Open discussion	All
11.55 – 12.00	Concluding remarks and next steps	Secretariat

Discussed topics:



Workshop 6: De-risking Investments

De-risking investments in RES on the non-interconnected islands

Online, 13 December 2023

Agenda:

PART A: DSOs supporting the deployment of RES on islands

10.00 – 10.05	Welcome and agenda	Secretariat
10.05 – 10.10	30 Renewable Islands for 2030	Edita Dranseikaite, DG ENER
10.10 – 10.15	Overview of main aspects causing risks to further RES investments and how to minimise them	Secretariat
10.15 – 10.25	The EU Grid Action Plan and its effect on the island grids	Riccardo Rennedo Williams, DG ENER
10.25 – 10.40	Commenting by DSOs	DSOs

PART B: Involvement of island stakeholders in the process, ownership, and benefits

10.40 – 11.20	Regulator round: Tender – auctions design	Regulators
11.20 – 11.50	Commenting on RES tendering from the perspective of EU islands stakeholders:	Islands stakeholders – Regional partners
11.50 – 12.00	Concluding remarks	Secretariat

Discussed topics:

- In Europe, transmission and distribution grids are under pressure to expand and connect RES. Distribution grids will play an increasingly important role, with 70% of the RES capacity to be connected at the distribution level.
- The EU made available two mechanisms for the expansion of transnational transmission grids: projects of common interest (within the EU) and projects of mutual interest (with non-EU countries). These also cover offshore transmission grids.
- Most grid investments are done through top-down public authorities planning. Anticipatory investments are rare, and the adaptation to the increasing fraction of offshore renewables present significant complexities. The EU is working on guidelines on the cost sharing for offshore grids, as well as on anticipatory investments. Anticipation on grids expansion can make saving money, as accelerated investment plans can be affected by higher interest rates.
- An additional risk for the development of EU grids is related to the supply chain of grid components. A common procurement plan for the EU might bring benefits in terms of costs and reliability of the supply.
- For small islands, the de-risking of the investments can be achieved via:
    - Specific feed-in tariffs for small and fragile installations (e.g., small PV plants, wind turbines in cyclonic areas).
    - Support from national organisations in the procurement of RES plants and storage plants, with provisions to guarantee reasonable returns to the investors (at least 9% return on capital for Li-ion storage is required).
- The framework for the remuneration of batteries serving the distribution and transmission networks is recent and complex, and are currently undergoing significant evolutions.

Organisations participating to the series of 6 workshops titled "Future-proofing electricity systems"

Organisation name	Country
Th!nk E BV	Belgium
3E	Belgium
Eurelectric	Belgium - EU wide organisation
SolarPower Europe	Belgium - EU wide organisation
EU DSO Entity	Belgium - EU wide organisation
European Comission	Belgium - EU wide organisation
EDF - Électricité de France	France
akuo - Entrepreneurs by nature	France
Commission de régulation de l'énergie	France
Steinbeis Europa Zetrum	Germany
Δίκτυο ΔΑΦΝΗ / DAFNI Network	Greece
ADMIE / IPTO	Greece
deddie / HEDNO	Greece
National Technical University of Athens	Greece
ΔΕΗ/ PPC Public Power Corporation S.A.	Greece
Landsnet	Iceland
ARERA - Autorità di Regolazione per Energia Reti e Ambiente	Italy
Consiglio Nazionale delle Ricerche	Italy
TNO	Netherlands
DNV	Netherlands
EEM-Empresa de Electricidade da Madeira, SA	Portugal
Governo dos Açores	Portugal
EDA	Portugal
INESC Porto	Portugal
aream group	Portugal
Enel Group	Spain
IDAE: Instituto para la Diversificación y Ahorro de la Energía	Spain
Endesa	Spain
Ministerio para la Transición Ecológica y el Reto Demográfico	Spain

Universitat de les Illes Balears	Spain
Red Eléctrica de España - REE	Spain
Enel Green Power	Spain
SEI - Stockholm Environment Institute	Sweden

Annex 4: Set of in-person meetings

In-person workshop - Spain

Energy storage regulation supporting Spanish islands energy transition

13 November 2023, Offices of IDAE in Madrid, Spain

Agenda:

09.00-09.30	Welcome and introductions	All participants
09.30-09.45	Recommendations from study on barriers and initial results from current non-interconnected islands systems study	Secretariat
09:45-10:15	Examples of stand-alone storage regulation and operation in other islands, regarding ownership, retributive scheme, operation	Secretariat
10:15-10:35	Enforcement of NECP and Energy Storage Strategy measures, implementation of regulatory sandboxes. Questions and comments	MITECO
10:35-11:00	Current incentives and ongoing programmes to support islands energy transition. Suggestions about new guidelines for FEDER 21-27 for islands	IDAE
11:00 -11:30	Coffee break	
11:30-12:30	Goals and requirements to achieve them	Regional governments
12:30-13:45	Discussion on the possibilities of implementation of other islands' solutions from a technical point of view (dispatching, operation...) Incentives and storage regulation and inputs from the participants on the current challenges and recommendations	All participants
13:45-14:00	Concluding remarks and next steps	MITECO/IDAE/Secretariat

14:00	Lunch

Main points of discussion:

- **<u>Financing of storage projects</u>:** The Spanish Government recently launched three calls for funding for storage projects: one for independent storage plants[219], one for hybrid plants[220], and one for reversible hydro storage[221]. Although within these calls the budget for single projects on islands was 5% higher than on the mainland, no call exclusively addressed to islands was launched nor envisioned. These financing schemes are helpful for financing the projects, but they do not foresee a remuneration scheme for operating and maintaining them. Revenues for the plants should be achieved by responding to the market, which on islands does not exist due to the absence of an adequate market price signal (see next bullet point). Therefore, **the business model for storage assets on Spanish islands is still to be developed**.
- **<u>Market price signal</u>:** On the islands there is no electricity market, but a regulated scheme for the remuneration of thermal generation and a solidarity mechanism to ensure that the retail price of electricity is the same as in the mainland. The price signal on islands is established based on the daily market price of the peninsula wholesale market, which is then modulated on an hourly basis based on the ratio of the hourly demand versus the average daily demand. **This price signal** is used both as a sale price for producers and a buy price for retailers. Such system is not considered efficient, as it **does not consider the marginal costs of the system**. An adequate price signal should be aligned with the costs of the system to provide an efficient signal to generators, storage assets, and consumers, therefore supporting efficient operational decisions. A correct market price signal would be extremely relevant for investments in storage and demand-side response, since it would indicate the price spread between low-price and high-price hours. **The effect of different designs of the price signal should be assessed** in a dedicated study of both the transmission and distribution grids.
- **<u>Grid access requirements</u>:** There is an urgent need to improve the access requirements for stand-alone batteries. The current methodology to allocate connection capacity (which treats storage as a combination of demand and generation, and analyses scenarios where storage is consuming energy in hours of high costs) poses a limit to the number of connection permits granted. The methodology to allocate connection rights should consider the specific operation of storage resources and the fact that storage helps enhancing the grid's flexibility, thus reducing congestion.
- **<u>Hybridization of existing power plants</u>:** A possible solution to overcome grid connection constraints is to hybridise existing power plants, thus introducing the exploitation of multiple resources at the same location/point of connection (e.g., solar farms and wind farms). This

[219] https://sede.idae.gob.es/lang/modulo/?refbol=tramites-servicios&refsec=almacenamiento-innova&refsec=almacenamiento-innova&idarticulo=146990
[220] https://sede.idae.gob.es/lang/modulo/?refbol=tramites-servicios&refsec=almacenamiento-hibridado
[221] https://sede.idae.gob.es/lang/modulo/?refbol=tramites-servicios&refsec=almacenamiento-innova&refsec=almacenamiento-innova&idarticulo=146992

could reduce the need for new connection capacity, given that production peaks often do not occur simultaneously. This could also apply to the existing thermal plants, that – where possible – could be coupled with solar or wind farms.

- **Operator's owned storage systems:** The installation and management of storage systems by the grid operators (DSOs/TSOs) should be assessed as a solution. Nevertheless, it was discussed how the European regulation requires the market to provide these services, except for specific cases where other market solutions have proved not possible.
- **Lack of operational regulation on storage:** The double role of storage systems (production and consumption) is not defined in the national regulation yet. This creates an additional uncertainty for the deployment of such systems and, especially in the Canary Islands, many projects are not being developed due to the lack of regulation for operation and remuneration of storage systems.

In-person workshop - Portugal

Ingredients needed for high-RES penetration and security of supply on Portuguese islands: Legislation, grid planning, renumeration schemes and technical requirements for RE

25 January 2024, Funchal (Madeira)

Agenda:

09.00 – 09.30	Welcome coffee and registration	
09.30 – 10.50	Introduction	Secretariat
09.30 – 09.45	Welcome and Presentation on Madeira's plan for further energy transition and policy needs	Madeira regional government
09.45 – 09.55	Current results of the ongoing Study	Clean energy for EU islands Secretariat
09.55 – 10.10	Challenges Portuguese islands grids face in the energy transition process	Joao Peças Lopes, INESCTEC
10.10-10.25	Azores' plan for further energy transition and policy needs	Azores regional government
10.25 -10.50	Questions and discussion	All

10.50 -11.10	Coffee break	
11.10 – 12.30	**Session #1 – RE and possible flexibility renumeration: fixed feed-in tariff to auctions** Discussion on remuneration scheme for renewable energy and how it changes going from defined feed-in tariff to auctions. What are some of the challenges and lessons learned and how it can be improved. Further discussion on the possible remuneration schemes or incentives for flexibility provisions. Presentations: • EEM • EDA • ERSE • Secretariat – examples of flexibility remuneration	Panellists
12.30 – 14.00	Lunch	
14.00 – 15.15	**Session #2 – Security of supply and grid planning** Legislation and needs for security of supply studies. Importance of security of supply studies for grid planning and tools need for the studies. Current practice, requirements and needed regulatory/legislation changes. Presentations: • Regional governments from Madeira and Azores • EEM • EDA	Panellists
15.15 – 15.30	Coffee break	
15.30 – 16.30	**Session #3 – Technical requirements needed for distributed generation and flexibility control** What type of communication and control architectures are needed to connect distributed RE generation (crucial for safe operation of systems on island grids)	Panellists

	Presentations: • EEM • EDA
16.30 – 17.00	Conclusions and next steps

Main points of discussion:

- **RES curtailment:** While significant additional RES generation is planned on the Madeira and the Azores, investments in RES suffer from uncertainty and risk due to the need of RES curtailment imposed by technical restrictions. The investment on storage systems has the potential to significantly reduce RES curtailment, as well as the energy requested from thermal units. At the same time, battery systems can also be exploited as grid forming units, bringing additional stability to the system, and avoiding the need of additional dispatch of synchronous units, again enabling larger RES integration. While in some cases it is cheaper to curtail RES than to invest in storage systems, it should be clear who pays for the electricity sale loss in case of curtailment. A lack of clarifications on the remuneration of RES curtailment was remarked, as well as a lack of data on how much energy is nowadays being curtailed. As a unicum, in Terceira (Azores) the system pays to the owner of the wind power generation plant for the curtailed energy (due to historical reasons since the wind farm is older than other RES plants); the mechanism involves the forecast of the wind power generation that would have been in case it wasn't curtailed. For the other Azores islands, there is not a clear picture of how much energy is curtailed, and a remuneration mechanism is not on place. Such a mechanism is also absent in Madeira, although curtailment is much lower today than it used to be thanks to an increase in storage capacity (hydro pumping and batteries).
- **RES and storage remuneration:** Madeira is in the process of using auctions for the remuneration of RES generation through a competitive procedure, via FIT price. In Azores, especially in the smallest islands, there is a lack of interest in tenders, especially when it comes to storage units.
- **Electricity system flexibility:** There is an increasing interest in using flexible assets for enhancing system flexibility, which are being tested with some pilot projects. On the islands, DSOs see the most potential in using EVs for this flexibility. Flexibility from the tourist sector (e.g., HVAC) is currently not being considered. Remuneration and activation of possible flexibility providers would need to be regulated and an adequate enabling regulatory framework developed. Data communication for grid management and control of RE generation is seen as an important technical request that is on the root of the success for further RES integration. In Madeira data communication issues were solved with 5G, whereas Azores aim to solve this on the local island-per-island level, e.g. via fiber optics (investment for a 5G network is too high).

- **<u>Stakeholders' engagement</u>:** Although challenging, there is a large interest from private investors that are building RES plants in Madeira and Azores. Stakeholder engagement is challenging mainly due to curtailments. Investors need to know in advance the maximum amount of curtailment they may face, namely the non-remunerated share.
- **<u>Exchange of experiences</u>:** While Madeira is ahead of Azores in certain electricity grid management aspects for integration of RES and security of supply, there seems to be limited exchange of experiences between the system operators of the two archipelagos. Transparency and exchange of lessons learned should be improved and more frequent.

In-person workshop - Italy

Towards high-RES penetration on the Italian small islands: what technical and legislative challenges?

26 January 2024, Sicily Region, Palermo

Agenda:

09:00 – 09:30	Welcome coffee and registration	
09:30 – 09:45	Institutional greetings	Regione Siciliana
09:45 – 10:00	Introduction and Agenda	*Secretariat, Politecnico di Torino*
10:00 – 11:25	**Panel #1 - Technical challenges towards RES penetration in non-interconnected islands** *Non-interconnected islands face particular challenges in trying to achieve high penetration of non-dispatchable renewable energy. These challenges require state-of-the-art solutions. The panellists will discuss the need to support the transition of island electricity grids, analysing the key role that storage technologies can play in the near future also in terms of contributing to the power system stability. Italian islands have the potential to overcome these challenges and emerge as pioneers, ready not only to ensure their own energy security, but also to lay the foundations for the decarbonisation of the entire continent. Embracing the complexities of grid integration, islands with high-RES penetration are becoming a catalyst for pioneering solutions, offering a model capable of reshaping the trajectory of sustainable energy development on a larger scale.*	Panellists and all participants

	Moderator: Enrico Giglio, *Politecnico di Torino* Panellists: • Carmelo Prestipino, *Support to the RUP for the implementation of the Green Islands National Recovery Plan, Lipari Municipality* • Daniele Groppi, *Università degli Studi della Tuscia* • Giuseppe Campagna, *Gruppo S.O.F.I.P.* • Gaetano Bonomo*, S.MED.E. Pantelleria* • Nicolas Henn, *Energy Pool* • Francesco Petracchini, *CNR-IIA* • Roberto Sannasardo, *Regione Siciliana* • Gianni Silvestrini, *Kyoto Club*	
11:25 – 11:40	**Coffee break**	
11:40 – 13:10	**Panel #2 – Regulation of services in non-interconnected islands and implementation of smart grid interventions** *The supply of electricity to end users in non-interconnected Italian islands is ensured through two different support mechanisms, depending on the DSO and the electricity producer operating in the specific territorial context. The speakers will introduce and discuss the regulation of services in non-interconnected islands, in terms of market participation and the provision of flexibility services, with a special focus on its recent developments and prospects. The extraordinary financing mechanisms foreseen for the implementation of storage systems through the National Recovery Plan "Green Islands" mechanism will then be presented, as well as their implementation plans in some of the islands. In conclusion, the speakers and the audience will discuss the administrative and management challenges for a wide diffusion of the technologies required for a complete transition to renewables on the non-interconnected Italian islands.* Moderator: Riccardo Novo, *Clean energy for EU islands Secretariat* Panellists: • Marco Pasquadibisceglie, *ARERA*	Panellists and all participants

	• Alessandro Bianco, *UNIEM* • Vera Zagami, *Società Elettrica Liparese* • Leonardo Padovano, *ENEL* • Francesco Amodeo*, MASE* • Giovanni Iacolino, *Lipari Municipality* • Salvatore Gambino, *Pantelleria Municipality* • Gaspare Inglese, *National Park Island of Pantelleria*	
13.10 – 13.50	**Panel #3 – The contribution of Renewable Energy Communities to the decarbonisation of islands** *Renewable Energy Communities (RECs) are establishing themselves in Italy and Europe as instruments to allow a further diffusion of distributed RES and, at the same time, ensure a high involvement of citizenship in the decarbonisation process, resulting in a better acceptability of interventions. The small islands, thanks to the great coordinating capacities of their communities and a particular attention to social innovation, can propose themselves as leaders in the creation of RECs that ensure a transversal and effective territorial governance, increase the RES production stock by ensuring high levels of self-consumption, and contribute to the fight against energy poverty. Starting from their experience on the islands and in the rest of Italy, the panellists will discuss the services and solutions that RECs can provide on Italy small islands.* Moderator: Claudio Moscoloni, *Politecnico di Torino* Panellists: • Eros Manzo, *CNR-IIA* • Sofia Mannelli*, Chimica Verde Bionet (Capraia)* • Sergio Olivero, *Energy Center del Politecnico di Torino*	Panellists and all participants
13.50 – 14.00	Conclusions from the three panels	Secretariat, Politecnico di Torino
14.00 – 15.00	Networking lunch	

Main points of discussion:

- **Technical aspects:**
  - **<u>Consumption variability and energy balance regulation</u>:** The high ratio between maximum peaks (summer) and minimum valleys (winter) of demand entails the need to have a dispatchable generation park with a delivery capacity well above the average power required by the grid, which is also oversized for redundancy and security of supply issues.
  - **<u>Reduction of system inertia and frequency control</u>:** The Società Elettrica Liparese (SEL) commissioned a study aimed at modelling the island's electricity system and how to ensure continuity of supply with high PV penetrations[222]. It was shown that the power plant synchronous generators and their rotating masses can guarantee frequency stability up to a maximum instantaneous PV generation of 50% of the total, above which power-intensive storage systems - centralised or distributed - are needed to limit frequency fluctuations and improve system stability. However, higher RES penetration also requires appropriate energy intensive, i.e. high energy/power ratio storage systems to ensure that variably available energy can be absorbed by the grid.
  - **<u>Storage systems</u>:** Several speakers shared the need to progressively introduce large quantities of storage systems, diversifying the technology portfolio in order to respond to instabilities on different time scales. While power-intensive technologies (e.g. lithium-ion batteries) are developed and - although characterised by considerable investment costs - are beginning to spread even on small islands, energy-intensive electrochemical storage technologies - necessary to achieve the highest RES levels in energy systems - are not accessible yet.
  - **<u>Electrical protections</u>:** The management of electrical protections in inverter-based systems, i.e. with limited rotating masses (e.g. large PV penetration), is challenging and requires the implementation of specific grid technologies, so that the short-circuit current can be identified by the protections.
- **Administrative and economic aspects:**
  - **<u>Compatibility of RES plants with the current regulatory framework and spatial energy planning</u>:** An obstacle mentioned by numerous speakers is the reduced compatibility of RES plants, which are necessary to achieve EU and national decarbonisation objectives, with the regulatory framework that currently exists on the Italian small islands. Without prejudice to the need to adequately protect all environmental components and ensure the preservation of biodiversity as well as the richness of the landscape of the small islands, the overlapping of the regional and national regulatory frameworks today allows little room for manoeuvre. As a matter of fact, wind turbines of any size are forbidden on most of the Sicilian islands, and there is limited possibility of installing ground-mounted PV. Therefore, the urgency of shared energy planning by all actors, first and foremost the regional administrations, was emphasised. This should lead to the identification of the areas on which to envisage the construction of RES plants, as well as the characteristics required for these technologies.

[222] https://ieeexplore.ieee.org/abstract/document/10389579/

- **<u>Economic sustainability of energy production and distribution and tariff regulation</u>:** Article 28 of Decree-Law No. 91 of 24 June 2014[223] calls for a revision of the regulation of integrated island electricity systems that should be based on efficient cost criteria and that stimulates energy efficiency as well as the economic and environmental sustainability of the service. This measure to revise tariff regulation has not yet been implemented to date. Unione Nazionale Imprese Elettriche Minori (UNIEM)[224] pointed out that the current system does not guarantee the economic sustainability of the production and distribution activities, nor particularly incentivises investments in favour of greater environmental sustainability. The representatives of the small electricity companies intervening in the discussion therefore requested the recognition of a specific legislative framework, and consequently a regulatory one, dedicated to small enterprises operating on islands, which would ensure legislative clarity and full economic sustainability.
- **<u>Coverage of the investments needed for decarbonisation</u>:** Some of the small electricity companies pointed out that the decarbonisation and conversion targets declared at different levels of government, and particularly those set at 2026 by Law no. 34 of 27 April 2022[225], are difficult to achieve through the current legal and regulatory framework. The investments needed to achieve a completely renewable energy mix and, especially, to make the electricity grids capable of hosting significant RES shares, also through the inclusion of storage systems, are in fact very high and not comparable with the costs encountered in the past. The availability of liquidity for such investments, which on the mainland are remunerated through the electricity market, is also an issue to be addressed with ad hoc solutions for islands.
- **<u>Regulation</u>:** The legal and regulatory frameworks that currently regulate the operation of non-interconnected networks is also linked to the fact that Italy has never requested, for its small insular systems, exemptions from Directive (EU) 2019/944[226], and in particular Articles 4, 5, 6, 7 and 8 as well as Chapters IV, V and VI. This possibility is given to the Member States in article 44 of the directive itself and has already been requested by other countries (including Portugal, Greece, Cyprus, Malta, France, also for islands of a size and final electricity demand greater than those of the Italian small islands). Its request has been envisaged by the Italian Government in article 8 of the Ministerial Decree of 14 February 2017[227], in order to allow the management of the electricity service by vertically integrated companies, under a regime of complete regulation of the service, also for the production and sale phases. According to UNIEM, this failure to request an exemption leads to difficulties in the standardisation of the small non-interconnected islands power systems in relation to dispatching, as well as calls into question the tariff integration mechanism and the vertical integration of the small electricity companies that manage the service.

[223] https://www.gazzettaufficiale.it/eli/id/2014/06/24/14G00105/sg
[224] The association of small electricity companies operating as DSOs and main electricity producers on eleven of the small non interconnected Italian islands
[225] https://www.gazzettaufficiale.it/eli/id/2022/04/28/22G00048/sg
[226] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019L0944
[227] https://www.gazzettaufficiale.it/eli/id/2017/05/18/17A03304/sg

In-person workshop - Greece

Challenges along the way for the decarbonization of the Greek islands

Friday 15 March, Event hall of RAEWW, Athens

Agenda:

15.00 – 15.10	Welcome – Salutations • Athanasios Dagoumas, President, Waste Energy and Water Regulatory Authority • Aristotelis Aivaliotis, Secretary General of Energy and Mineral Resource	Authorities
	Session A: Island decarbonisation initiatives	
15.10 – 15.20	Introduction: European initiative "Clean energy for EU islands" • Kostas Komninos, Director General, DAFNI	Secretariat
15.20 – 16.00	The development of the electrical systems of the Greek islands Presentations / Interventions • Tenders for storage units and hybrid stations on the islands – Dimitris Fourlaris, Vice President of the Energy Department, RAEWW • Modernization of electrical systems in non-interconnected islands - Theodora Patsaka / Kon/nos Kostoulas, Director of Island Regions Management, HEDNO • New interconnections of the Greek islands – Michalis Hatzipanos, Director of New Power Transmission Projects, IPTO • The next day of thermal plants in non-interconnected islands – Alexios Paizis, Deputy CEO of Production Operations, PPC	Speakers
16.00 – 16.30	Is the carbonization of the Greek islands an opportunity for Greece and Europe? Panel discussion	Panellists

	Participants: Aristotelis Aivaliotis, Athanasios Dagoumas, Panagiotis Papastamatiou, Stavros Papathanasiou	
16.30 – 16.45	Coffee break	
	Session B: Challenges in transforming island electricity systems	
16.45 – 17.00	Introduction: Presentation of the results of the CE4EUI study on the Challenges of Operation and Management Of Non-interconnected electrical systems of European islands • inPetros Markopoulos, Head of the Clean Energy and Sustainable Transport Department, DAFNI	Secretariat
17.00 – 17.50	Discussion on the challenges of implementing decarbonization projects of island electrical systems • Challenge 1: Curtailments of RES projects and management practices to ensure system stability • Challenge 2: Design, development and operation of hybrid power plants and storage units • Challenge 3: Island interconnections and formation of new project penetration conditions Participating: PPCR, AKUO, EUNICE, TERNA, VOLTALIA, SIEMENS GAMESA, EGP, PROTASIS, SIEMENS, MAS	Participants
17.50 – 18.00	Conclusions and closure of the event	

Main points of discussion:

- **Interconnections**:
  - Despite technical difficulties and problems in the logistic chains, the interconnections of the islands are set to be completed according to the timeline set. The Dodecanese islands and Northeast Aegean islands are the last to be interconnected in 2027 and 2028 respectively. Concerning Crete, the first interconnection with the mainland electricity grid has already had positive impact providing stability to the grid of the island; a second DC interconnection of Crete with Attica is set to be completed in 2025.

- The local community of the islands, that have been interconnected so far in Cyclades, can see the advantages of the interconnection and are providing really good feedback, despite initial concerns mainly related to potential environmental and aesthetical impacts.
- Once an interconnection with the mainland is completed, it is important to further upgrade the local distribution grid so as to enhance the system stability in terms of voltage and frequency and reduce congestion and outage incidents.
- The interconnection of the islands with the mainland system is still considered the most feasible way for the decarbonization of most of the non-interconnected islands with the exemption of very small and remote small islands.

- **Transitioning from thermal power plants to decarbonization:**
  - The slow progress of islands decarbonization has resulted in the gradual downgrade of the thermal power stations. Thermal power stations should be treated as part of the energy transition and are still fundamental in facing crises due to emergencies. Thermal power stations will stay on the islands as cold reserves and should be used efficiently, in parallel with the renewable energy stations, to ensure grid security and supply.
  - Hybrid power stations, i.e. RES plants combined with energy storage, are already mature and tested technological solutions with the essential regulatory framework in place. New relevant RES installations should be coupled with storage facilities.
  - New energy control centres are installed by HEDNO in all the non-interconnected islands enabling the distant monitoring and dispatching of all, thermal and renewable, power plants of the electricity systems, ensuring their efficient and secure operation.
- **Curtailment, storage, and hybrid stations:**
  - Curtailment of wind energy production is a key issue for wind park owners in non-interconnected island systems (especially for the Rhodes-Chalki system). It was reported that the installation of the new thermal power plant in Rhodes island resulted in the reduction of wind energy curtailment levels. Also, the increased licencing and installation of PV stations, supplying electricity to the system with no limitation, increase curtailments to other technologies whose production can be regulated by HEDNO. Hybrid power and stand-alone storage stations but also small-scale behind the meter storage coupled with RES installations, can contribute substantially to curtailment reduction. The energy control centres installed by HEDNO can also contribute to the reduction of curtailments. However, it has been broadly discussed that curtailments will be fully confronted only after the full interconnection of the island electricity systems.
  - The issuing of a ministerial decision remains to allow the launch of hybrid power stations tendering in the non-interconnected islands. Also, the lack of regulatory framework for storage stations not coupled with RES plants poses difficulties on the implementation of new storage projects.
  - In the case of wind farms repowering, the licenced capacity may be lower than the nominal of the commercially available wind turbines resulting to power curtailment of the new wind turbines. This difference comes from the fact that the RES installation margins do not necessarily match with the existing nominal WT capacities leading to installed capacities sometimes significantly higher than the respective licenced capacity. In such cases, it is recommended that those wind farms could occasionally be permitted

to produce excess power through increased set-points. This will however pose a challenge for the remuneration of this additional energy batch while also contradicting with the non-interconnected islands grid code.

- **Exploration of different technologies and information of the local community:**
  - Local communities should be better informed about the impact of technologies such as wind and geothermal plants.
  - Geothermal energy and biomass / biogas are some of the alternatives to hybrid power stations to provide constant power after the interconnection.
  - Green hydrogen production as an energy storage solution could be feasible for large non-interconnected island electricity systems with high curtailments.
  - Demand-side management is a prerequisite to potentially reach a cost-efficient full decarbonisation of all the islands.
  - A holistic approach with the incorporation of the adequate system integration is recommended when planning for the full decarbonisation of the islands.

In-person workshop – France

Facilitating the energy transition in the French Overseas: technical and legislative challenges

20 March 2024, Te Moana, Tahiti (French Polynesia)

Agenda:

08.00 – 08.15	Welcome and start of the day	Secretariat
08.15 – 09.00	Presentation by Pierre Boscq, Direction Polynésienne de l'Energie - Energy issues and main challenges in French Polynesia	Direction Polynésienne de l'Energie
09.00 – 09.45	Presentation by Yann Wolff, EdT Engie - Networks and support measures for small islands: network evolution in Tahiti, challenges and necessary next steps.	EdT Engie
09.45 – 10.15	Coffee break	
10.15 – 11.00	Presentation by Romain Gitton-Rivière - Enabling greater penetration of renewables in island energy systems: best practices.	Secretariat

11.00 – 12.30	Round-table discussion with representatives of the Polynesian Ministry of Energy, distribution, and Transmission System Operators, participating OCTs and the workshop team - Enabling greater penetration of renewable energies in island energy systems: feedback from participating OCTs.	Panellists
12.30 – 13.30	Networking lunch	

Main points of discussion:

- **<u>Uncontrolled distributed solar PV development</u>**: Polynesia has around 50 MW_p of installed solar PV capacity. In Tahiti, solar PV is currently mainly decentralised and will continue to be so, since small roofs represent a large volume of future development. There is no certainty about the numbers, since most solar PV panels for self-consumption are installed without the required approval from the municipalities. The Polynesian Direction for Energy (DPE) at the moment has no sworn officer allowed to carry out checks and issue fines. There are plans to rectify this when a permanent official at the DPE will be in place and available for this purpose.
- **<u>Variable solar PV production:</u>** In Tahiti, solar PV is currently mainly decentralised and will continue to be so, since small roofs represent a large volume of future development. Installations are concentrated in a single 2 km^2 area in the Punaruu valley, making production particularly volatile because of shading from clouds. What's more, in the Tahitian valleys, thunderstorm cells form very quickly, which in addition to suddenly reducing solar output, can create a one- or two-minute production peak when rain hits panels that are still warm, thus increasing their output.
- **<u>Making room for solar PV</u>**: A particular example of the solar energy management arises in the case of concomitant production of hydro and solar PV. A significant share of the solar installations under 100 kW_p cannot be curtailed, so hydro production is curtailed. In some cases, this might mean letting a full hydro dam overflow. A future solution would be to increase solar curtailment possibility and/or to install batteries able to make use of both solar and hydro in such a case. The latest Tahitian solar tender specifies that curtailment can be decided by the grid operator up to 110 hours per year without compensation, paving the way for future adapted solar curtailment.
- **<u>Management of hydroelectric dams:</u>** In Tahiti, hydroelectric installations have historically been required to supply a certain amount of power during the day, in accordance with the Modulated Guaranteed Hydraulic Power policy. This daytime power obligation competes with solar production and should therefore be abolished. This will enable hydropower to smooth out solar production during the day and produce at night, thus reducing the load on thermal generators.

The Clean energy for EU islands secretariat is managed by the European Commission Directorate-General for Energy

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