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ELECTRICITY FOR EUROPE

Towards the Energy Transition on Europe's Islands

A EURELECTRIC Report

February 2017

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Our structure of expertise ensures that input to our policy positions, statements and in-depth reports comes from several hundred active experts working for power generators, supply companies and distribution system operators.

We have a permanent Secretariat based in Brussels that is responsible for the overall organisation and coordination of EURELECTRIC's activities.

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▶ COMMITMENT, INNOVATION, PRO-ACTIVENESS

SOCIAL RESPONSIBILITY
▶ TRANSPARENCY, ETHICS, ACCOUNTABILITY

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Key Messages

1 Despite sharing some common aspects with mainland energy systems, the unique features of islands require energy supply solutions to be tailored to the particular needs of the energy system on each specific island. This holds true for the adoption of clean energy solutions that would accommodate the needs of island communities and their economies.

Ensuring secure and balanced supply of electricity on islands is significantly more burdensome and expensive than on the mainland. More analysis on the associated challenges and potential solutions to island communities is critically important to find cost-effective, proportionate, practical and efficient ways to ensure the sustainable and affordable supply of electricity on islands. The European Commission has a crucial role to play in this process.

2 European energy and climate policy should cater for the specificities of island. It should ensure that local energy communities are enabled to engage in the transition process, thus promoting local participation and stakeholder engagement. Proportionate exemptions from certain regulatory obligations that apply to mainland energy systems should be implemented as a one-size-fits-all approach does not deliver effective solutions.

3 Tailored solutions would have to be identified in a legitimate context. This is why a European framework for islands (including Energy Community signatories' islands[1]) is needed. Such a framework would offer the base for structured and informed discussions on successful solutions, best practices and coordinated planning.

Initiatives such as the Association of the Overseas Countries and Territories of the European Union (OCTA) and the outermost regions (OMR) EU islands could provide important lessons on how to design a similar initiative covering all European islands and targeting their transition to low carbon economies.

In Annex II ("Action to boost the clean energy transition") of the Commission Communication on Clean Energy for All Europeans, (30 November 2016) the Commission refers to the launch of a process to support islands in their clean energy transition. We believe that this process should lead to the development of such a European framework for islands.

1 Energy Community: https://www.energy-community.org/portal/page/portal/ENC_HOME

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A logical next step would be to improve the bankability and economic viability of islands' energy projects through an appropriate legal framework (similar to the Regional Seas Conventions and the Alpine Convention), to ensure legal and regulatory stability for financial and technical cooperation.

Designing innovative cooperation mechanisms and financing instruments should be part of this process. Examples include project aggregation to ensure economies of scale and cost reduction, regional system peer-management, benchmarking energy costs based on island specificities, and securing ad hoc access to essential technical and regulatory expertise.

While the Connecting Europe Facility or the Projects of Common Interest address connectivity issues in Europe's electricity network, similar funding facilities, potentially under the structure of the European Fund for Strategic Investments 2.0, would need to be designed for efficient isolated energy systems, micro-grids and smart-grids on islands.

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Increased knowledge of the specific challenges and opportunities of islands can lead to the drafting of blueprints on options for islands' energy systems development. These blueprints could be then adapted in cooperation with local and national authorities to develop roadmaps specific to each particular island maximising the use of indigenous resources. The implementation of such roadmaps could be supported by specific programmes to train skilled young people to work in the energy sectors of their native islands and contribute to the growth of their economies. The TILOS Horizon 2020 Project presented in this report shows one approach to the transfer of technological experience through an islands skills and information exchange platform.

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Infrastructure to support the further deployment of Electric Vehicles (EVs), considering the possible impacts on the network, could be developed on specific islands. Similar initiatives may serve as a demonstration and test-bed for pilot projects on micro-grids, decentralised systems and the deployment of e-mobility solutions in the EU, in remote communities or isolated energy systems.

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Island energy managers will benefit from support to raise awareness amongst their local island population of the different and challenging situation faced by the operators of island electricity energy systems. This would further help advance the goal of training and retention of on-island staff charged with maintaining energy systems.

1. European islands' energy systems today

Europe's islands face considerable challenges in meeting their energy needs in a sustainable, affordable and reliable way. Island energy systems, despite their diversity, share common characteristics and are subject to common challenges. Their sustainable energy future depends on an improved investment climate and policy framework. Islands themselves are highly motivated to contribute to the energy transition, but this must be supported by innovative polices that are proportionate and realistic and cater for their needs. They must reflect the fact that islands' energy needs often differ significantly from those on the mainland.

> *"Europe's islands face considerable challenges in meeting their energy needs in a sustainable, affordable and reliable way. Island energy systems, despite their diversity, share common characteristics and are subject to common challenges."*

In this report, EURELECTRIC builds on its June 2012 report "EU Islands: Towards a Sustainable Energy Future" and highlights the energy situation of European islands. It also shows a number of important opportunities and challenges that lay before them in terms of setting up a stable, cost-efficient and low-carbon energy supply system, thus contributing to the development of the EU's Energy Union objectives. The focus of this report is to show practical solutions that shed light on how challenges can be resolved. Several success stories on low carbon electricity projects across different European islands are included to show how islands decarbonise their power systems in practice.

Particular features of islands

Throughout the report the term "island" implies the definition used by Eurostat. In this context, islands are defined as territories having:

- A minimum surface of 1 km²;
- A minimum distance between the island and the mainland of 1 km;
- A resident population of more than 50 inhabitants;
- No fixed link (bridge, tunnel, dyke) between the island and the mainland.

Many islands exist in relative isolation, with no or limited interconnection to the mainland or to other islands, and this results in more difficult and expensive energy supply. Due to the relatively small size of their markets, investments in energy related infrastructure are economically less attractive than they might be on the mainland, as often those projects cannot benefit from economies of scale. Proposals in the recently published Commission Communication on Accelerating Clean Energy Innovation[2] to offer project aggregating platforms (thus ensuring access to EU financing and funding to small-scale projects) can provide potential solutions that may be extended or tailored to match the needs of islands.

A formal recognition of the specific characteristics and conditions experienced by islands, which impose numerous challenges to island communities and their fragile economies, is needed. Islands face very different challenges to similarly small communities on the mainland and a one-size-fits-all approach does not work. A recent resolution by the European Parliament[3] acknowledges this in a more general context and draws attention to the various challenges that islands face.

[2] Communication on Accelerating Clean Energy Innovation, COM(2016) 763 final, 30 November 2016: http://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v6_0.pdf

[3] EU islands: call for action to overcome permanent handicaps: http://www.europarl.europa.eu/pdfs/news/expert/infopress/20160129IPR11941/20160129IPR11941_en.pdf

Acknowledging the special needs of islands is also in the interest of the entire European economy. In view of islands' isolated nature, new technologies, procedures and services are often easier to install, test and implement. Islands can therefore serve as a test-bed for innovative energy solutions, micro-grids, smart-grids and other technologies that aim to further electricity system decentralisation. Furthermore, islands are often host to a unique part of European cultural heritage and history, which needs to be carefully protected and supported.

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Islands, particularly small islands, are economically vulnerable than mainland communities. Many employment options (e.g. heavy industry) are automatically excluded and entry barriers for newer light industries are often prohibitive due to the lack of economies of scale. Many island communities therefore rely on traditional tourism or agriculture for employment, which often has a strong seasonal focus and a "low" pay culture. As a result, unemployment figures are usually higher on islands. This results in island communities struggling to offer an attractive future perspective for the younger generations[4].

Tourism with a seasonal focus has an additional implication for islands' energy systems: a relatively large generation capacity needs to be installed in order to accommodate the energy needs of the increased number of customers during high season. This capacity then remains largely idle during low season. Furthermore, the chosen generation option must blend harmoniously with the atmosphere and landscape of the island in order not to hamper tourists' experience.

Environmental and landscape protection plays a central role on many islands, as apart from tourism, the major industries are mostly fisheries and agriculture, which are highly dependent on the continuity of local environmental conditions. Any depletion of the natural resources will immediately threaten these sectors. Therefore, any solution for a smarter and more sustainable power system needs to take into account the effects it may have on the environment and landscape.

[4] Islands of the EU: Taking account of their specific needs in EU policy, Jan. 2016 http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/573960/EPRS_BRI(2016)573960_EN.pdf

2. Energy on islands – Key Challenges

Islands are exposed to general economic challenges that are largely due to their relatively small size and isolated location, but there are also some specifically energy-related challenges that many islands face. While the situation of “energy islands” is addressed, albeit briefly, in policy documents and proposals aimed at developing the Energy Union, the special situation of physical islands as so far been broadly ignored. This is a serious problem since islands will also go through the energy transition.

ELECTRICITY CAN BE **DECARBONISED** RELATIVELY EASILY COMPARED TO OTHER FORMS OF ENERGY AND THUS **ELECTRIFICATION** WILL PLAY A **KEY ROLE** IN THE **DECARBONISATION OF ISLAND ECONOMIES**.

In this report EURELECTRIC aims to focus on the role of electricity in the energy transition of islands, while bearing in mind two important factors:

- Electricity can be decarbonised relatively easily compared to other forms of energy and thus electrification will play a key role in the decarbonisation of island economies.
- The specific conditions of islands (small market and isolated location) imply much greater constraints for electricity generation. This is because the intake and outtake of electricity from a system has to be balanced at all times and, as yet, flexible storage facilities for large amounts of electricity are still in the development stage.

THE SPECIFIC CONDITIONS OF **ISLANDS** (SMALL MARKET AND ISOLATED LOCATION) IMPLY MUCH **GREATER CONSTRAINTS FOR ELECTRICITY GENERATION**. THIS IS BECAUSE THE INTAKE AND OUTTAKE OF ELECTRICITY FROM A SYSTEM HAS TO BE **BALANCED AT ALL TIMES** AND, AS YET, **FLEXIBLE STORAGE** FACILITIES FOR LARGE AMOUNTS OF ELECTRICITY ARE STILL IN THE **DEVELOPMENT STAGE**.

MAJOR CHALLENGES THAT ISLANDS HAVE TO ADDRESS IN THE ENERGY TRANSITION

1. Many islands suffer economically from their dependency on fuel imports. Again, the lack of economies of scale makes the import of these fuels more expensive for islands than for the mainland. The need for frequent supply of relatively small amounts of fuel, leads to higher transport costs per energy unit contained in the fuel that islands have to pay in comparison to the mainland. As the costs of construction of large storage facilities are often prohibitive, islands are more vulnerable to global oil price fluctuations than the mainland, as they cannot rely on full stocks and expected price decreases.

2. Power production on islands faces a similar problem. Due to their small size, islands lack economies of scale in financing and power production. As a result, 1 MWh produced on islands is on average more costly than 1 MWh produced on the mainland, because the benefits of large-scale interconnected production cannot be realised.

3. Islands also face operational constraints originating from the isolated nature of their power systems. If an island is not equipped with interconnectors, all balancing and flexibility has to be procured on the island itself. This could mean that peaking plants have to be built on the island, even though they might have very few running hours which can be used to recover their fixed costs. This is why integration of intermittent renewable electricity is more costly on islands than on the mainland. The mainland can profit from large balancing regions, where geographically distributed intermittent renewable electricity generation can be balanced with relatively less flexible generation capacity.

4. Replacing the currently predominant diesel engines on islands with less carbon emitting, non-intermittent traditional technology like natural gas or LNG is often not possible, since the costs of building a pipeline of a re-gasification plant and storage are prohibitive. As a result, most islands do not enjoy many options for diversifying their energy supply and a vast majority still rely on oil-fired diesel engine generation for their electricity, operated with a significant plant margin to ensure reliability.

5. As this situation prevails, the decarbonisation of islands' power systems becomes even more urgent. Increasingly strict fuel quality requirements, as well as stringent maximum values for NOX and SOX particles contained in flue gas imposed by European legislation, will require islands to take action to improve air quality through reduced exhaust gas emissions. These requirements make power production from diesel engines on islands even more expensive, since they increase the operating cost of diesel power plants. This might be intended in order to provide an additional push factor to shift from diesel generation in favour of technologies with a lower carbon emission factor.
However, the effectiveness of technologies such as selective catalytic reduction and flue gas desulphurisation (which are installed to reduce emissions of NOX and SOX) hinges to a large extent on the stable (base load) operation of the respective diesel engine. This stands contrary to the needs of a power system accommodating a big share of electricity from renewable sources and managing to meet a variable daily load curve, which needs dispatchable plants that quickly ramp up and down.

6. Islands therefore face additional challenges in order to decarbonise their energy systems. While they are committed to overcome such challenges, policymakers and regulators should acknowledge that islands might require a regulatory framework that recognises their specific situation and can be adapted to their needs, as well as additional support in order to achieve such goals.

7. While all these aspects make the energy supply of islands more challenging, there are some positive sides that should also be mentioned. Due to their isolated and small integrated power systems, islands have the potential to become ideal locations where innovative energy solutions can be demonstrated and tested. New technologies, like smart grids or electric transport and related infrastructure, can be tested quickly and efficiently on islands.

3. Toolkit to address challenges

There are various approaches to address the challenges faced by islands' energy systems. Solutions vary greatly from the potential for indigenous energy sources available on islands to the proximity of islands to the mainland and hence the potential to access mainland energy grids. This section briefly outlines some of these solutions and their limitations.

The geographical conditions for electricity generation from certain forms of renewables can be very favourable on some islands, as some of them have more stable weather conditions than the mainland. For example, in the case of islands situated in Southern Europe (such as the Mediterranean area, which accounts for 85% of the European population that lives on islands), photovoltaic (PV) solar energy is a viable alternative to produce electricity.

Similarly to the mainland, energy storage is an important issue that affects the choice of islands in moving forward with the integration of renewables into their power system. Here again, the generally small size of islands works to their advantage: relatively small storage facilities can play a central support role for islands' energy systems and can help ease concerns related to security of supply. Batteries are appropriate for short-term peak shaving and load levelling, and they might play an even more critical role in the future as the technology evolves.

Some islands might also have the necessary geological conditions to use pumped hydro, which can contribute to control network frequency and provide reserve generation. Even very small islands with no means to build two reservoirs could use pumped storage, if a favourable business case (cost justification) allows them to use the ocean as the lower reservoir. In such cases, seawater is pumped and released. This requires specific attention in dealing with salt water and the protection of marine life.

Another option to increase security of supply and integrate renewables into islands' power system is to build interconnections between islands, or between an island and the mainland, where possible. Through interconnections, the market size increases and balancing becomes easier. However, interconnections constitute significant expense, and should only be installed after a positive cost-benefit analysis.

> *“Islands can and will contribute to the EU's energy and climate targets and to the development of the Energy Union project. However they require different pathways to get there.”*

Interconnections can help reduce the power generation margin, the overcapacity islands have to install in order to ensure security of supply. Storage facilities on islands can be a solution to balance frequency in operation. In the absence of both, high generation margins may be needed to ensure system adequacy at any time, which puts additional costs onto the islands' power systems.

It can be concluded, that islands can and will contribute to the EU's energy and climate targets and to the development of the Energy Union project. However they require different pathways to get there. Islands should be enabled to benefit from innovation schemes and funds adapted to their particular needs. These funds should aim to stimulate innovative approaches to unlock potential for the development of local smart energy systems on islands but also help retain talent that would be able to sustain these systems in the future. The main focus should be on overcoming barriers related to grid capacity, energy storage and active network management, demand response and distributed generation, delivering sustainable, reliable and affordable electricity to island electricity consumers.

4. Islands are part of the solution
Best Practices

Some islands have already taken the initiative to shift towards safe, sustainable and low carbon energy supply. This chapter focuses on successful examples of integrating energy solutions to electricity systems across Europe's Islands.

The information contained in these case studies has been provided by EURELECTRIC's members.

Project STORE[5], Canary Islands

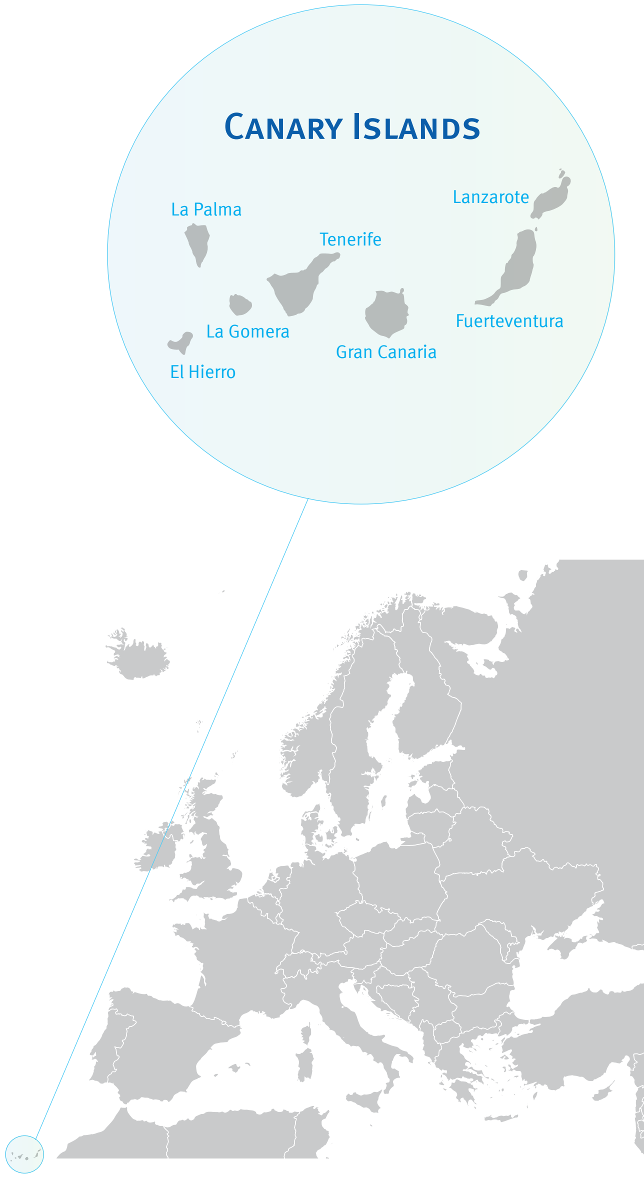
The Canary Islands are a Spanish archipelago located just off the southern coast of Morocco. The main islands are (from largest to smallest): Tenerife, Fuerteventura, Gran Canaria, Lanzarote, La Palma, La Gomera and El Hierro. The archipelago covers a total area of 7,446.95 km² with a population of 2,128,647.

The Canary Islands are home to Project STORE, a European energy storage project in island areas that is composed of three different technologies:

- Electrochemical storage by Li-ion batteries, 1 MW/3 MWh, in Gran Canaria, testing the real capacity to provide services such as a unit of conventional generation, allowing the management of demand, providing inertia and active power, regulating voltage, and participating in secondary regulation.
- Flywheel, 0.5 MW/18 MWs, in La Gomera, providing inertia and active power upward or downward for primary regulation, continuously improving the frequency stabilisation of the island.
- Ultra-capacitors, 4 MW/20 MWs, in La Palma, improving response in primary regulation and stability in the system frequency by constant vigilance but timely action to shocks, giving the insular electrical system more stability and quality of supply.

The main objective of the project is to demonstrate the technical and economic feasibility of large-scale energy storage systems to provide ancillary generation services; boosting quality, efficiency and supply security and facilitating the integration of new energy sources that cannot be managed, as well as distributed generation.

Project STORE also offers greater knowledge on the grid integration of the technologies being studied in a real-world setting and under the operating conditions inherent to isolated electricity systems.



[5] http://www.store-project.eu/

Gorona del Viento[6], El Hierro

El Hierro is the smallest of the major islands of Canary Islands covering 268.71 km^2 with 10,753 inhabitants.

Gorona del Viento is a wind-pumped hydropower plant situated on El Hierro Island that has been operating since June 2014 and is composed of:

- Wind farm 11.3 MW
- Pumping hydro-electrical plant (11 MW turbines power and 6 MW pumping station)

The hydro-wind power system transforms an intermittent source of energy into a controlled and constant electricity supply thereby maximising the use of wind energy, and facilitating its integration into the system.

The project aims to cover the electricity demand of this island, making El Hierro a 100% renewable system in terms of electricity. Furthermore, it increases the use of renewable energy by implementing an innovative, efficient and sustainable energy model with social and environmental benefits such as: reducing fossil fuel dependence, reducing CO_2 emissions and enhancing air quality.

Gorona del Viento is an experimental project with investment from public and private partners. Subsidies from the Spanish General Budget were committed, up to an amount of €35 million, to guarantee the viability of the project.

Planned Project, La Graciosa

La Graciosa is a volcanic island in the Canary Islands, covering a total area of 29.05 km^2 and with roughly 700 inhabitants. The LA GRACIOSA Project[7] will be developed during the period 2016-2018 with the following objectives:

- Control of distributed generation, transforming the network into a smart grid.
- Developing an innovative hybrid system of multiservice storage to compensate energy flows and provide dynamic response.
- Managing aggregate demand developing autonomous control systems and systems of interaction with the user/client.

The objective is to develop a clean energy supply solution aimed at making the island self-sustainable in terms of energy, in a feasible and efficient way. The project has benefited from Spanish and European funding.

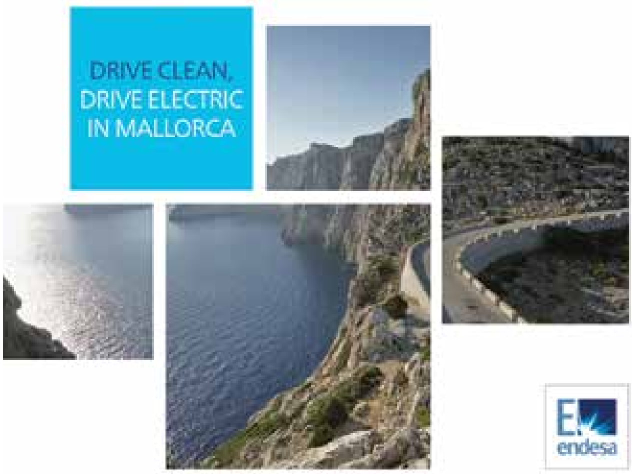
[6] http://www.goronadelviento.es/
[7] https://www.endesa.com/en/projects/a201701-la-graciosa-the-intelligent-energy-island.html

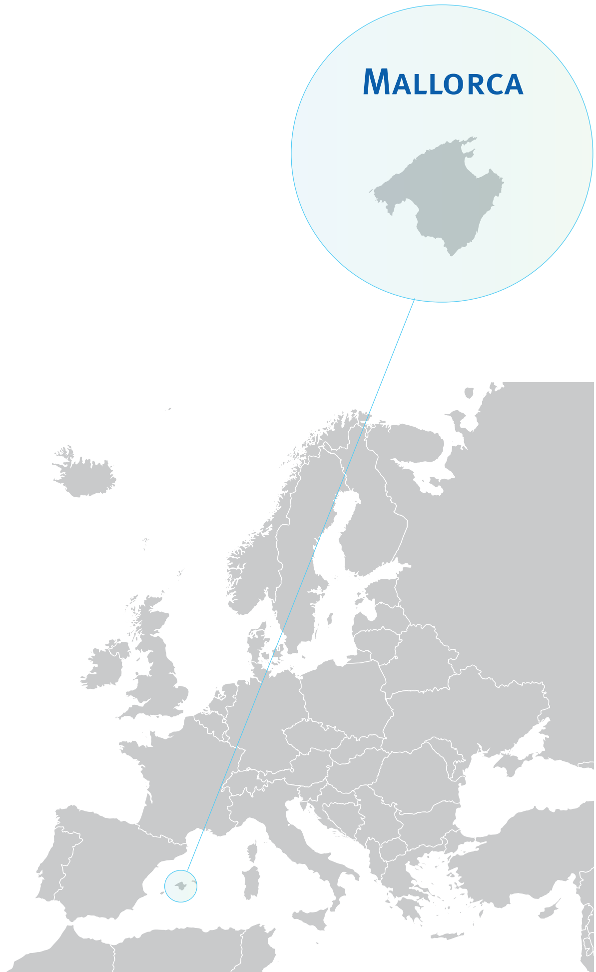
ecaR Project, Mallorca

Endesa club de auto-Recarga

The Spanish island of Mallorca in the Balearic Islands archipelago is home to a project by Spanish company Endesa. The project comprised the deployment of the first electric charging network for electric vehicles with six fast strategically placed charging points.

Taking advantage of this charging infrastructure, the “ecaR Project” was created, the first Fast Self-Charging Club, which enables the entire island of Mallorca to be driven by electric vehicle. This project also uses a smartphone application which allows users to find these charging points and useful related information (nearest location points, reservations, finding the best route to reach them and calculating travelling time). The application is designed to cater for individual customers with their own e-vehicles, as well as fleets or customers who hire e-vehicles to visit the island. This is a European funded project.

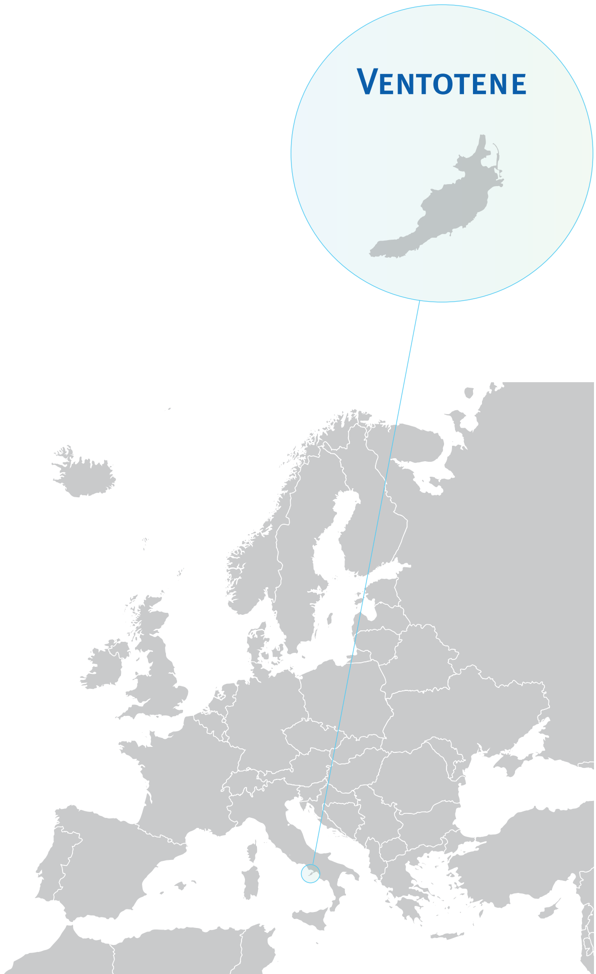




Storage solutions, Ventotene

The Mediterranean Italian island of Ventotene has an area of 1.55 km² and is located about 100 km south of Rome, in the Tyrrhenian Sea. The island is not connected to the Italian national power supply grid and is currently powered by four diesel generators of 480kVA each. These struggle to cope with seasonal swings in power demand caused by the annual influx of tourists, as well as the growing popularity of rooftop solar panels. Enel is the utility responsible for operating the conventional diesel generation plant and the distribution network.

In 2015 Enel installed a storage system project of 300kW/600kWh, based on lithium-ion batteries, which enables integration of solar power generation into the island. The project's main goal is to enhance the flexibility of the grid operation and optimise use of power from existing diesel engines, thereby increasing the island's sustainability. The battery system, in operation since the end of 2015, is integrated in the power station and allows 15% fuel consumption reduction, 15% annual CO_2 emissions reduction and enables an increase in distributed renewable hosting capacity, while ensuring a stable and effective energy supply to Ventotene inhabitants. The investment benefited from financial support from the EIB.



The key innovation in this project lies in an advanced control system integrating battery and diesel operation, developed by Enel. This ensures that the diesel generators in particular can be used in a more efficient operating mode because short-term peak loads are covered by power from the storage system and not from the generators. During off-peak periods, it is even possible to switch off the diesel generators completely. This saves fuel, extends the service life, minimises maintenance, and reduces the stock of fuel reserves. The result is lower CO_2 emissions and significantly reduced consumption of diesel fuel, which has to be transported to the island from the mainland. In addition, this will prepare the network for future applications, such as charging stations that can charge electrically powered transport vehicles. In early 2016 the battery supplied the full island load alone for 39% of the operating hours, in certain periods.

The project represents a best practice in the way the storage system is coupled to diesel generators. A true hybrid system is in fact realised whereby storage fast dynamics are used to enable diesel even operation at almost full loads for most of the time, while grid dynamics are addressed by the batteries. This operation required the development of a specific hybrid control system with two functions: a) guarantee that grid dynamics are properly managed; b) schedule optimal operation of the storage system and of the diesel engines to minimise fuel consumption.

Green+ and SmartPV, Cyprus

Cyprus is an independent island state, a full Member State of the EU, with a population of 1.1 million and a total area of 9,250 km^2, located in the Eastern Mediterranean Sea. The Electricity Authority of Cyprus (EAC) develops, maintains and operates an electrically isolated system in view of the lack of interconnections with any of the surrounding countries. The electrical system of Cyprus comprises a total of three power stations with a total installed capacity of 1477.5 MW. There are 559,640 customers who annually consume 4,500GWh of energy. The RES penetration in the country is approximately 8.5%.

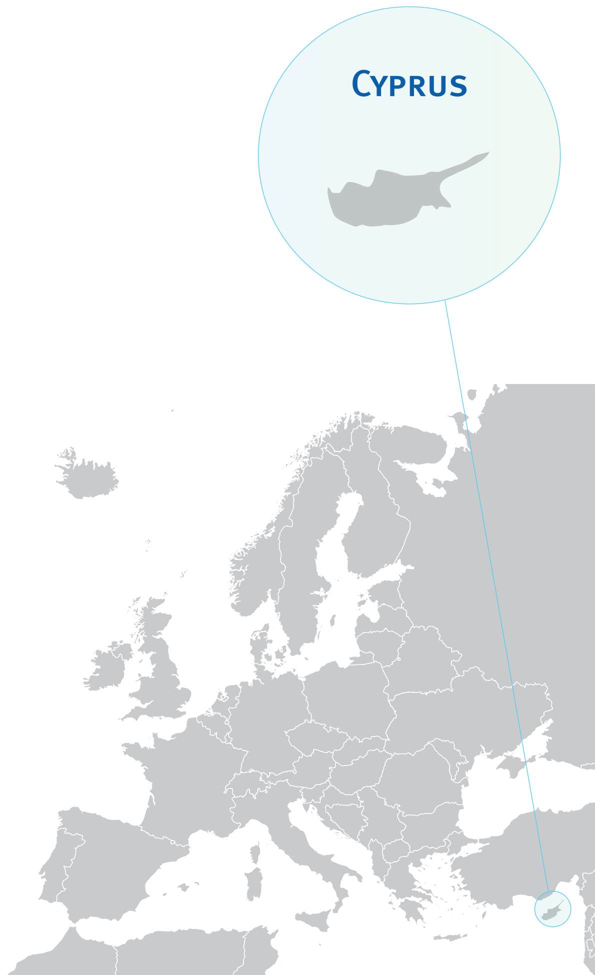
The EAC is the sole energy supplier on Cyprus, the Distribution System Operator (DSO) and the Distribution and Transmission System Owner. The Distribution Network consists of 15,600 km of Overhead MV and LV lines and 9,600 km of Underground MV and LV Cables. Many Renewable Energy Sources (RES) installations are connected to the Distribution Network in Cyprus. There are also three wind farms with an installed capacity of 24 MW, 14 biomass installations of 9.7 MW in total, self-generation, commercial and residential installations up to 20 MW and large scale PV installations of 11 MW.

Utilising the various schemes for RES that were issued by the Cyprus Energy Regulatory Authority (CERA) and the Ministry of Energy (MoEICT), EAC and DSO (EAC) managed to connect, control and operate a total of 10,179 private and independent Distributed Generation points.

To assist further development and maximise RES penetration, the EAC is participating in the research and development programs “Green+” and “SmartPV”.

The project “Green+, Zero Energy Mountains of Cyprus”, has been developed through the 2nd Phase of NER300 Program and had maximum financing of €11.1 million. The main goal of the project is to manage and optimise RES distributed generation in rural areas of PVs installed on low voltage network (20 MW) and medium voltage network (50 MW).

The project “SmartPV[8], smart net metering for promotion and cost-efficient grid-integration of PV technology in Cyprus”, is being co-financed by the European Commission and LIFE+ Environment Policy and Governance, has a total budget of €1,219,838 and is scheduled for completion in April 2017. The main objective of the project is the improvement of the net metering scheme to achieve the maximum possible RES penetration.



[8] http://www.smartpvproject.eu/

E-Mobility, Cyprus

The e-charge is an electric vehicle charging service offered by the Electricity Authority of Cyprus (EAC) all over Cyprus to electric vehicles (EVs) owners, who have access to EAC owned charging infrastructure in public areas. This service was initiated and funded by EAC as a pilot project, in order to investigate the impact of EV-charging on the distribution system and to promote e-mobility on the island. This initial infrastructure consists of 16 charging stations installed at publicly available locations all over the island.

The semi-fast charging stations installed comply with IEC Standards, (Mode 3 charging and Type 2 plug) and are able to charge an electric vehicle up to 21kW (3-Ph). At each charging point there are two charging plugs that can serve two vehicles simultaneously.

Faroe Islands

The Faroe Islands are an archipelago located in the north Atlantic sea, between Scotland and Iceland, consisting of 18 small islands, 17 of which are populated. The islands are an autonomous self-governing country within the Kingdom of Denmark. They cover a total area of approximately 1,400 km^2 with a population slightly greater than 49,000 inhabitants.

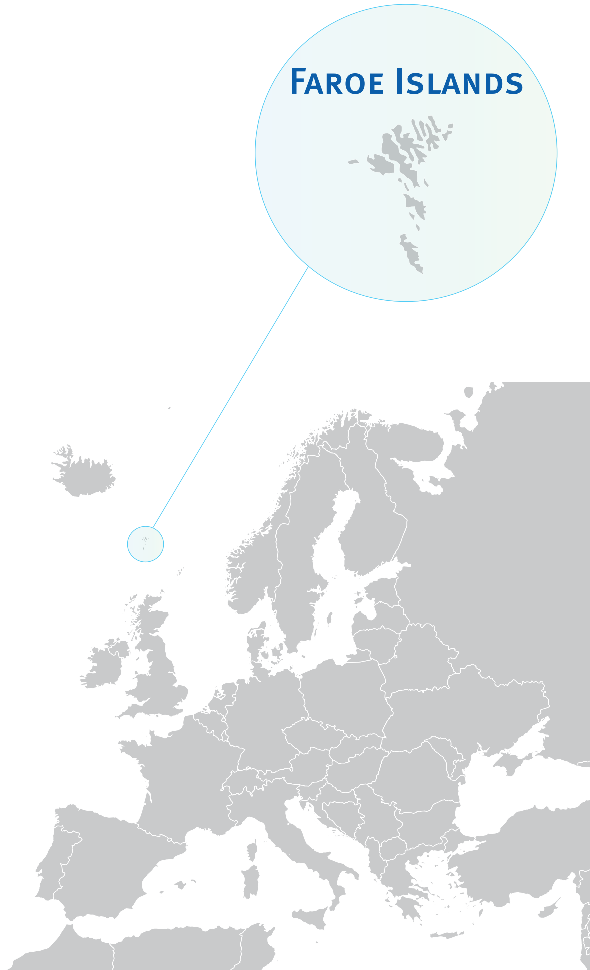
The islands are surrounded by an abundancy of renewable resources in terms of wind, hydro, tidal and to a certain extent solar energy. They have set an ambitious goal of a 100% clean and carbon-free electricity production by 2030, taking into consideration the electrification of both the transport sector and the heating sector, both of which currently rely on fossil fuels.

Since 2012, the share of wind power has increased from 4 MW to more than 18 MW, and in 2015 the annual share of wind power was more than 18%, with instantaneous wind penetration levels exceeding 80% of the total load. The energy mix in the electricity production in 2015 was 42% hydro, 18% wind and the remaining 40% from fossil fuel. With such a large share of renewable energy, already today the power system in the Faroe Islands faces the various issues and challenges that the mainland will face in a few years (e.g. short circuit, inertia, stability etc).

Therefore, the Faroe Islands, which are electrically isolated from the mainland, are seen as a perfect area for testing new technologies, due to the small but still full-scale environment. Projects like the EU-funded “TWENTIES PowerHub” project have been tested in the islands with great success. Through the project industrial consumers have been integrated in a load shedding system, decoupling loads like heat pumps, cold storages and freezing compressors when a local frequency deviation is experienced.

In May 2016 a 2.3 MW/0.7 MWh battery system was inaugurated in order to stabilise the fluctuations in an 11.7 MW wind farm output. The battery system has proven very successful in flattening the output from the wind farm, and is considered as an enabling technology for further integration of wind energy in the islands.

In order to decarbonise the whole energy system the Faroese Government and SEV, the Faroese Power Company, are working on different incentives to make electric vehicles and heat pumps more attractive to the inhabitants. A QuickCharger infrastructure is implemented with strategically placed public chargers making it possible to move freely in the islands with electric vehicles. However, the intention is for the electric vehicles to be charged with excess renewable energy, particularly in the night time.



PEGASE Project, La Réunion[9]

The French island of La Réunion is located in the Indian Ocean, 700 km east of Madagascar. The island has a population of around 850,000 inhabitants, mainly spread out on the coast, while the centre of the island is much sparsely inhabited. It is characterised by a tropical climate, with steep peaks and volcanoes with one of them being among the most active in the world.

Power generation on the island is delivered by two bagasse/coal power plants (6 generators for a total of 211 MW), a diesel plant of 12 engines (211 MW in total), 2 gas turbines of 40 MW each, several hydro plants (136 MW set up), 2 wind farms (6.3 MW and 8.5 MW), and around 175 MW of photovoltaic (connected to 20 kV and 220 V), mainly distributed but with some large units connected to 20 kV (3 of them with a battery storage). The island's 63 kV transmission grid lays on overhead lines, which are generally meshed. The load peaks increase up to around 400 MW/450 MW during austral winter/summer respectively.

The La Réunion energy system is highly dependent on fossil fuel (crude oil and coal), with a strong demand from the local government and the population for "greener" means of power generation. This was further boosted at the end of 2015 by the new French law ("Energy transition for a green growth") which states that the island must be fully autonomous by 2030 (ground transportation included), including zero imports of fossil fuels.

As described above, La Réunion is already taking advantage of the various sources of RES on its territory. According to French policy, RES sources have priority grid access. However, apart from a few power stations backed with storage, power generation from RES is intermittent and therefore likely to jeopardise the system balance between demand and supply. For this reason, the maximum rate for instant supply by intermittent RES must not exceed 30% of the load, in order to respect system stability. When this threshold is crossed, the legislation states that RES generators are to be disconnected from the network to reach the 30% limit with the more recent installations being disconnected quicker.

The "PEGASE"[10] project was designed and set up in the territory to improve the RES system. The project brought to the island a sodium/sulphur (NaS) battery of 1 MW/7 MWh to optimise the intermittent RES on the network, thereby overcoming the 30% rule, and to help the load/generation balancing, during evening load peaks in particular.

PEGASE

Day-ahead and intra-day forecasting of generation for the two main PV farms, based on data issued from direct weather observations from the ground by cameras, and from satellites used in infra-red and visible spectrum, is also performed as a consequence of the project.

[9] https://reunion.edf.fr/

[10] http://grid.imginternet.it/Articles/Library/PEGASE-New-Tools-To-Enhance-The-Cooperation-Among-TSOs-For-The-Real-Time-Control-And-Operational-Planning-Of-The-Pan-European-Transmission-Network.

The combination of storage and RES energy control allows for:

- Smoothening of intermittent energy;
- “Smart” management of the storage and the generation of intermittent RES.

As intermittent RES generation depends greatly on climatic risks, generation forecasting is a powerful lever supposed to boost intermittent energy on islanded systems and to foster its integration by better foreseeing risky occurrences linked to intermittence.

Various studies have provided an opportunity to design digital tools which are able to make an optimisation of the necessary storage size, regarding the system demand. The battery shows a very fast response to quick and large frequency drops. In addition, the intermittent risk goes down with coupling RES to NaS battery, which increases the system safety.

The PEGASE project has now been completed and is considered a success. The battery management software has enabled the 30% threshold to be increased in La Réunion. Centralised batteries on an electrical system are a good answer to the intermittence problems (much better and efficient than a decentralised storage associated to each generator), mainly towards PV manufacturers which are used to complain because of the 30% threshold; a good answer also to deliver a quick primary reserve for a reasonable cost. For this reason, Direction des Systèmes Energétiques Insulaires (SEI)[11] is developing two storage projects in the French Antilles, based on an alternative battery technology (less sophisticated than NaS), with a power capacity of 5 MW.

[11] https://www.edf.fr/groupe-edf/premier-electricien-mondial/strategie/edf-dans-les-territoires-insulaires

MALTA

Malta is an independent island state in the central Mediterranean, a full EU Member States, having a population of around 450,000 and an area of 316 km², making it by far the most densely populated EU Member State. Enemalta plc is a vertically integrated electricity utility and operates and maintains the generation and distribution systems in the country.

The electricity generation sector in Malta is currently undergoing a major transformation. Enemalta plc is the successor of a state owned corporation which was partly privatised in 2014. As of 2015, Enemalta operates only one power station at Delimara, in the South East of the island, as another plant centrally located at Marsa has been put on cold standby. In the same year, a 200 MW interconnection to Italy (Sicily) was commissioned and is now operational[12]. The 230kV interconnection with Italy consists of 19km of underground cables and 98 km of submarine cable.

Furthermore, the oldest plant at Delimara (2 x 60 MW HFO fired, steam) is due to be decommissioned as soon as a new gas fired combined cycle plant (200 MW) will be commissioned in early 2017. Fuel for this plant shall be delivered by means of a purposely built LNG facility consisting of a floating storage unit (FSU) and onshore regasification plant. The gas facility will provide gas to another internal combustion engine plant at Delimara (8x17 MW ICE + 1x14 MW Steam) which is currently being converted to run on natural gas.

Conversion of HFO-fired plants to natural gas (Enemalta plc)

The island also has a large number of small scale PV installations, currently having a nominal capacity of around 80 MW and an effective annual penetration of 3.3%. There are also a small number of waste-to-energy generators.

The maximum demand registered was 439 MW in August 2015 from around 300,000 registered customers with an annual energy consumption of 2,335 GWh.

Enemalta is the sole Distribution System Operator (DSO) energy supplier in Malta. The onshore network consists of four voltage levels, namely 132kV, 33kV, 11kV and 400V served by 1,316km of MV underground cables, 82km of MV overhead lines, 1,036km of LV underground cables and 2,082km of LV overhead lines.

[12] https://www.enemalta.com.mt/index.aspx?cat=2&art=247

Decision Making Process (Involvement of Citizens) to Decarbonise

The Government of Malta prepared a series of national plans, which included the National Energy Policy for the Maltese Islands, the National Renewable Energy Action Plan and the National Energy Efficiency Action Plan, with the aim of addressing security of supply, affordability and sustainability of the energy sector. These plans were comprehensive and addressed the entire energy sector with specific focus on promoting Renewables and Energy Efficiency. The plans therefore already included elements that contribute towards the Energy Union objectives such as interconnectivity, decarbonisation, gasification, RES and energy efficiency. In view of the importance and impact of the energy sector on the general public, the public was engaged through public consultation.

Measures Taken

Malta is a small island with no indigenous fuel sources and has been historically dependant on energy imports. Malta has understood that the way forward in the process towards decarbonisation is its 'interconnectivity' and tapping the economies of scale which are available on the European mainland. The commissioning of the electricity interconnector between Malta and Italy on 9 April 2015 (supported by the European Energy Programme for Recovery) marked an end to the isolation of the Maltese distribution network from the rest of Europe. As a result of the project, Malta's electricity interconnection capacity increased from 0% to around 35%.

Nonetheless Malta is still isolated from the European gas network and plans are underway to eliminate this isolation. The introduction of natural gas is an important step in the decarbonisation process. The power sector is the main GHG emitter on the Maltese Islands. The country's decarbonisation roadmap includes the closure of less efficient installations combusting Heavy Fuel Oil, the commissioning of engines running with high efficiency, and ultimately the supply of gas for power generation through a floating gas storage vessel, and an exercise that includes also the retrofitting of high efficiency engines to run on Natural Gas. Currently Malta is also actively engaged in a Project of Common Interest (PCI) in gas that will bring to fruition the connection of Malta to the European Gas network.

For the Maltese Islands, renewables are a major source of locally generated energy that contributes towards achieving the decarbonisation objectives. The initial uptake of renewables was slow in the Maltese Islands partially due to high costs of RES. However following a number of government schemes aimed at increasing the uptake of renewables, the share of renewables is continuously increasing. Malta plans to reach its 2020 RES target by exploiting the indigenous resources in the most cost-effective way. Malta's 2020 target is set to be achieved thanks to a number of initiatives in the renewable energy sector, namely support to photovoltaic installations and solar water heaters, heat pumps, waste-to-energy plants, as well as the obligation on importers to introduce biofuels to the market.

Problems Faced

PV penetration levels have had effects on grid stability. In a small isolated grid, the effect of PV generation has caused a displacement of conventional generation, thereby reducing grid inertia. This is particularly evident when Malta is not connected to the European grid due to any ongoing maintenance on the interconnector. Furthermore, due to the very small geographical spread of PV installations, any change in weather conditions will almost immediately affect the output of all PV generators. This disturbs the grid frequency when the Maltese system is isolated and the power balance when the Maltese system is synchronised to the Italian network.

Malta Italy Interconnector Ragusa Station - 230 kV air-insulated switchgear (Enemalta plc)

Aegean Islands, Greece[13]

Smart Grids in 5 Aegean Islands – Development of smart-grid infrastructure in autonomous islands of the Aegean Sea[14]

DAFNI
Network of Sustainable Greek Islands

Islands: Kythnos, Milos, Santorini, Lesvos, Lemnos (all NII)

Island	LV clients	MV clients	MV/LV Substations
Lesvos	75993	34	1304
Limnos	15273	14	380
Milos	7260	7	23
Kythnos	3163	0	10
Santorini	17205	19	251
TOTAL	118894	74	1968

The project is aimed at promoting smart grids in five Aegean islands in order to improve the quality of electricity provided to the islands, increase the penetration of RES in the local grid and allow for the more flexible management of loads. The project was funded by the ELENA programme of the European Investment Bank and involved the development of studies and tender documents for the:

Introduction of Energy Control Centres
- Energy Management Systems (EMS)
- Market Management Systems (MMS)

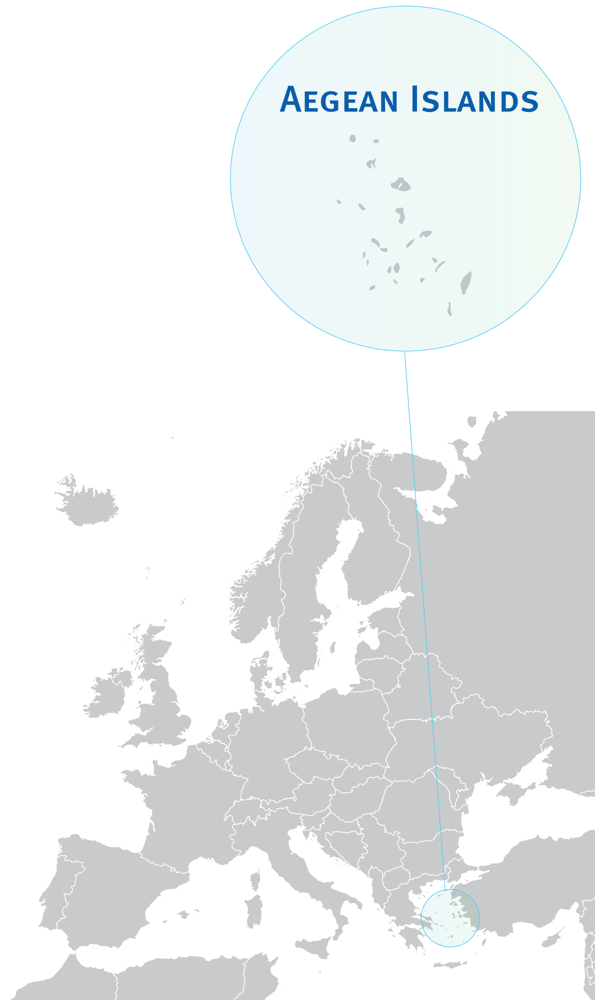
Automated Metering Infrastructure
- On-going tendering process by HEDNO
- Metering points on the islands

EV Charging Stations (EVCS)
- Select the most suitable EVCS type
- Investigate alternative solutions for metering and billing
- EVCS communication with ECC for EV load management purposes

Energy Efficiency in Street Lighting
- Feasibility studies for each one of the 5 islands
- Smart metering for the remote control of luminaires

"Smart Island" planned project

HEDNO (Hellenic Electricity Distribution Network Operator S.A.) is currently in the design stage of the project and in search of the island that is best suited to host the project. The project aims at the maximisation of RES penetration in a non-interconnected island system (>60%), the reduction of operational costs, the protection of the environment, resource efficiency and the provision of reliable and continuous supply of electricity. For the realisation of the project, interventions in the regulatory and legal landscape are foreseen in order to move ahead with the tendering and the investment by the selected entity.



[13] Contribution by DAFNI – Network of Sustainable Aegean and Ionian Islands
[14] http://www.dafni.net.gr/en/collaborations/elena-ta.htm

TILOS Project, Tilos[15]

Technology Innovation for the Local Scale, Optimum Integration of Battery Energy Storage

The island of Tilos is located at the North West of Rhodes Island, surrounded by high and rocky mountains, steep coasts, beaches with clear waters and caves. It offers unique attractions like medieval castles, a Byzantine monastery, many small graphical churches and a village that is a declared cultural heritage site. Until now, the local population of Tilos (about 500 islanders) covers its electricity needs through a poor interconnection to the host island of Kos, where a diesel-oil power station is operated.

Owing to undersea cable faults, Tilos suffers from quite frequent, and in many cases, long-lasting blackouts. What the project aspires to do is to make this small and remote island the first global blueprint for smart microgrids facilitating increased participation of renewable energy sources under the optimum exploitation of energy storage assets.

The main objective of the "TILOS" project will be the development and operation of a prototype battery system based on FIAMM NaNiCl2 batteries, provided with an optimum, real-environment smart grid control system and coping with the challenge of supporting multiple tasks, including:

- Microgrid energy management
- Maximisation of RES penetration
- Grid stability
- Export of guaranteed energy
- Ancillary services to the main grid of Kos

The battery system will support both stand-alone and grid-connected operation, while proving its interoperability with the rest of microgrid components, such as demand side management aspects and distribution, residential heat storage in the form of domestic hot water. In addition, different operation strategies will be tested in order to define the optimum system integration.

The TILOS project addresses the high-priority area of island regions. Apart from Tilos, the project also engages with the islands of Pellworm, La Graciosa and Corsica, aiming to create an island platform that will enable the transfer of technological experience by making use of the smart grid system of Pellworm, and by offering new case studies for the development of similar projects.

Replication of the proposed system will be enabled by the development of an advanced microgrid tool, i.e. the Extended Microgrid Simulator, while novel business models will be elaborated for the market diffusion of the integrated battery solution, engaging also the local public.

Technology Innovation for the Local Scale
Optimum Integration of Battery Energy Storage

[15] http://www.tiloshorizon.eu/

WiseGRID Project, Kythnos[16]

Wise Scale Demonstration of integrate solutions and business models for European Smart Grid

Kythnos is an island and municipality in the Western Cyclades, with a population of 1,632. The island has a thermal installed capacity of 4,966 MW, with a peak power consumption of 2.7 MW, it has three MV distribution lines at 15 kV voltage level, and does not have any transmission network.

Kythnos has a long history of sustainable energy applications since it hosted the first wind farm in Europe back in 1982. This was followed by the installation and testing of a 100kW PV plant coupled with batteries, a hybrid station comprising of a 500kW Wind Turbine, battery storage and an automatic control system, and finally the development of one of the first PV powered autonomous micro-grids with batteries and diesel generator back-up. Unfortunately all the systems (except the small stand-alone installations) are currently not in operation. Due to the long-time of inactivity and the old technology used in the various subsystems, it is not possible to repair or restore these systems.

Over the last years the tourism infrastructure of the island has gradually increased attracting more and more visitors and creating conditions for local economic growth. This has come at a price which includes, among others, increased pressures on the island's resources and environment. The island's infrastructure provides the essential utilities such as electricity, water and sewage to locals and visitors. These are planned based on the peak demand which is heavily connected to the seasonal population of the island related to the influx of tourists.

For the municipality and the citizens of Kythnos, the vision is to move towards the smart and sustainable development of the island, promoting the extension of touristic season while minimising the impact of related activities. At the same time the integrated planning of the island's future infrastructure will take stock of the past sustainable energy projects and incorporate smart and innovative technologies in the fields of energy, water, waste and mobility.

The "WiseGRID" project foresees 4 large scale demonstration sites for the deployment of new, innovative and smart technologies that will help make electricity distribution grids safer, smarter and more efficient. The demonstration sites are located in Belgium, Italy, Spain and Greece, with the latter situated on Kythnos.

[16] http://www.wisegrid.eu/

WiseGRID Scenarios

On Kythnos, an integrated management system that combines EVs, demand response (public buildings), critical infrastructure (port, desalination unit) and grid management will be demonstrated. The goal is to demonstrate that the combination of these systems leads to a more efficient and economic operation of the system.

Increase RES penetration: the operation of a non-interconnected system with high RES penetration is very complicated since it is a weak system. Usually this leads to significant RES curtailment. On Kythnos the wind turbine is inactive for long periods since it not possible to absorb the production. The goal is to demonstrate that with the tools developed in the WiseGRID project it is possible to increase the RES penetration.

Energy efficiency: The thermal production is based on units using light diesel, thus the variable cost of the island is extremely high. The goal is to test new policies that will allow the reduction of the fuel cost and increase the energy efficiency in the island.

Integration of critical infrastructure: The desalination unit and the port (the ability to provide electricity to docked ships will be simulated) are critical infrastructure for the island and they have special characteristics and power requirements. The goal is to demonstrate the integration of such infrastructure in the system management.

Integrated infrastructure

- Existing RES sources (1 WF 500kW)
- Possibly storage (to be decided in the Future)
- Electric Vehicles (10-20 EVs via leasing for summer period)
- Demand Response (public buildings)
- Desalinisation unit
- Port

End-users involved

- DSO HEDNO
- ICCS/NTUA
- EV users
- Aegean Energy Agency
- Municipal authorities
- Port Authorities

Notes

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