# BERLENGA ISLAND – SUSTAINABLE SMART MICROGRID

Cláudia Pinto
EDP Distribuição – Portugal
claudia.pinto@edp.pt

Ricardo Jorge Santos
EDP Distribuição – Portugal
ricardojorge.santos@edp.pt

Gonçalo Faria
EDP Distribuição – Portugal
goncalo.faria@edp.pt

Luís Tiago Ferreira
EDP Distribuição – Portugal
luistiago.ferreira@edp.pt

António Joyce
LNEG – Portugal
antonio.joyce@cm-peniche.pt

Nuno Cativo
Câmara Municipal Peniche - Portugal
nuno.cativo@cm-peniche.pt

## ABSTRACT

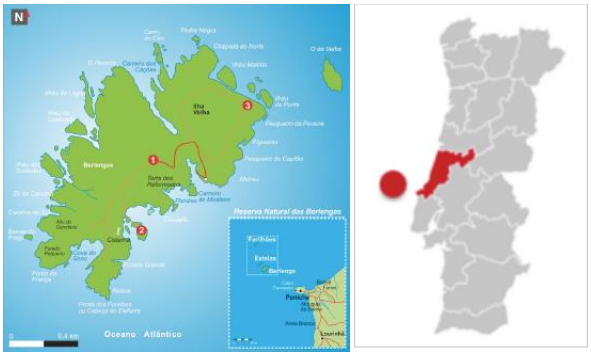
*EDP Distribuição is EDP Group Distribution System Operator, operating in the regulated distribution business in Portugal. It holds the concession for most of the high, medium and low voltage distribution grid concessions across mainland Portugal.*

*The Berlenga Island is classified as a UNESCO natural reserve, making it a heavily protected area. Currently, the island is supplied through diesel generators, this kind of generation bears obvious environmental and safety risks regarding maritime transportation, transfer and storage of diesel fuel. Furthermore, this system involves high operation and maintenance costs. The Berlenga Project aims to provide a sustainable and viable alternative to this energy scenario, combining renewable generation, energy storage and demand side management through smart grid technology. Tackling environmental, regulatory and business model issues will be key to deliver the results of this project.*

## INTRODUCTION

The Berlenga Island is classified as a UNESCO natural reserve and one of the nine natural reserves in Portugal. Human occupancy and electricity supply on the island is restrained and ruled by a strict protocol. Throughout the year, the island's electricity supply is shut down from December to February, and from March to November has strict protocol that defines when to run the diesel generators.

The main operational challenge the current situation entails is the transportation and storage of nearly 15,000 Liters of fuel per year, presenting not only a major environmental risk in case of an oil spill but also a safety risk. EDP Distribuição is currently responsible for the exploration of the existing diesel generators, as well as the distribution grid on the island.




**Figures 1:** Berlenga Island Map

The main challenges of this project are:

i. Sizing the renewable generation mix (PV+Wind) and energy storage required to replace the diesel generator;
ii. Identify current consumers, their consumption patterns and needs, including flexibility resources potential;
iii. Designing an energy microgrid management system capable of dealing with local RES generation, backup diesel generation, storage and flexibility.
iv. Analyzing the relevant environmental and regulatory framework, identifying key stakeholder's responsibilities (namely the responsible for the generation assets and its maintenance) and interactions.

## ISLAND OVERVIEW

Berlenga island stands 10 km northwest of Peniche and belongs to the Berlengas Archipelago, along with two smaller island groupings. It's enforced by strict protection measures with respect to fauna, flora, wildlife and geological features that are native to the island. It is monitored jointly by the IUCN (The International Union for Conservation of Nature) and the ICNF (Portugal's Nature and Forest Preservation Institute). [1]

### Berlenga Energy Consumption and Generation

The island's highest occupancy is in the touristic season, from mid-May to September, period in which there is regular maritime transportation of passengers between the island and the mainland. Although the law limits the

number of people in the island to 350 people per day [2], it has registers of more than 1,000 simultaneous visitors in an August day, reaching more than 20,000 visits per year. During off-season months of the year, human activity consists mainly of the rotation of the lighthouse workers present 24/7 all year long.

The island comprises a total of 31 electricity customers, 17 of them residential (mainly fishermen shelters, with the lowest contracted power available) and a restaurant, which represents more than half of the island consumption. There is also a lighthouse, under the responsibility of the Portuguese Navy, that's disconnected from the grid and operates solely on PV and a vertical axis wind turbine, and three groups of small batteries, making it completely autonomous.

There are some municipality services such as two water treatment pumps, of 4,2 kW each (which never work simultaneously), a salt water pump, of 2,3 kW, that works 5 times a day on a scheduled period, a waste crusher of 2,3 kW, that works twice a day on a scheduled period as well. These pumps and waste crusher represent a good opportunity of demand side management, and to improve the load behavior throughout the day.

The annual consumption in 2016 was of 32 MWh (resulting in over 43 tons of CO2 emissions per year) with a load peak of 26 kW. The supply is guaranteed by a group of 3 diesel generators G1, G2 and G3, with capacities of 40 kVA, 50kVA and 60 kVA respectively (which never work simultaneously). Diesel consumption is nearly 15,000 L/year, with a solo maritime transportation per year, meaning this amount of fuel is stored on the island itself.


**Figures 2:** Group of generators

## Main Stakeholders

**EDP Distribuição:** The current responsible for distribution and exploration of existing generators, EDP Distribuição has been seeking for more cost-efficient, less risky and higher quality energy supply solutions for the island. Several options have been studied, including a costly undersea cable to connect the island to the mainland grid.

**Peniche's Municipality:** With a population of 27,312, Peniche's main economic industries include fishing, agriculture, food transformation and tourism. The Municipality owns the restaurant and shelters on the island, which it leases annually. The Municipality has great interest in turning Berlenga into a renewable island.

**Portuguese Navy:** The Portuguese Navy is the naval branch of the Portuguese armed forces with a full-time presence on the island. It has experience with local renewable operations by means of their own PV panels/wind generators to power the lighthouse.

**ICNF (Nature conservation institute):** The ICNF is the public body responsible for environmental policies and licensing. Any implementation in Berlenga will require authorization from ICNF.

**ERSE (Energy Sector Regulator):** EDP Distribuição is considered a natural monopoly and therefore subject to economic regulation. ERSE regulates transmission and distribution tariffs, as well as allowed investments and returns.

**DGEG (Energy Directorate public body):** DGEG is the public body supporting the Government in legislation and energy policy. Renewable generation in Berlenga will require DGEG licensing.

**Inhabitants:** The consumers of electricity on the island, it's important to have them on board the project. In fact, costumer engagement will be crucial if flexibility through demand side response is to be tried in this project.

## LEGISLATION FRAMEWORK AND ENVIRONMENTAL ISSUES

### Legislation on renewable generation models

Currently, Portugal has two models available for local renewable generation, described under Decree-Law n.º153/2014 [3]. Both models present a challenge to the project, since the legal framework isn't suitable for the particular situation on the island.

**UPAC model (Generation for self-consumption):** a consumer may install renewable generation behind the consumption meter. Occasional generation in excess of local consumption may be injected into the grid (and remunerated, if applicable). Some relevant restrictions apply: the nominal power at the exit of the inverter is limited to the contracted power of the consumption site; the maximum capacity of the generation unit cannot exceed twice the nominal power of the generation unit's inverter.

**UPP model (Generation for full injection into the grid):** for small generation units, below 250 kW and associated with a consumption site, where all the energy is injected into the grid and remunerated at a rated tariff (currently 95 €/MWh). Under this model, the nominal power at the exit of the inverter is limited to the

contracted power of the consumption site and to 250 kW. On an annual balance, the UPP's generation cannot exceed twice the energy consumed by the consumption site. There can only be one renewable technology involved, which implies the same site cannot have PV and Wind at the same installation.

The restaurant represents the maximum load on the island, having a contracted power of 34,5 kVA. According to the UPAC restrictions, it could not inject in the grid more than 34,5 kVA, and the maximum capacity allowed for the generation unit would be 69 kWp.
According to the UPP model, the restaurant might comply with the restrictions imposed, since it represents more than half of the islands' total consumption.

## Environmental licenses

Since the island is classified as a UNESCO nature reserve, it has strict environmental policies and limitations, impacting on the installation of any PV and Wind units. The generation units, though they are renewable units, cannot present a threat to the island's ecosystem.

In 2010, under a project called "Berlenga-Sustainability Laboratory", ICNF and the Environment Ministry approved a site on the island to install PV generation, with a maximum capacity of 80 kW. Wind generation was not allowed, due to horizontal axis turbines danger to the birds species on the island (Figure 3), comprising a total of 700 $m^2$. The installation never went forward, though, and thus a reevaluation by the ICNF and Environment Ministry is needed.
Another site option for the renewable generation units would be the area around the lighthouse, under the management of the Portuguese Navy. This solution may nevertheless present an issues with the distance between the lighthouse and main village and the present condition of the low voltage cable connecting them.


**Figure 3:** Approved area for PV installation in 2010

## Microgrid dimensioning and inertia-less challenges

The island's consumption is very peculiar, impacting on the dimensioning of the system. The periods with higher consumption are always related with the restaurant use (since the restaurant represents about 60% of the island's total consumption), at lunch time between 12:00 and 14:00 and at dinner time between 19:00 and 21:00. Regarding the mix of PV and Storage, there are some key points here to be considered:

- To avoid requiring more than 500L of diesel generation per year, the PV capacity must be above 55 kWp, due to lunch time demand on days with lower solar radiance (high reserve capacity requirement);
- During the afternoon, between lunch and dinner time, demand is very low and PV production is still very high under the average solar conditions, possibly reaching full charge of the battery (and forcing heavy curtailment of the PV system);
- The battery's main discharge time is to supply dinner time, (during the night there is currently no consumption in the island, since the protocol demands that the generators are shut down between 01:00 and 09:00).

This presents a big opportunity for demand side management of the municipality services and the restaurant consumption. Using some flexibility from this consumption sources could (e.g. sometimes shifting the pumps and the waste crusher schedule to work during the afternoon period), could have a serious effect on the PV curtailment and PV + battery investment requirements.

Another challenge is the management of a low inertia system, mostly based on power electronics. Under the very high penetration of renewables foreseen, there may be frequency instability and voltage surges due to rapid changes in generation/consumption. This must be managed, either by the battery energy management system, or by using multiple coordinated sources of flexibility.

Two possible alternative sources of flexibility for stabilizing the power system could be (1) the PV system, which may have to work frequently below maximum power point due to necessary over-dimensioning. This presents an opportunity for delivering flexibility to the system through control of the PV inverter, using variable-speed controlled water pumps, which may allow fine control over this source of consumption.

An energy management system of the island microgrid should also be able to control and optimize the dispatching of the diesel generators, in order to guarantee operation above the minimum load standards, avoiding degradation.

## Maintenance challenges

One of the main challenges of the project is to guarantee PV maintenance and cleaning due to the high presence of

seaguls on the island. As can be seen on Figure 4, the seagul's excrements can present a real impact on damaging or underperformance of the PV system, which must be prevented by manual or automatic systems for keeping these animals at bay and for cleaning the PV panels. These systems need to be environmentally compliant with the protection of other native species of the island.

**Figures 4:** Seaguls and its effect

As mentioned before, the Portuguese Navy has its own independent PV system, and the lighthouse worker is responsible for the cleaning of the panels, almost every day. The disregard of the system's cleaning can lead to a significant increase in diesel generation, going back to the current situation (relying more on diesel generation).

## BUSINESS MODELS

Considering the current O&M costs associated with the purchase of fuel and its transportation to the island, incurring nearly 1000€/MWh (and the high risk of oil spill, which would cause serious environmental repercussions), and the continuous decline of PV and storage market prices, a serious study of the future business models on the Berlenga Island should be considered.
Bearing in mind the challenges presented with the legal framework on the production units, the environmental licenses, the assets ownership and maintenance of the PV panels, the following key points and solutions approach regarding the possible business models were considered:

- According to national laws, the RES generation assets should be owned by a local agent with a consumption facility and not the DSO;
- The business model should comprise a virtuous connection between the revenues and other benefits of exploring/ maintaining the RES resources and avoiding diesel fuel consumption, costs and blackouts;
- Renewable reserve capacity required for replacing the diesel generation is high, implying significant levels of curtailment, which reduces potential profitability under the existing legal framework of energy sale to the grid;
- Taking advantage of the existing demand side management potential (which represents around 30% of total demand power) may reduce curtailment significantly, leading to better integration of RES resources, higher revenues potential and lower energy costs for the island;
- The existing legal framework does not provide explicit remuneration for these flexibility services and the economic potential would probably be insufficient for a profitable business model around the flexibility services potential from water system pumps and other local consumption loads;

Considering the abovementioned, the renewable generation assets maintenance and revenues should be tied to a local stakeholder, taking advantage of synergies with other local activities and the interest in keeping the system up and running, avoiding diesel-based generation.

As well, taking advantage of the significant potential from local demand management must probably be tied to the holistic/community interest in maximizing the penetration of RES generation and not to a direct economic incentive to the provider of flexibility.

## CONCLUSIONS

This paper exposes the different considerations for a business model analysis, highlighting the Berlenga Project main challenges and limitations, and the considered approaches to a solution. The lessons learnt from the implementation of such a project may give directions for future requirements and solutions coming from distribution systems with ever-increasing penetration of renewable sources. As a final remark, this study shows that there are indeed feasible ways to ensure renewable energy supply to this island, which are becoming competitive to the use of diesel generation costs or an expensive submarine cable to mainland grid connection.

## REFERENCES

For a Conference citation:

[1] http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/biosphere-reserves/europe-north-america/portugal/berlengas

[2] Portaria n.º270/90, April 10th

[3] Decreto-Lei n.º153/2014