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SMILE

Smart Island Energy Systems

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SMILE Replication Plan

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1 Introduction

The overall scope of the SMILE project is to demonstrate, in real-life operational conditions, a set of both technological and non-technological solutions adapted to local circumstances targeting distribution grids to enable demand response schemes, smart grid functionalities, storage, and energy system integration with the final objective of paving the way for the introduction of the tested innovative solutions in the market in the near future. To this end, three large-scale demonstrators have been implemented in three island locations in different regions of Europe with similar topographic characteristics but different policies, regulations, and energy markets: Orkneys (UK), Samsø (DK), and Madeira (PT). The technological solutions vary from integration of different battery technologies, power to heat, integration of electric vehicles and boats, energy management system, aggregator approach to demand side management (DSM) and predictive algorithms.

For each pilot, the aim was to demonstrate operation of the distribution grid under stable and secure conditions in the context of the implementation of solutions enabling demand response and the intelligent control and automation of distribution networks to provide smart network management of the distribution grid.

For the Orkney Islands the main goal was to alleviate the current fuel poverty in Orkney by maximizing the productivity of the existing generation assets, mostly owned locally, and to support the rollout of electric vehicles. Their objective is to transform a semi-smart grid system into a fully smart system, by using existing grid infrastructure and integrating new communications and control systems, as well as new controllable energy demand for heat and transport.

On Samsø the goal is to lower the CO2 emission on the island and have a 100% fossil free island by 2030, while optimizing local use of local renewable energy sources. Their objective was to develop a smarter and more integrated energy system at one of the marina sites which will allow energy to be generated locally, demand side management to be used for its better utilization at times when it is produced, and excess electricity from renewables to be stored also locally.

Madeira is a total energy island, not connected to any other landmass electrically, with all energy consumed on the island being generated locally and the grid resulting difficult to balance for the local DSO. Within this framework, the project had the scope to increase the self-consumption of PV in micro-producers thanks to DSM services and BESS, to favour the expansion of EVs through smart charging and to introduce solutions for voltage control and peak-shaving thanks to BESS.

1.1 Scope and objective

The goal of this document is to foster the market introduction of the SMILE technologies by illustrating replicability guidelines for the SMILE solutions to become of interest for other (European) islands with similar political-legal, economic, social, technological, or environmental characteristics. To showcase the feasibility of replicating the SMILE solutions on other islands a high level replicability assessment has been performed. This includes a feasibility study of the SMILE solutions on several Greek shadow islands. Ideally, each Greek island will replicate one or more SMILE solutions to showcase the replicability potential of these solutions. This document will give a clear overview on the different SMILE technologies, how these technologies are combined into a solution and demonstrated on Samsø, Madeira or Orkney including technical and non-technical characteristics, and how these solutions could be replicated on other islands using Greek shadow islands as an example. To demonstrate the replicability potential of the SMILE solutions this replication plan exists out of the following three parts;

Part 1: SMILE Technologies

This part incudes a catalogue describing the different key enabling technologies developed throughout the SMILE project by Lithium Balance A/S, OVO Energy, Route Monkey, BrightCuriosity Lda (PRSMA) and Sunam Ltd. Each technology description includes the following elements: 1) customer segments, 2) value propositions and main functionalities, 3) components, 4) requirements, 5) limitations, and 6) technical specifications.

Part 2: SMILE Solutions

By combining the SMILE technologies, different solutions were developed and tested on the SMILE large-scale demonstration sites. This part gives an overview of the different main SMILE solutions demonstrated on Orkney, Samsø, and Madeira including their: 1) value proposition and main functionalities, 2) target group, 3) components, and 4) requirements and limitations including technical and non-technical aspects based on different political-legal, economic, social, and environmental factors. This part includes replication guidelines for the following SMILE solutions:

- Madeira: “DSM and BESS for optimizing self-consumption”
- Madeira: “Voltage control and peak-shaving”
- Madeira: “EVs smart charging”
- Samsø: “A grid connected solar battery for a marina”
- Orkney: “Heating and Hot Water Optimisation”
- Orkney: “Electric Vehicle Charging Optimisation”
- Orkney: “Aggregated / Industrial Load Optimisation”

Part 3: SMILE Replication on Greek shadow islands

Samsø, Orkney, and Madeira have tested different combinations of technological solutions according to local specificities and conditions and the existing infrastructure. For each island, the aim was to demonstrate and develop the optimal operation of the system under stable and secure conditions. Each of the demonstrators brings a specific set of challenges, technology options and most importantly, energy market conditions. The sites are therefore effectively representative of the majority of the EU energy markets and offer excellent demonstration settings which will deliver maximum impact in terms of replicability in EU islands. In this part, representative Greek islands having similar characteristics with the project demonstrator islands, have been selected to investigate whether the technologies tested can be used in each island. For each of the three selected islands the project’s consortium produced a pre-feasibility study of the technologies under consideration considering the specific characteristics of each island.

In chapter 4, the methodological approach towards the identification of the Greek shadow islands is described. Furthermore, the beneficiary Greek islands are introduced pointing out their energy power system characteristics. Finally, a contextual technical solution is proposed briefly, for each SMILE demonstrator. In chapter 5, the conclusions are reported.

2 SMILE Technologies

The key enabling technologies of SMILE that combined in different ways determined all the solutions developed in the framework of the project are:

- Energy Management System
- Thermal Energy Storage
- Predictive Algorithms
- Battery Energy Storage System
- Energy Flexibility Platform

2.1 PRSMA – Energy Management System

PRSMA (BrighCuriosity Lda) is an SME that was founded in 2015 with the goal of developing and commercializing the EnergySpectrum Energy Management System (EMS).

Based in Funchal, Portugal, PRSMA is currently composed by five persons, three PhDs (computer science and human-computer interaction) and two engineers (electrical engineering and informatics engineering).

PRSMA has participated in three EU funded research projects in the broad area of Sustainable Energy Systems, one of which is the SMILE project, from EU under the H2020 framework program.

The EnergySpectrum system, from now on referred to as EMS, is a proprietary platform from PRSMA, that is the backbone of the Madeira demonstrator in the SMILE project. More precisely, the EMS was initially deployed to handle all the data collected in the five pilot sites in Madeira Island, but it soon evolved to also support more advance features, such as real-time storage control via third-party integration.

Website: https://www.prsma.com/

2.1.1 Customer segments

Segment 1: Vendors and installers of distributed generation equipment (e.g., PV and storage) that do not own a cloud infrastructure to store and access the generated data items.

To this consumer segment, PRSMA provides an out-of-the-box solution that is hardware agnostic, hence allowing the integration of virtually any monitoring equipment (provided that some minimal requirements are met – see section 2.1.4). By default, PRSMA provides two main features to this consumer segment: 1) back-end infrastructure (Figure 1, and Figure 2) to handle all the data acquisition life cycle; 2) a series of web-services that allow querying the existing data (Figure 2). If required, additional web-services (e.g., for data processing) can be developed upon request.

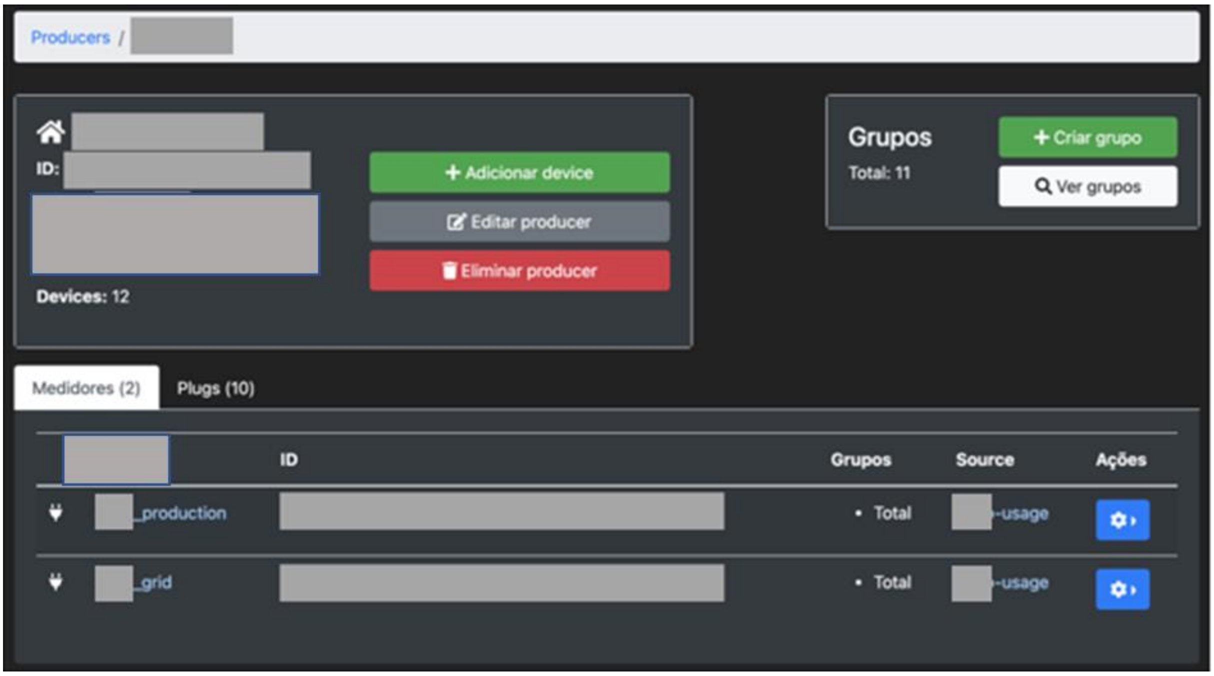

Figure 1. Data storage user interface for system administrators. In this particular case, the customer owns 12 data sources (2 smart-meters and 10 smart-plugs).

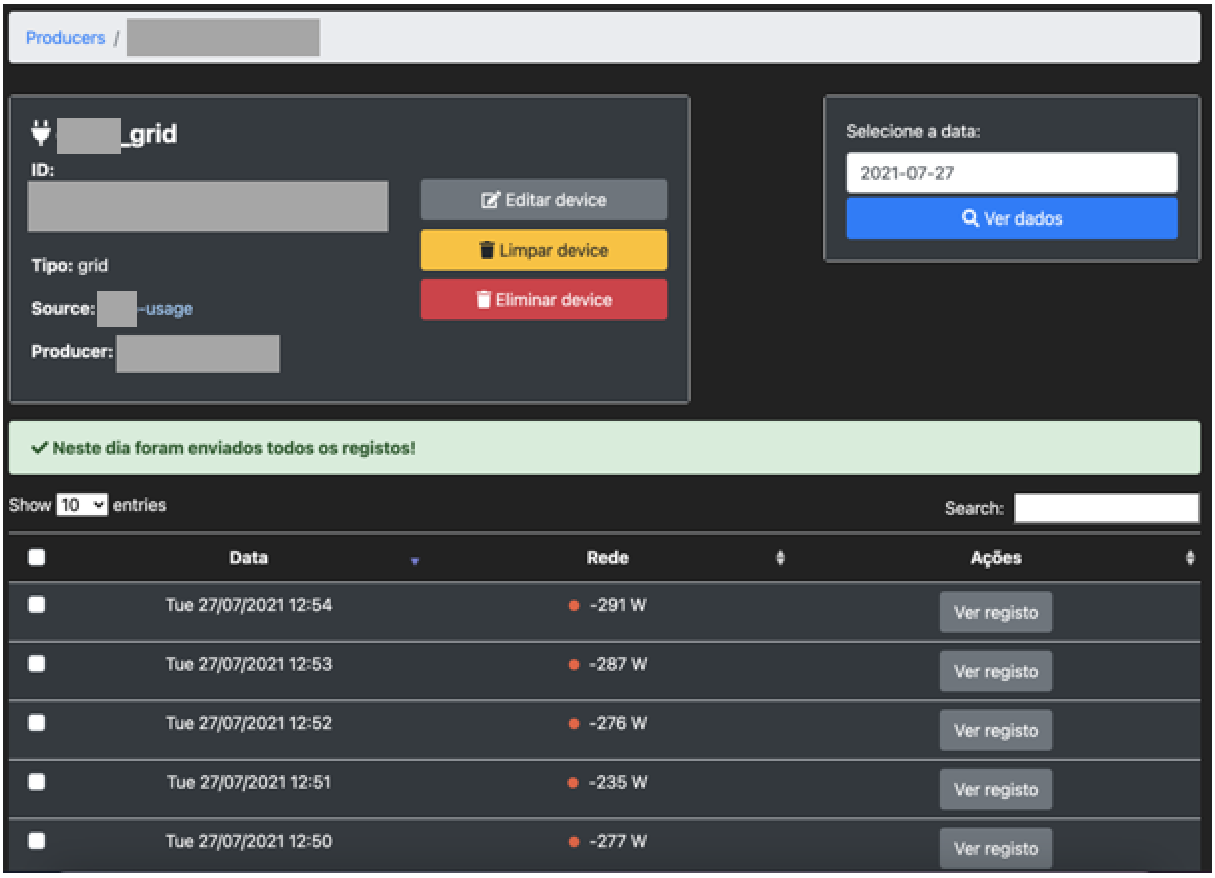

Figure 2. Data storage user interface for system owners showing the results of a basic query to a data source (in this case, showing all the data points for a particular date).

Segment 2: Vendors and installers of distributed generation equipment (e.g., PV and storage) that do not own a cloud infrastructure to store and access the generated data, but also want to access and offer interactive dashboards to their customers.

To this consumer segment, PRSMA provides all the benefits from the previous consumer segment, plus a set of pre-defined visualization elements that can be used to develop custom dashboards (see Figure 3 for an example). While, by default, this functionality is only available for the data managers, it can also be made available to the end-users, provided that the data sources are associated with an individual user-account. Moreover, upon request, it is possible to develop additional dashboard widgets.

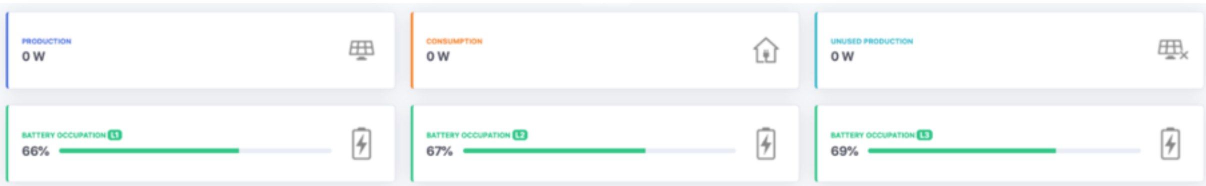

Figure 3. UI widgets to show near real-time information. In this case, information is being displayed for the most up-to-date measurements for solar PV production, electricity consumption, surplus PV production injected in the grid, and the state-of-charge (SOC) of three batteries.

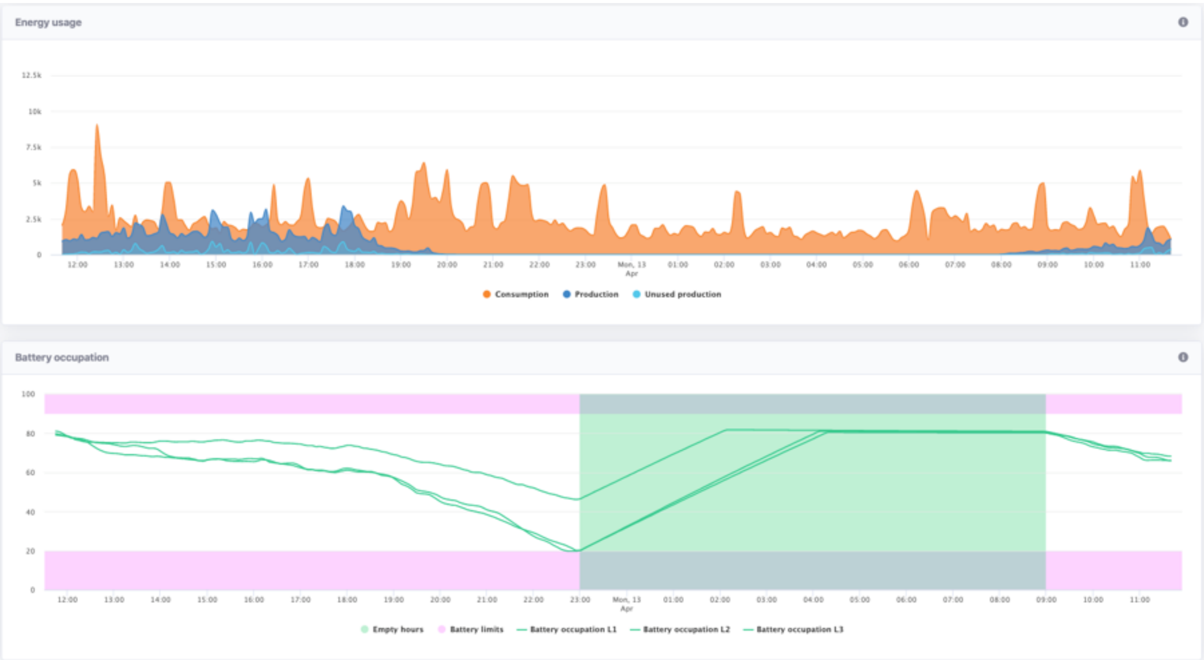

Figure 4. UI widgets to show time-series information. On the top the load flows (consumption, PV production, and PV surplus), on the bottom the SOC of each of the three batteries.

Segment 3: Vendors and installers of distributed generation equipment (e.g., PV and storage) that besides wanting to store and visualize data also want to control energy storage devices remotely.

In this consumer segment, PRSMA provides all the benefits from the previous consumer segment, plus the possibility to deploy algorithms for storage control. It is important to remark that for enabling storage control the necessary APIs have to be provided by the costumer. In the case of SMILE, this API was provided by the provider of the Battery Energy Storage System - BESS (Lithium Balance -XOLTA), hence enabling full integration of storage control both in real-time, or via predefined control schedules (see Figure 5 for an example of storage control).

Figure 5. Combination of UI widgets to provide a dashboard with information about storage control. On the top the load flows (including battery charge and discharge), in the centre the battery SOC, and on the bottom the active and reactive power as seen from the battery inverter.

Segment 4: Vendors and installers of EV charging equipment, or EV charging equipment owners and operators that need a solution to store and access the collected data (e.g., for billing), as well as the possibility of controlling the charging process remotely.

For this consumer segment, PRSMA provides all the benefits of customer segment 3, however focusing on EV charging infrastructures. If an API is available to control the charging equipment, the solution is also able to provide smart-charging, e.g., real-time control of the charging levels. See Figure 6 for a screenshot of the EV charging dashboard that was developed for the SMILE project.

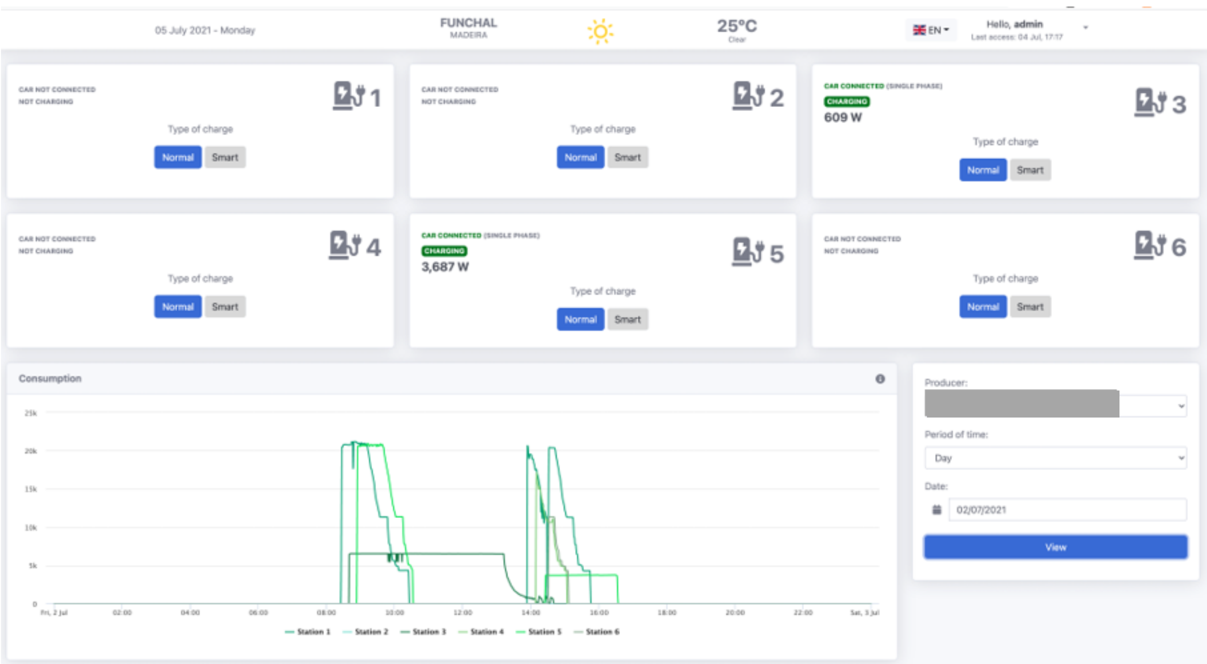

Figure 6. Combination of UI widgets to provide a dashboard for EV charging information. On the top, the real-time information of each charging station. On the bottom, the consumption profiles of each charging station in a particular day

2.1.2 Value proposition and main functionalities

The main value proposition is providing an **out-of-the-box and hardware agnostic solution for storing, accessing, and processing energy related data**. With this solution, hardware vendors and installers, particularly the smaller ones, can also benefit from cloud-based storage and computing to enhance the services that they provide to their own consumers.

Furthermore, by offering the service in different tiers (as seen above), PRSMA is making sure that no one is left out, from a small vendor/installer that just want to store data, to a large company that also wants to provide a series of services on top of the stored data.

To sum-up, the five main functionalities are:

1. Provides mechanisms to store and access energy related data, e.g., micro-production and EV charging;
2. Provides mechanisms to process the data, e.g., calculating energy flows and different pricing options;
3. Provides a set of widgets that can be used to develop a dashboard to visualize the stored (and processed) data. E.g., real-time and historical visualization of the energy flows (as shown in Figure 5);
4. Provides mechanisms to deploy algorithms for remote control of battery energy storage devices;
5. Provides mechanisms to deploy algorithms for remote control of EV charging infrastructures.

2.1.3 Components

The EMS has five main components. 1) the back-end, 2) the front-end, 3) the gateway, 4) storage control, and 5) EV charging control. Figure 7 illustrates the main components of the EMS, and their respective interactions. Note that the only hardware that is part of the EMS package is an optional gateway to account for the situation in which the data is not already uploaded to a cloud-based system.

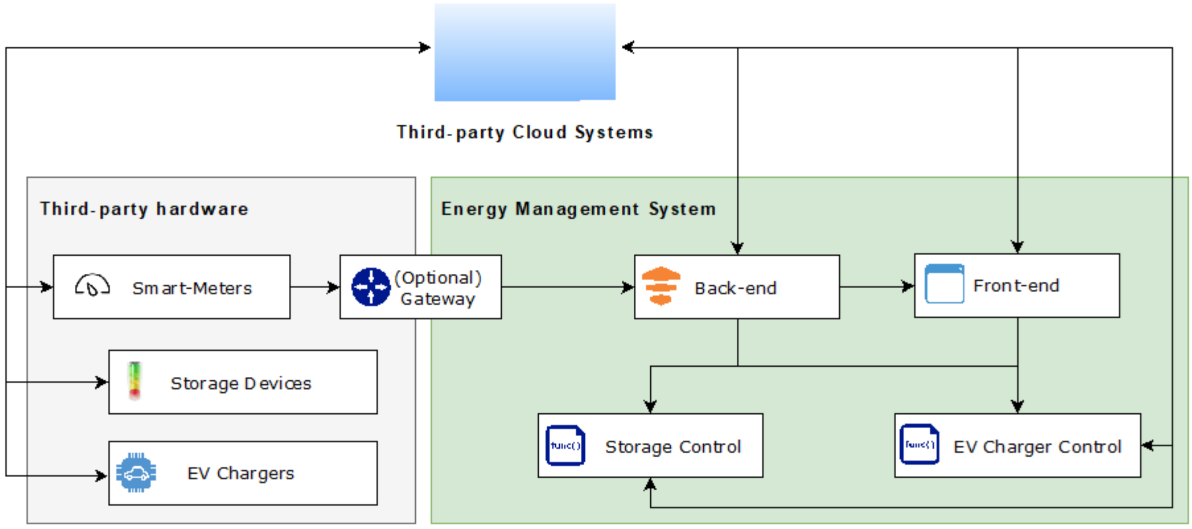

Figure 7. Diagram depicting the main components of the EMS and their respective interactions between each other.

2.1.4 Requirements

There are up to four requirements that must be met in order to use the EMS. Still, these vary depending on whether the monitoring hardware is already deployed.

- No energy monitoring hardware is deployed:
  - (R1) Install smart-meters with support to Modbus (RTU or TCP);
  - (R2) Gateway to establish the communication between the smart-meters and the EMS;
  - (R3) A stable Internet connection to connect the gateway to the internet. This can be either WIFI, Ethernet, of 3/4/5G.
- Energy monitoring hardware is deployed, but the data is not being collected:
  - (R1*) The installed smart-meters need to support Modbus (RTU or TCP);
  - (R2) The gateway needs to be installed;
  - (R3) A stable Internet connection must be available.
- Energy monitoring hardware is deployed and the data is already being collected and stored online
  - (R4) Remote access to the services that store the monitoring data. This requires additional software development to integrate with the different services provided. Note that to provide services that go beyond data storage and access, the monitored data should be made available online at specific time intervals.

2.1.5 Limitations

Despite the system offers the possibility to perform queries/operations in near real-time, the data/operation will only be as updated as the rate of data upload. For example, in a deployment that the data is only uploaded every five minutes, the "real-time" measurement can be up to five minutes old. This is something that can be solved by enabling direct access to the gateway, which can be done both offline and online. A downside of this solution, however, is that it would make the gateway a mandatory requirement independently of the hardware already available.

2.1.6 Technical specifications

Overall, the PRSMA EMS consists of two main layers: the operational technology (OT), and the information technology (IT) layers. The former consists mostly of the hardware components (in this case the smart-meters, EV charging stations and gateways), whereas the latter consists mostly of software components (e.g., databases, web-services, and control algorithms). A simplified representation of the EMS architecture is provided in Figure 8, which also includes an illustration of the integration with third-party cloud services, namely the Route Monkey (RM), and XOLTA.

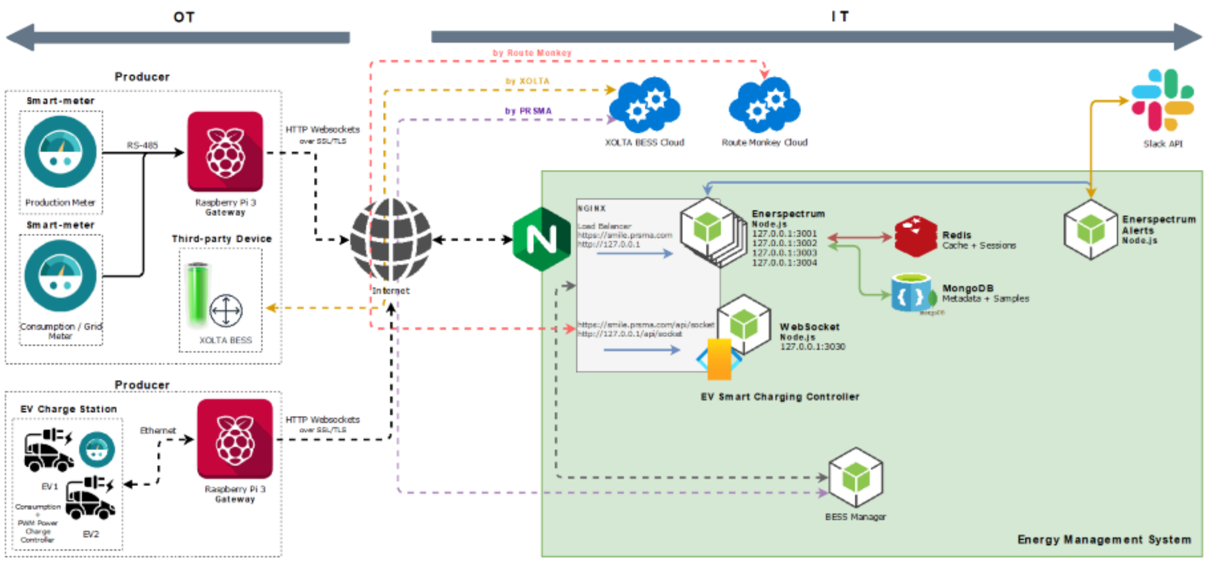

Figure 8. Representation of the EMS architecture, as deployed for SMILE in Madeira Island. In this diagram, only prosumers monitoring (pilots 1 and 2), and EV charging (pilot 3) are represented.

As it can be observed, the data is persisted using NoSQL databases, more precisely, MongoBD. Furthermore, in order to speed-up query operations, a cache mechanism has been put in place using Redis, which is an in-memory data structure store.

All the operations related to storage, are performed on the **BESS Manager (BM)** entity. More precisely, this entity has three main responsibilities: 1) read telematic data from the XOLTA BESS cloud (XBC), e.g., SOC, 2) run the control strategies for each BESS (e.g., greedy control), and 3) send control commands to the XBC. All the communications between the XBC and the BESS are taken care by XOLTA.

The operations related to EV charging, i.e., data access and control, are performed on the **EV Smart Charging Controller (EVSCC)** entity. This is done using Websockets, which enable a two-ways communication between the EMS and the EV charging stations, through the gateway. In smart-charging mode, the provider of smart charging algorithms (Route Monkey- Trakm8) has access to island level production and EV consumption data using the EMS APIs. These data are used to produce daily charging schedules that are exposed to the EMS through the Route Monkey Cloud (RMC). These schedules are then "translated" and sent to the charging stations through the EVSCC. In contrast, in standard charging mode, start and stop charging commands can be sent by the end-users to the EV charger thought the EVSCC. Still, it is important to note that in standard mode, the EVs are in full control of the charging duty cycles.

2.2 Sunamp – Thermal Energy Storage

Sunamp Heat Batteries use Phase Change Material (PCM) to efficiently store heat energy for delivery of high-power hot water and heating (Figure 9).

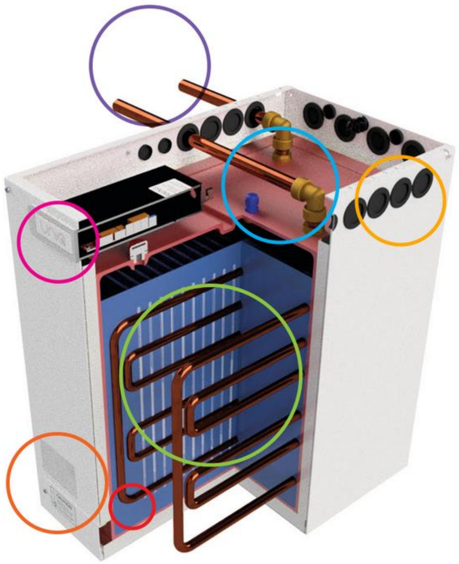

Figure 9. Sunamp's Heat Battery based on Phase Change Materials (PCM).

Sunamp Heat Batteries are available in a number of sizes that can be connected together depending on the size of the system required and the heating and/or hot water support that they deliver. Cells are charged either thermally from an external heat source or from an internal 2.8kW electric element.

Thanks to the Qontroller developed within the SMILE project, the Heat Batteries were used on the Orkney islands to be controlled in a smart manner, to maximise charging during periods in which the local community owned wind turbines would otherwise be curtailed by the local DNO as there was not enough demand on the network. In this way the turbines kept spinning for longer and the income generated was increased.

The storage was used to support nearly 30 homes and was a combination of Heat Batteries with internal electrical elements for charging, or systems charged by an Air Source Heat Pump (ASHP).

Website: https://sunamp.com/

2.2.1 Customer segments

The Heat Batteries used within the SMILE project create value for homeowners, the local community as well as the local Distribution Network/System Operators (DNOs/DSOs).

The homeowners are always the most important Sunamp customers. Actually, the company aims to ensure that they receive an equivalent or better service in terms of their heating and hot water support than their previous system, whilst reducing their overall costs.

The local community benefits as the community owned wind turbines keep spinning for longer and the income generated increases.

The local DNO/DSO also benefits as the grid is stabilised automatically and their reliance on alternative fossil fuel generators is reduced.

2.2.2 Value proposition and main functionalities

For homeowners Sunamp offers reduced costs of running their heating and hot water systems, whilst also ensuring a reliable and robust system with plenty of capacity to offer high power delivery. Sunamp Heat Batteries also save space within the home as they are up to 3 times smaller than the hot water tank alternative and are also better insulated so are cheaper to run. When combined with an Air Source Heat Pump the systems will also be cheaper to charge and are better for the environment as they reduce the reliance on fossil fuel alternatives. For half out the SMILE participants, Sunamp installed electrically charged cells, and the other half received a mix of electrically charges and those charged by the ASHP.

The DNO has very little option in terms of alternative solutions that can be remotely controlled in response to a curtailment signal from the wind turbines on the island, so the combination using OVO control and Sunamp Heat Batteries is a novel solution to this.

2.2.3 Components

Within the SMILE project, Sunamp used hardware and software from OVO in terms of signalling software and Gateways in each home to communicate the signals to the Sunamp hardware.

The Sunamp installs involved UniQ HW Heat Battery products in energy capacities of 3 kWh, 6 kWh, 9 kWh and 12 kWh for Central Heating (CH) support, as well as UniQ eHW 3, 6 and 9 batteries with internal heating elements for Direct Hot Water (DHW). These were either controlled by external B100 Qontrollers or by the SMILE HT Qontroller which intercepted the control signal from OVO platform. Sunamp developed a special version of our control software for this application, which in turn controlled the CH, DHW discharge and charge functions, as well as CH circulation and temperature.

2.2.4 Requirements

In each install location Sunamp required an internet connection so that the hardware could be communicated with, and also an understanding of the size of the property, the expected heat loss, and also the number of occupants. This helped to size the system effectively.

Each Heat Battery has internal temperature monitoring which feeds back to the Qontroller, so this was all incorporated into the installation package.

2.2.5 Limitations

The systems on the Orkney islands for SMILE are very efficient, however an off-peak tariff is needed for improving performance of the system and investment costs of the householders. If this is used, the systems can be preferentially charged during these cheaper electricity periods which helps to further reduce the overall system running costs.

The equipment itself is certified for use within Europe in terms of hot water and electrical and product safety regulations, however, may need further certification or modification for use in other international countries such as the USA (project in progress now).

2.2.6 Technical specifications

The Heat Batteries used within the SMILE project were a mix of Sunamp full range of UniQ compact thermal stores. The UniQ HW range store at least 3, 6, 9 and 12 kWh of thermal energy respectively, and if fitted with an internal electrical element can charge at up to 2.8kW electrically and charge and discharge up to 35kW thermally.

The products weigh 70, 125, 175 and 220 kg respectively, and all have the same footprint of 575mm x 365mm with heights of 435, 635, 890 and 1055mm.

All standard pipework connections are UK 22mm OD however can be easily converted to an International ¾" male brass thread instead, and the electrical connection if required is a 16-amp fused spur. The internal heat exchanger is suitable for pressures up to 10 bar and requires a minimum of 1.5 bar to operate effectively.

The Heat Battery cell has10-year warranty with an expected lifetime of many decades of use.

The Heat Batteries must be installed within a dry and temperature-controlled building and can produce hot water up to 80℃, although the majority of the output will be around 50 - 55℃ at the phase change temperature of the material inside.

2.3 Route Monkey – Predictive Algorithms

Route Monkey is a wholly owned subsidiary of Trakm8 Ltd. Trakm8 is a UK based technology leader in fleet management, insurance telematics, connected car, and optimisation of fleet routing and scheduling. Through IP owned technology, the Group analyses data collected by its installed base of telematics units to fine tune the algorithms that are used to produce its' solutions; these monitor driver behaviour, identify crash events and monitor vehicle health to provide actionable insights to continuously improve the security and operational efficiency of both company fleets and private drivers.
Trakm8's algorithm expertise is being used for all three SMILE islands: Orkney; Madeira and Samsø. For Orkney and Madeira, smart charging of Electric Vehicles (EVs) has been demonstrated. On Samsø, the algorithms are forecasting renewable energy generation and demand to smart charge local battery storage.

Website: https://www.trakm8.com/

2.4 Trakm8's fleet electrification and EV charge point back-office expertise

The growth of on-site renewables and increased uptake of plug-in vehicles both bring new challenges for energy management. Route Monkey-Trakm8 is pioneering new ways of optimising smart grid applications, whether this is better management of peak load demand, smarter network planning, or transforming electric vehicles into optimised energy assets that generate savings for their owners. A specific example of this is Trakm8's development of priority load balancing for EV fleets. This feature gives charging priority to vehicles based on state of charge (SOC), historical demand, user need (app controlled), historical odometer, time and optimisation schedule. **This is a key differentiating feature of Trakm8's Insight-Charge Point back-office (CPBO) platform.** These key capabilities are being demonstrated as part of the SMILE project for Orkney, Madeira and Samsø.

More in specific, Trakm8's expertise in optimisation enables to provide to customer unique fleet electrification solutions. By analysing existing operational data, the potential within a vehicle fleet for electric vehicles (EVs), whether these are plug-in hybrids or pure EVs, can be accurately demonstrated.

2.4.1 Customer segments

Route Monkey-Trakm8 aims to serve the needs of EV & Internal Combustion Engine (ICE) fleet operators, energy utilities and charge point back office operators. Trakm8's Insight-CPBO proposition is charge point technology agnostic and therefore highly interoperable for integration with new or existing systems.
Trakm8 supplies products and service to the Fleet, Optimisation, Insurance and Automotive sectors.

2.4.2 Value proposition and main functionalities

Route Monkey-Trakm8's value proposition for fleet operators includes:

- Optimised use of locally generated renewable energy for EV charging
- Optimised charging during off-peak, low cost periods
- Load management to mitigate upgrades to local infrastructure

The Insight-CPBO value proposition is aimed at EV fleet operators, energy utilities and charge point back office operators.

Trakm8 Insight-CPBO: Full Integration of Fleet Vehicles with Smart Charging
Current state of the art CPBO platforms are typically focused on smart tariffs and billing. Trakm8 provides a fully integrated single Smart Charging CPBO with Trakm8 "Insight" fleet management features, delivering a disruptive set of combined features that do not currently exist in CPBOs designed from a charge-point manufacturer, energy supply or traditional transport management system perspective.

Fully integrated services
Route Monkey-Trakm8 is an expert in energy demand prediction, aggregation and optimisation.
Trakm8's solutions control demand-side assets, such as stationary batteries, electric vehicles and rooftop PV. Its unique algorithms can aggregate and optimise energy management across multiple locations. Using this data, energy requirements can be accurately predicted in order to procure energy at wholesale prices. This creates substantial savings for customers, large and small.
Trakm8's intelligent optimisation further minimises each asset's energy costs, by utilising time-of-use tariffs and demand response opportunities.

2.4.3 Components

For the SMILE project, Trakm8 has developed software and algorithms only. Trakm8 has not provided any hardware for the SMILE project.

Trakm8 provides algorithms for forecasting EV demand, for smart charging, and for generally estimating the flexible capacity that EVs deliver to the wider system.
It uses an activity model based (ABM) approach. The algorithm runs multiple simulations to cover the future prediction horizon of interest, and then capturing these in a probabilistic demand profile. This profile provides confidence levels around the potential demand in future time slots, and therefore used by Demand Response (DR) or similar services to estimate the capacity available from EV charging in the short or longer term.

The smart charging algorithm capabilities are demonstrated on the islands of Orkney, Madeira and Samsø. Figure 10 illustrates the connection between the different stakeholders with Trakm8's technology.

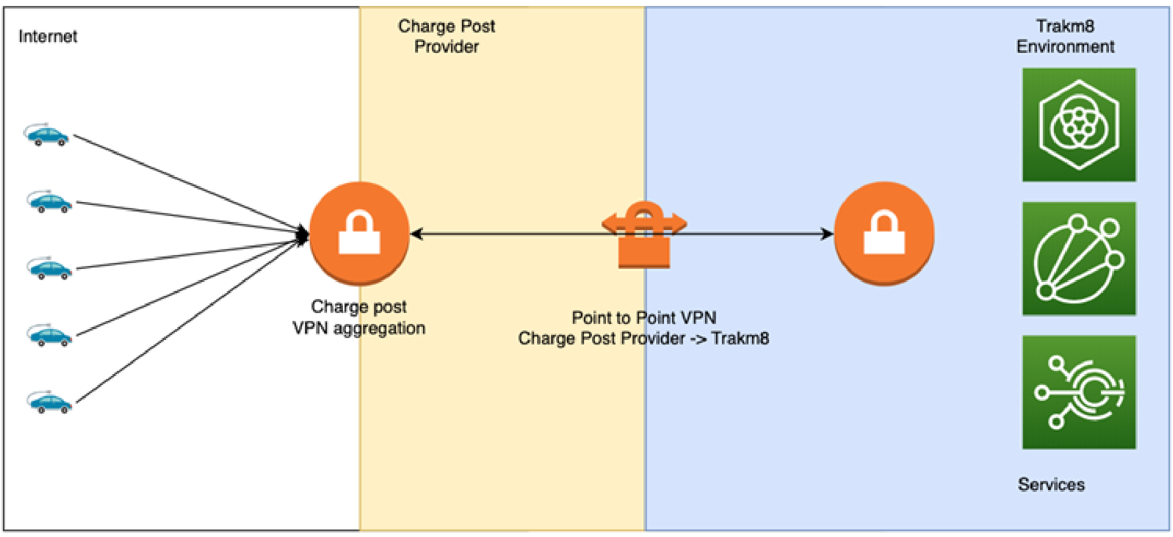

Figure 10. Diagram illustrating the connection between EV's, Charge Post Provider, and Trakm8's services through IoT.

2.4.4 Requirements

Internet connectivity.
EV drivers may have concerns about being left without charge. Drivers need to be reassured and expectations carefully managed.
In the event of failure of Internet connectivity, the charge points connected to Trakm8's CPBO will continue to operate ensuring that no EV is if left without charging capability, i.e. the charge point will continue to provide power for EV charging, but the communications to provide smart charging capabilities will be lost until internet connectivity is restored.

2.4.5 Limitations

The algorithm is capable of generating recharge plans for EVs to ensure that it meets the requirements of the energy supplier while also meeting the unique needs of each individual EV driver e.g. the time a vehicle may be connected to the charge point and the minimum level of battery charge necessary, depending on the EV driver's needs.

Trakm8's Insight-CPBO proposition fully supports industry standards & interoperability via the Open Charge Point Protocol (OCPP), so is fully compatible with any charge point manufacturer's testing and integration requirements that also operate under OCPP. OCPP1.6/2.0 accommodates different smart charging modes/models/levels such as slow, fast and rapid charging, V2G, Demand Side Management, AC or DC charging along with public or private infrastructure. Trakm8's Insight-CPBO is capable of supporting roaming via secure API interfaces with any third parties, giving full supplier/customer control over exchange of EV data such as charging session or driver/billing point ID. The company flexible, interoperable and hardware agnostic approach offers significant procurement advantages in terms of both hardware and software system build modularity, technology future proofing and avoidance of stranded assets. This provides much welcome risk mitigation for the majority of fleet operators who are new to fleet electrification strategy and implementation.

The growth of on-site renewables and increased uptake of plug-in vehicles bring new challenges and opportunities for energy management. Trakm8's Insight-CPBO proposition fully supports new ways of optimising advanced grid systems, whether this is better management of peak load demand, energy curtailment, smarter network planning, or transforming electric vehicles into optimised energy assets that generate savings for their owners.

2.4.6 Technical specifications

Trakm8 algorithms and CPBO is hardware agnostic and there is the possibility to connect via secure API to any other CPBO or OCPP1.6 compliant charge point.

2.5 Lithium Balance/Xolta – Battery Energy Storage System

Lithium Balance/Xolta is a company that designs and manufactures battery management systems (BMS) and residential and C&I battery systems (BESS). The BESS provided by Xolta have the following features: designed for indoor and outdoor operation, minimal total cost of ownership (TCO), extraordinary safety, high round-trip efficiency during operation and standby, cloud-connected (for telemetry, operation visualisation and system control).

In the scope of the SMILE project, Lithium Balance/Xolta developed and provided 14 battery systems to the following locations:

- Samsø island demonstrator:
    - BESS, 3ph. 50kW/237kWh;
    - Battery system controlled and operated by Lithium Balance/Xolta
    - PV self-consumption combined with energy cost minimisation by performing intelligent control of battery and local loads (demand side management);
- Orkney island demonstrator:
    - 5 x 1ph. 3.5/8kWh residential battery systems;
    - All battery systems are operated Kaluza via API;
    - Battery provides heat pump load following service and it minimises power curtailments on the island;
- Madeira island demonstrator:
    - BESS 1 x 3ph. 40kW/79kWh;
    - 7 x 1ph. 3.5/8kWh residential battery systems;
    - All battery systems are operated by PRSMA via API;
    - Batteries provide different services (PV self-consumption, frequency and voltage support);

Website: https://lithiumbalance.com/

2.5.1 Customer segments

Battery Energy Storage Systems can be of great value for many users. The main customers for this technology are;

- Commercial and Industrial (C&I) customers
- Microgrid developers
- Private homeowners
- Housing associations
- Distribution System Operators

Both Housing Associations and Private Homeowners are the most important customers. The value proposition and main functionalities for each customer are described in more detail below.

2.5.2 Value proposition and main functionalities

C&I customers
With the use of energy storage C&I customers can increase their use of green energy and add to the company's green transition. Customers can minimize the impact of high tariffs and demand charges by using stored energy in peak hours. They increase the benefit of their solar investment by using more green energy. Furthermore, customers can provide frequency support by offering their battery as a

balancing unit for the grid in markets that allow it. Experts call it a “game-changer” for battery asset owners, since it can result in a significant extra source of income and speed up asset payback time. As XOLTA batteries are modular and scalable, customers could at any time their needs should increase, add more batteries to existing ones. And as the batteries are cloud-connected, they are constantly monitored for performance and safety and customers could always follow their production, consumption and savings in the XOLTA web app.

Microgrid developers
Using XOLTA energy storage systems when developing microgrids means that it is possible to limit the genset use and save both time and money transporting diesel to the site. The ability to scale the solution based on increasing need means to avoid over-investing from the beginning and can add capacity if and when the customer needs grow. XOLTA batteries are like building blocks that way.
The XOLTA battery racks are designed for outdoor installation and function in virtually any climate around the world. The racks are easily installed and operated which is a great benefit when developing and installing microgrids in remote areas. Inside the cabinet itself, everything is modular.

Private homeowners
With the addition of a XOLTA battery to their solar installation, homeowners can get even more out of their solar investment. With a battery they are able to use the solar energy even when the sun is not shining as it is saved on the battery. This means that homeowners will have a lower energy bill, they will save on tariffs, they become more independent of the grid and they increase their green footprint by saving CO_2 as well. Moreover, a battery supports the green transition and the wish to do more for the climate which is present for many homeowners who have chosen solar cells for their house. Private homeowners can choose between BAT-5 or BAT-10 depending on their need for storage capacity.

Housing associations
More and more housing associations – or apartment complexes / housing cooperatives are turning to green energy when energy optimizing the buildings they live in. To optimize energy use many choose to have a solar installation that can help save money on the energy for common areas or individual apartments. Often, the investment can be paid by the savings – if batteries are also included. This provides more energy to the buildings and at hours when the sun cannot provide enough. At the same time it adds to the green image of the complex which can make it more appealing to future residents. All XOLTA batteries are expected to be suitable for apartment complexes and as they are modular and scalable, customers can at any time their needs should increase, add more batteries to existing ones. And as the batteries are cloud-connected, they can be constantly monitored for performance and safety and customers can always follow their production, consumption and savings in the XOLTA web app.

Distribution System Operators (DSOs)
DSO is responsible for grid stability, energy quality and distribution system operation. The battery storage system can bring benefits to the DSOs. Battery system is then connected as an asset to the distribution grid. The battery can support grid management by helping to avoid, grid congestion, transformer overloading and providing the service of peak shaving. This allows DSOs to defer costly grid reinforcement and at the same time enabling a higher share of renewable generation. Furthermore, battery system can support power quality management and lower transmission losses in the distribution network by providing appropriate active, reactive power in all four quadrants. The proposed battery has an advantage in comparison to competing solutions by fast deployment and scalability. Moreover, it could be easily relocated from one part of the grid to another if required.

The main advantages of the solution are:

- Flexibility in location, fast deployment;

- Indoor and outdoor operation capability;
- Multipurpose (many services possible: renewables integration, different services for the electrical grid support ,etc.);
- Very high round-trip efficiency during operation and minimal losses during standby;
- Interoperability with other system by means of cloud solutions;

2.5.3 Components

- The solution provided by Lithium Balance/Xolta consists of hardware and software components. The main hardware components are: battery cells, battery packs, cabinet rack, BMS, battery protection unit, battery monitoring sensors, thermal management system, battery inverter, energy meters, microprocessor for system control and monitoring.
- The most important software components are: the site controller for 1) battery system monitoring and control; 2) multiple rack management; 3) communication with internal components (e.g. battery inverter, thermal management system) and externals (energy meters, Xolta cloud). Moreover, there is the BMS software which is responsible for battery system monitoring, battery cell balancing, battery diagnostics and battery system safety.
- The cloud software solutions for storing battery system telemetry battery, battery system remote monitoring, and battery system remote control over provided API.
- The Xolta mobile app for real-time and remote battery system monitoring and diagnostics.

2.5.4 Requirements

The minimum requirements for implementing this solution are:

- electrical grid connection (single or three phase depending on the system type);
- internet connection;
- energy meters connection;

2.5.5 Limitations

The system limitations are as follows:

- The system needs to be certified according to the country specific grid codes. It is currently compatible with the most of the European grid codes (but not with all of them) which limits replicability (additional grid code compliance certification is required);
- Telemetry data are collected in the cloud with 10 seconds resolution. However, this is expected to be fine for most of customers. More frequent telemetry gathering could be possible but it highly would increase the cost for data storage.
- Limitations in regards to number of API calls if battery system is to be controlled by the external energy management system (EMS). The number of API calls can be also increased for the higher cloud related price.

2.5.6 Technical specifications

The technical specifications of a Commercial and Industrial (Table 1) and Residential (Table 2) Battery Energy Storage System (BESS) are illustrated below.

Table 1. BESS Specifications of the singular rack.

Chemistry	NMC	
Power/rack	50 kW	
Energy/track	75 kWh	
Battery Voltage	585 – 806V (DC)	
Power/energy density	83W/kg, 125Wh/kg	
Weight	~600kg	
Dimensions	600x600x2100 mm	
Recom. Abient Temp.	10℃– 25℃	
Round-trip eff. (with inverter)	>90%	
Expected life	15 years	
According to	CE, UN38.3, EN 62619	
Protection class	IP21	

Table 2. Residential BESS Specifications of the singular rack.

Chemistry	NMC	
Power/rack (max)	3.4 kW	
Energy/track	8 kWh	
Battery Voltage	40 – 50V (DC)	
Weight	~60kg	
Dimensions	589x410x338 mm	
Recom. Abient Temp.	10℃– 25℃	
Round-trip eff. (with inverter)	>86%	
Expected life	15 years	
According to	CE, UN38.3, EN 62619	
Protection class	IP21	

2.6 OVO Energy/Kaluza Flex - Energy Flexibility Platform

Kaluza, proposed by OVO, is a real-time, B2B2C SaaS platform aiming at accelerating the shift to a zero carbon world. From revolutionising billing to smart electric vehicle charging, the expectation of Kaluza's technology is to empower biggest energy retailers and utilities to better serve customers. The real-time cloud platform is transforming retail operations, reducing cost to serve, boosting customer engagement and enabling decarbonisation through smart, low carbon energy technologies.

The module Kaluza Flex is focused on enabling residential demand response solutions. Built to intelligently charge millions of smart in-home devices, Kaluza Flex is expected to mobilise customers in the energy transition by making decarbonisation simple and rewarding. Bridging the gap between distributed renewable generation and smart devices, Kaluza Flex is expected to help consumers shift their energy consumption to times of plentiful renewable energy – not only saving them money, but enabling society as a whole to meet the challenge of decarbonising transport and residential heating/cooling.

Website: https://www.ovoenergy.com/

2.6.1 Customer segments, value propositions and main functionalities

Segment 1: Energy retailers and utilities building innovative propositions for consumers who own flexible devices

A flexible device is defined as one whose energy consumption can be shifted towards times of lower grid demand while still being able to meet the primary needs of the consumer that owns and operates the device. An example of this could be a domestic electric vehicle charge point paired with an electric vehicle. Typically, for a vehicle that plugs into such a charge point in the evening, the user may not need their vehicle until the early hours of the morning, for example 7 AM. Yet, the actual amount of charging hours required may only be for 5 hours. Kaluza's algorithms are able to exploit this "flexibility" by shifting the energy consumption of the car towards times of lower grid demand, such as the overnight hours, giving the consumer a full electric vehicle when they need while not increasing grid demand during peak periods such as the evening period.

Kaluza's technology achieves this by integrating with a range of flexible devices such as electric vehicle charge points, electric vehicles, home batteries and smart heating, ventilation and air conditioning (HVAC) devices. The consumer should use a companion app enabled by Kaluza, expected to be provided to the consumer by or on behalf of their device manufacturer or energy retailer, to indicate how they intend to use the device so that Kaluza's algorithms can take that into account when shifting energy consumption. For example, Figure 11 illustrates how a consumer with a Kaluza-enabled electric vehicle charge point can specify at what time of the day they need their car "ready by", and Kaluza's algorithms will shift the charge point's energy consumption while also ensuring that the car is at the consumer's desired state of charge at the ready by time.

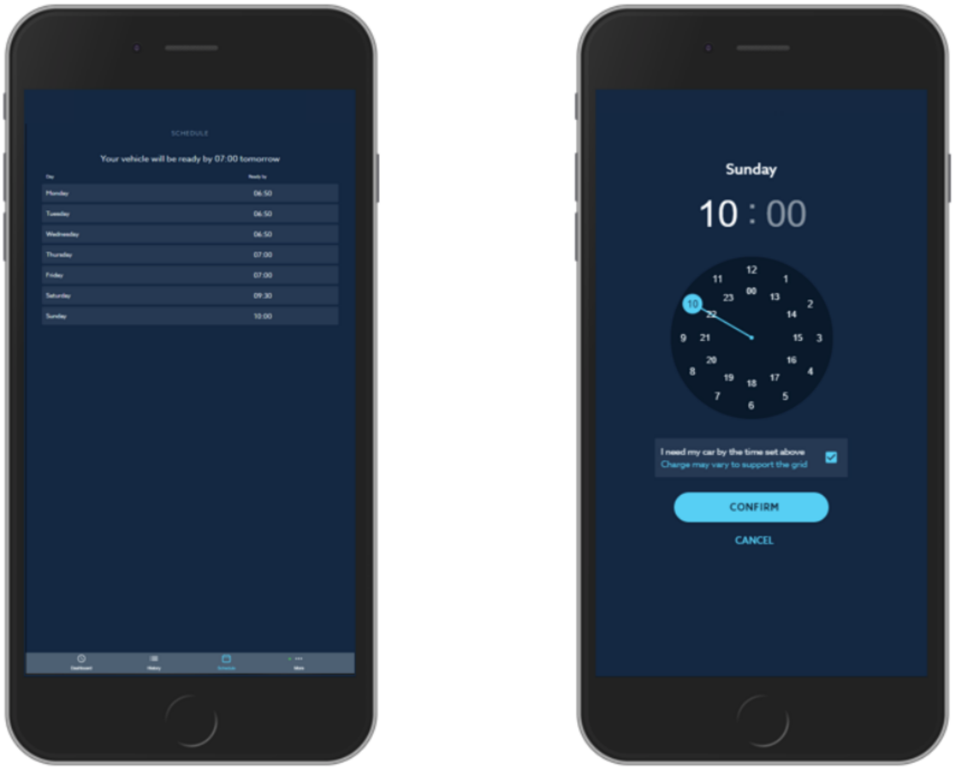

Figure 11. Setting the "ready by time" for the charger

By shifting consumption away from times of peak grid demand to low grid demand, Kaluza is expected to reduce the energy retailer's cost of supply for owners of such smart devices. This in turn, allows the energy retailer to attract and retain consumers who have such smart devices in their homes with attractive propositions that take advantage of this reduced cost of supply and pass some of those benefits to the consumer. Consumers also receive insights on their electric vehicle electricity consumption and how that compares to the rest of their home, as well as insights on the positive carbon impact from their choice to have and intelligently charge smart devices. Finally, energy retailers are able to understand any issues that their consumers might face in relation to the smart control of their flexible device by utilising an Operations Console which helps them visualise the day to day behaviour of individual devices so as to answer any end customer queries relating to managed charging, while also offering paths to resolution to some common customer issues. It is also integrated with issue management tools so that support teams can raise issues with Kaluza relating to a specific device and track them within the Console.

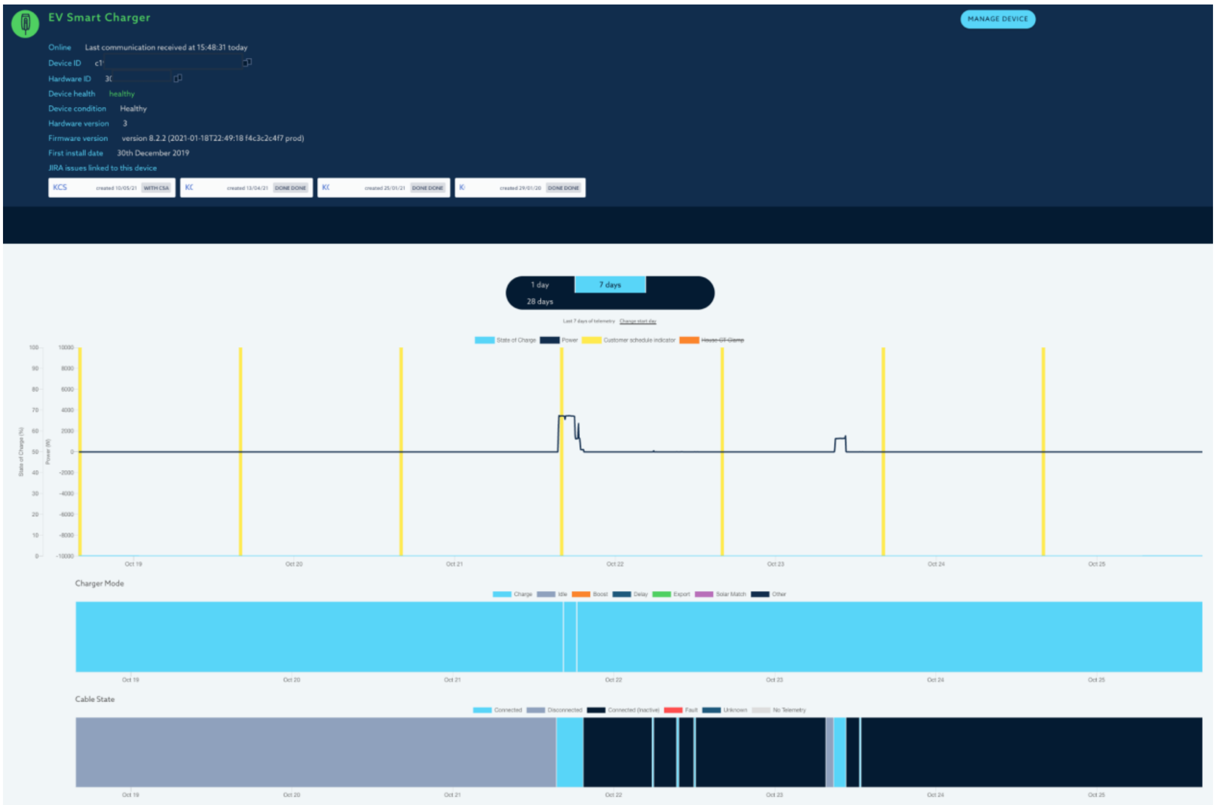

Figure 12. Kaluza's Operations Console showing an EV smart charger's activity

Segment 2: Trading teams in energy retail companies, Distribution System Operators (DSOs) and Transmission System Operators (TSOs)

Flexibility value is generated from flexible devices on behalf of the trading teams in the respective energy retail companies as well as Distribution System Operators (DSOs) and Transmission System Operators (TSOs), as well as entities that work on their behalf - such as the ANM system in Orkney whose signals Kaluza followed to determine curtailment mitigation strategies.

Various routes have been built by which such flexibility operators can interact with the platform and influence the charging decisions of various flexible devices, all the while ensuring that consumer needs - such as having a ready car at their ready by time - are met. Below an example as to how grid operators can inspect and assess the value of the flexible devices in their portfolio / region.

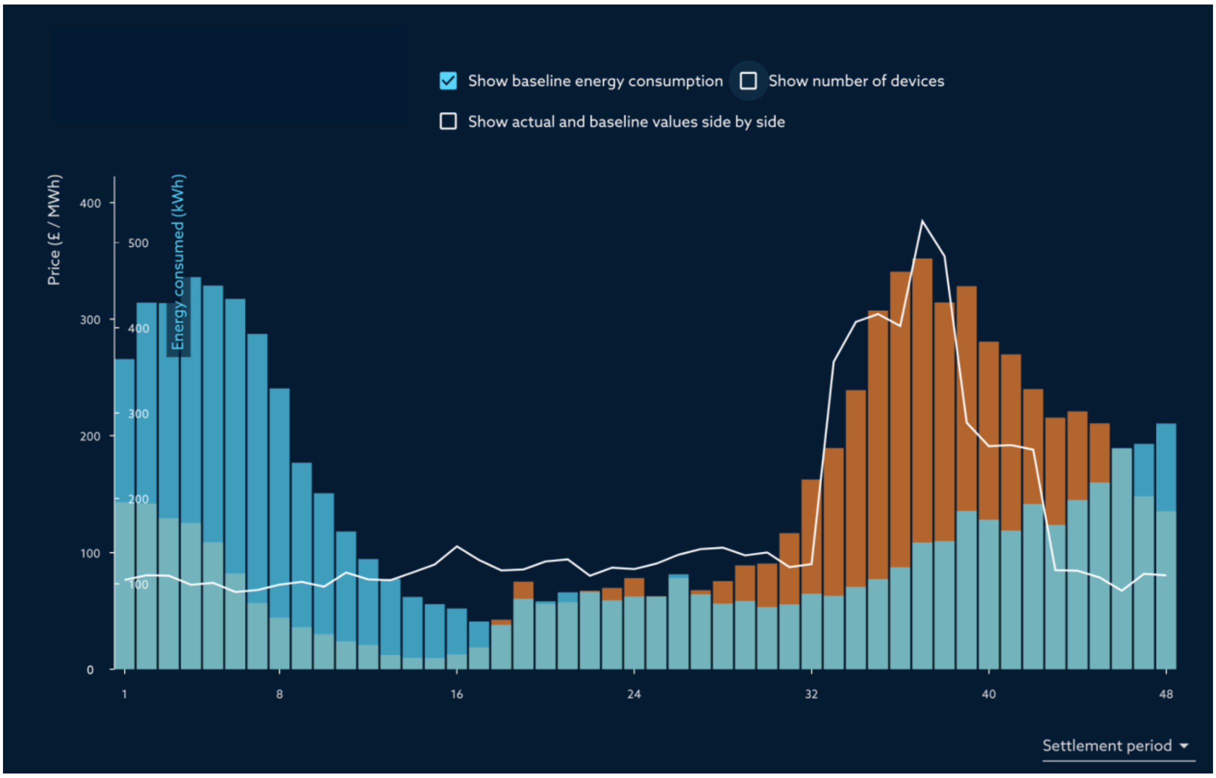

Figure 13. Kaluza Consumption Shifting Value dashboard showing how Kaluza's intelligent managed charging of its portfolio creates value compared to unmanaged charging, against an energy price curve

Segment 3: Original Equipment Manufacturers (OEMs) manufacturing devices that can be smartly controlled

For value from flexibility to be generated, Kaluza Flex needs to be able to smartly control flexible devices. This means connecting to and controlling various types of devices so as to unlock innovative propositions as the ones described in Segment 1 above which saves consumers money over the long run. Therefore, OEMs whose devices can be connected to and controlled by Kaluza benefit from their consumers enjoying reduced total cost of ownership over the lifetime of the device. This can in turn lead to increased device sales as well as access to potential future recurring revenue streams after the device sale.

Kaluza's system can communicate with a variety of device types (and brands)

- Domestic electric vehicle charge points (unidirectional)
- Domestic electric vehicle charge points (bidirectional / "Vehicle to Grid")
- Electric vehicle manufacturers ("direct to vehicle" / "telematic charging")
- Home energy storage batteries
- Smart heating, ventilation and cooling (HVAC) systems

There are a series of APIs enabling device manufacturers to integrate their connected devices for Kaluza connectivity and control so that they can be part of Kaluza-enabled consumer propositions.

2.6.2 Components

At a high level, the Kaluza Flex system consists of the following components which allows it to be deployed for a variety of grid flexibility applications:

- OEM APIs - that allow various OEMs to connect their devices so that they can be controlled by Kaluza. In some cases, Kaluza may directly integrate with the OEM's APIs or backend systems to facilitate connection and control; or via a gateway device co-located with the flexible device that can communicate with the flexible device over MODBUS-RTU or RS-232
- Energy Retailer APIs - that allow energy retailers to build experiences enabled by Kaluza Flex data and control within their existing consumer experience, as well as to facilitate the link up of the consumer's energy account to their Kaluza-compatible device so that they can be part of Kaluza-enabled retailer propositions
- Consumer Experience Toolkit - that allow OEMs / energy retailers to deliver a branded consumer experience so that they can enter their requirements around which Kaluza can flexibly charge. In many cases, the Kaluza system can work alongside any local control system employed by the OEM
- Market Integrations - integrations with the relevant grid operator / DSO / TSO / trading team's systems so that Kaluza Flex optimises around the desired flexibility objectives
- Flexibility Engine - A device and market-agnostic optimisation engine that can take in a variety of consumer needs and market needs as well as real-time telemetry from devices to deliver the desired flexibility objectives
- Administrative Interfaces - A series of dashboards and tools built for a variety of administrative personas that:
    - Enable support for flexible devices, for permissioned first line support teams within the retailer and device manufacturer that receive direct contact from consumers
    - Enable visualisation of flexible devices
    - Alter the optimisation pathway for a portfolio of devices, for a permissioned flexibility operator
    - Increase understanding of how flexible devices create value

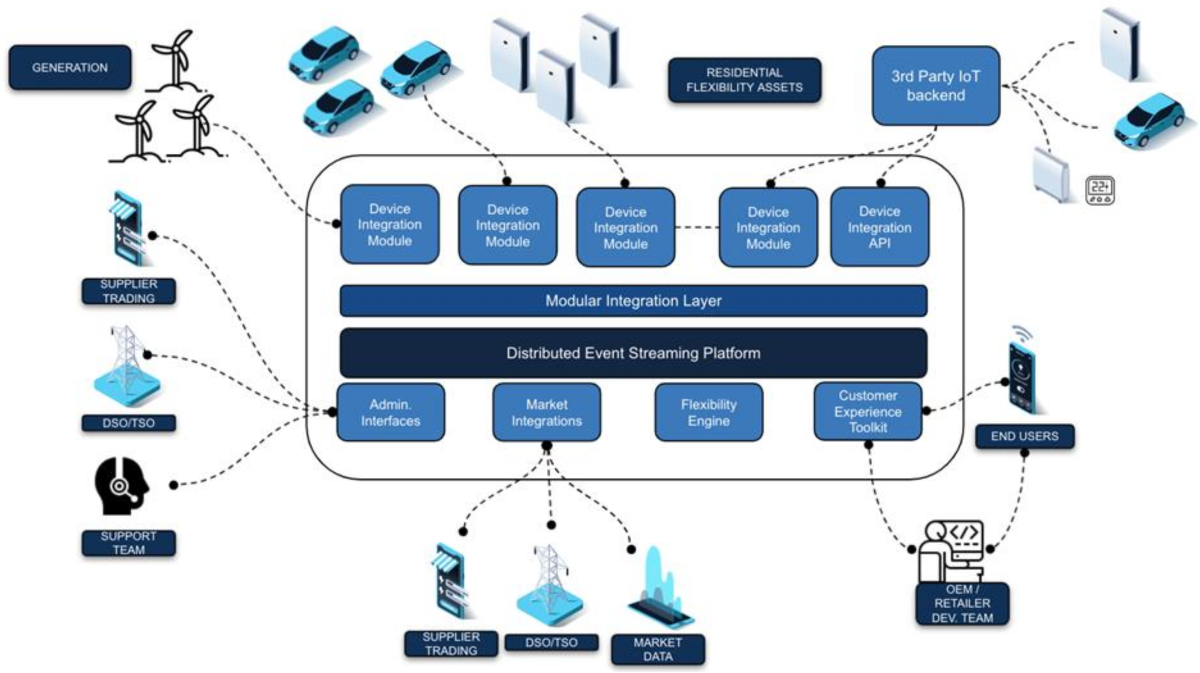

Figure 14. Representation of Kaluza's architecture and services offered for different customer groups

2.6.3 Requirements

The requirements that need to be met for devices to be connected to and controlled by Kaluza for flexibility objective are the following:

- A device that can either communicate either via MODBUS-RTU, RS-232 or directly to the internet via TCP
- A gateway device to establish communication between the relevant device and Kaluza Flex over the internet, if the device cannot itself be connected to the internet
- A stable internet connection to connect the gateway or device to the internet. This can be either WIFI, Ethernet, or 3/4/5G.
- Where required, a companion application that enables the consumer to specify their charging needs to Kaluza

2.6.4 Limitations

Devices communicate information at varying levels of resolution, with some devices communicating data only at 15 minute intervals. This can affect Kaluza’s ability to respond to certain grid events or validate that the right response has occurred within the time window of the event. Devices used for the SMILE project however did not have this issue.

2.6.5 Technical specifications

Kaluza’s technology is based on a modular microservices model backed by a distributed event streaming platform. The core flexibility engine is device type, flexibility use-case and market agnostic.

3 SMILE Solutions

3.1 Madeira – overview of the proposed solutions

Madeira Island is located in the North Atlantic Ocean, close to Morocco and Canary Islands (Figure 15). It is the main island of the Madeira archipelago - which includes Porto Santo, Desertas, and Selvagens Islands - and is one of the two Portuguese autonomous regions.

Figure 15. Location of Madeira Island

Due to its remote location, Madeira is a total energy island – i.e., not electrically connected to the mainland. In such a scenario, increasing the penetration of RES (unstable by nature) while maintaining grid stability is very challenging. The Madeira demonstrator in SMILE was designed with the goal of tackling such a challenge and consists of three main solutions (thoroughly described in sections 2, 3 and 4):

- Solution 1, "*DSM and BESS for optimizing self-consumption,*" aims to optimize self-consumption in the so-called UPACs – i.e., those PV production units that operate in self-consumption regime and are not allowed to inject excess production into the grid. From a technological standpoint, this solution relies on the use of Battery Energy Storage Systems (BESS) – provided by Lithium Balance\Xolta (see chapter 2.5) -, which are managed according to ad-hoc control algorithms (developed by PRSMA, see chapter 2.1).
- Solution 2, "*Voltage control and peak-shaving,*" aims at providing load-levelling and voltage control services at the distribution network level. This is achieved by upgrading a LV distribution substation with a properly dimensioned BESS that can work as a buffer for the grid.
- Solution 3, "*EVs smart charging,*" provides a set of cheap and non-intrusive smart charging systems for different typologies of electric vehicles. It consists of a set of off-the-shelf and custom-made hardware, combined with software solutions provided by PRSMA and Route Monkey (see chapter 2.3).

The three above-mentioned solutions are integrated into and managed by the Energy Management System (EMS) developed by PRSMA (Figure 16).

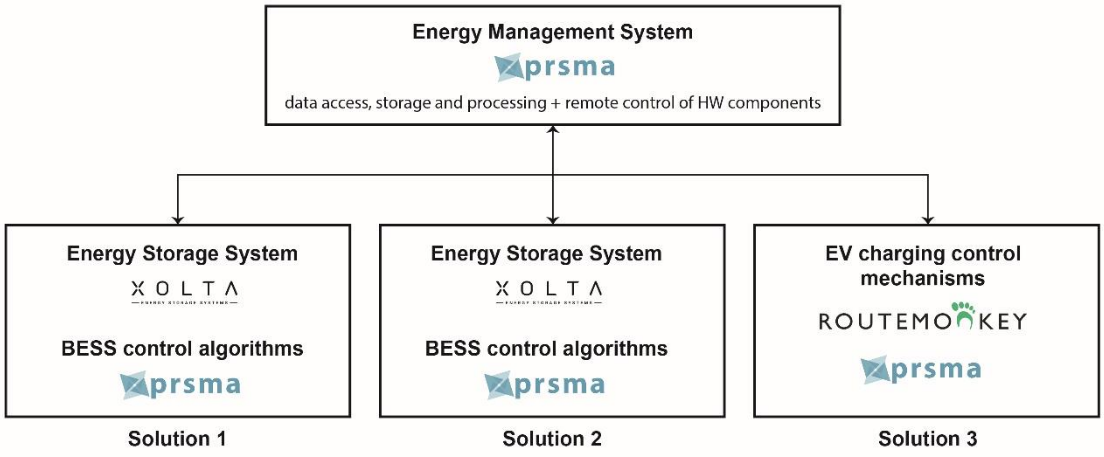

Figure 16. Role of the SMILE technology providers in each of the solutions demonstrated in Madeira.

3.2 Energy Management System

3.2.1 Value proposition and main functionalities

The PRSMA Energy Management System (EMS) is the backbone of the Madeira demonstrator. Its main value proposition as mentioned in chapter 2.1 is to provide a **software solution for storing, accessing, and processing energy-related data** (e.g., micro-production and EV charging) collected from the pilot sites where each of the above-mentioned solutions is being deployed.

Two are the main strengths of the EMS:
1. **Interoperability**: the system is hardware-agnostic (i.e., compatible with different third-party systems and technologies, like BESS or energy monitoring systems).
2. **Flexibility**: it can be easily adapted and upgraded with new features and data sources.

The EMS provides the following main functionalities:
- data access, query, and storage mechanisms.
- data processing functionalities e.g., calculating energy flows and different pricing options.
- a set of widgets that can be used to develop a dashboard (Figure 17) to visualize the stored - and processed - data. E.g., real-time and historical visualization of the UPACs' energy consumption and production patterns.
- remote control of battery energy storage devices deployed at the pilot sites (solutions 1 and 2).
- mechanisms to deploy the EV smart charging algorithms for remote control of pilot sites infrastructure (solution 3).

Figure 17. Combination of UI widgets to provide a dashboard for UPACs comparing production and consumption data from two different weeks.

3.2.2 Target group

In Madeira, two are the main target groups of the EMS:

- The system administrator (i.e., the local SMILE partners managing the Madeira demonstrator).
- The end-users of the different solutions being deployed. Specifically:
  - Distributed generation equipment owners (solution 1).
  - Distribution System Operator (solution 2).
  - EV charging equipment owners and operators (solution 3).

Additional customer segments (not involved in the Madeira demonstrator) that could benefit from the implementation of the EMS are:

- Vendors and installers of energy storage systems.
- Companies providing flexibility services to DSOs and TSOs.
- Vendors and installers of EV charging equipment.

3.2.3 Components

The EMS has five main components.

1. the back-end.
2. the front-end.
3. the gateway (optional - for the situation in which the data is not already uploaded to a cloud-based system).
4. storage control.
5. EV charging control.

Figure 18 illustrates the main components of the EMS and their respective interactions.

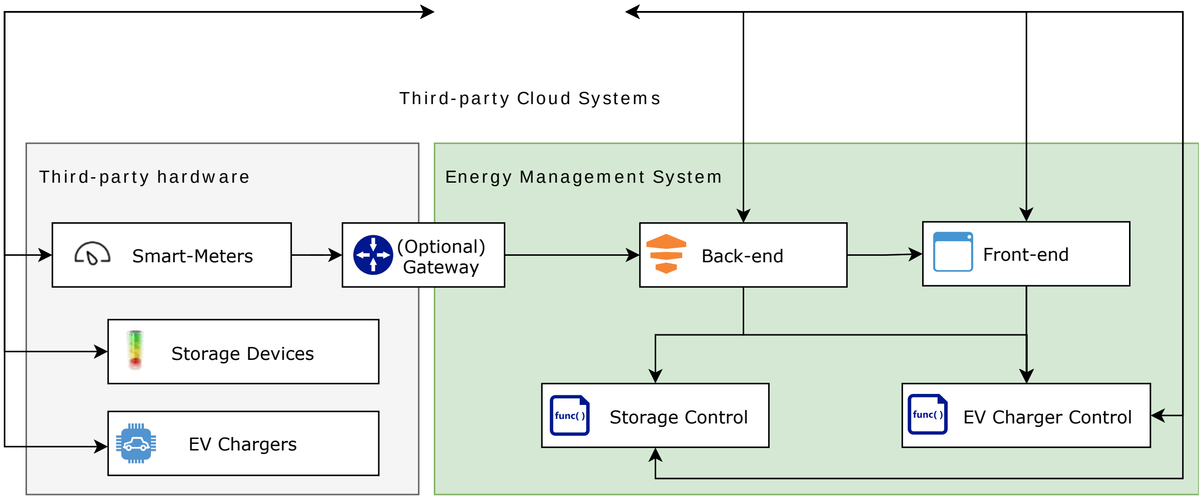

Figure 18. Diagram depicting the main components of the EMS and their respective interactions with each other.

In summary, the system consists of a set of databases and APIs (**back-end**), intended to:

- store and provide access (via the **front-end**) to different types of energy-related data collected (through a **gateway**) from the different third-parties hardware.
- run the **storage and EV charging control** strategies.
- send commands to the third parties hardware (i.e., storage devices and EV chargers).

3.3 Solution 1: DSM and BESS for optimizing self-consumption

3.3.1 Value proposition and main functionalities

Goal of this solution is to **optimize self-consumption from solar PV generation by providing real-time cloud-based control of BESSs.** Based on the user's production and consumption data, an algorithm running on the EMS manages charge and discharge of a BESS according to a set of control strategies. The storage control mechanism could be set to meet very diverse goals, for instance:

- increase self-consumption by storing excess production for later use.
- reduce the electricity bill by pre-charging the BESS during off-peak periods (when the cost of energy is lower) and use it to cover demand during peak periods or early morning loads (particularly relevant in the case of commercial UPACs) when there is little or no production from PVs.

The main advantages of this solution are:

- compatibility with different monitoring and energy storage systems.
- the possibility of implementing several control strategies.
- access to detailed energy feedback on production, consumption, and battery status, provided through a user-friendly web interface (Figure 19).

Figure 19. Interface providing information about (on the top) load flows - consumption, PV production, and PV surplus - and (on the bottom) State of Charge (SOC) of the BESS.

3.3.2 Target group

This solution targets:

- commercial and domestic UPACs (whether they are allowed to inject energy surplus into the grid or restricted to self-consumption).
- local energy communities.

3.3.3 Components

Hardware:

- Solar PVs.
- Energy monitoring systems.
- Gateway (optional).
- BESS.

Software:

- EMS back-end.
- EMS front-end.
- BESS control algorithms.

3.3.4 Requirements and limitations

Political-legal factors

In some countries or regions there could be limitations in terms of maximum installed capacity or other regulatory barriers that could impact the effectiveness of this solution. In the case of Madeira, from 2014 (with the publication of the Decree-Law 153/2014) until June this year (when the new RDL 1/2021/M entered into force), new UPACs installations were not allowed to inject excess production into the grid. For this reason, some of the existing UPACs (at least those installed over the last 7 years) have very limited excess production and consequently would not significantly benefit from our solution.

Moreover, it should be pointed out that under some legal frameworks, the components of a PV installation have to comply with a set of technical requirements - e.g., inverters with specific characteristics must be installed (especially in installations located at the end of the branch) in order not to compromise the distribution grid. All these regulatory limitations could compromise the economic feasibility of implementing this solution.

Economic factors

Energy Storage technologies are still relatively expensive and may not be a viable investment for a small domestic UPAC. For example, in Madeira it was found that for UPACs with limited installed capacity, savings resulting from the deployed system do not justify the initial investment cost. In those cases, increasing the production capacity appears to be the most viable workaround to this issue.

Social factors

People's knowledge of Energy Storage Systems and DSM is still relatively limited. Promoting initiatives to raise people's awareness of these technologies and the benefit they could bring may be an effective strategy to overcome such a barrier. In Madeira, for example, during the participants' recruitment phase, the local partners organized several information sessions to explain how the system works and address UPACs concerns about energy storage technologies. Adopting this strategy allowed the research team to engage the local community and gain their trust. An aspect, the latter, that is extremely important when people do not trust the technology.

An additional social barrier - though deeply related to regulatory and economic factors - encountered during the project is the lack of interest of some UPACs in improving their systems. Some of the potential participants initially approached reported to regret the decision of installing a PV generation asset and claimed not to be willing to invest any more time or money into it. This disappointment is due to the fact that in Madeira there are no incentives for installing solar PV panels, and currently, the feed-in tariff is very low, which limits the ROI. Once again, engaging the community in discussions around energy generation and strategies for better management of their installations helped mitigate this initial barrier.

Ultimately, energy storage systems could be considered unappealing. In Madeira, only a few participants expressed (minor) concerns in this regard. However, in a different geographic/cultural context, the aesthetics of such systems could represent a potential barrier to technology adoption.

Technological factors

The minimum requirements for implementing this solution are:

- **Reliable internet connection**. Such a requirement represented a barrier in Madeira. In fact, due to the poor quality of the internet connection in those installations located in rural areas, the local partners had to install a dedicated network.

- **Energy monitoring system** (collecting consumption and production data). Poor quality of the PV installation or the use of the so-called plug-and-play PV systems may prevent installing any monitoring system. In Madeira, some of the participants initially engaged in the project have been dropped because of this limitation.
- **Communication gateway** (in case the energy monitoring system do not provide access to consumption and production data).
- **Battery Energy Storage System.**

Moreover, despite this solution (software-side) is highly compatible with several systems, the HW used should comply with the following requirements.

Monitoring equipment:

1. Support communication through the ModBus protocol;
2. Support documentation for the implementation of the ModBus protocol.

Communication gateway:

- allow the use of Modbus protocol.

BESS:

- Provide access to an interface (e.g., web APIs) for monitoring the BESS;
- Provide access to an interface (e.g., web APIs) for controlling the BESS.

Finally, an additional limitation that could hinder the adoption of this solution relate to the fact that the installation place must meet a set of minimum conditions (e.g., space, ventilation, temperature, humidity, etc.) for ensuring safe and optimal operation of the BESS.

Environmental factors

Some control strategies could result in perverse incentives. For example, in Madeira it was found that pre-charging is more profitable even if this represents a decrease in the self-consumption rates.

Real-time control using a cloud-based solution implies the deployment of computing and communication infrastructures. The more granular the control (e.g., in Madeira control is performed every 5 minutes), the more processing is required. While this may not be visible for a low number of installations (e.g., in Madeira the deployment involves only 5 UPACs), as systems scale, it is important to take also these aspects into consideration.

Ultimately, the environmental impact of the energy storage system (which varies depending on the typology of battery used) is a potential limitation of this solution.

3.4 Solution 2: Voltage control and peak-shaving

3.4.1 Value proposition and main functionalities

The value proposition of this solution is to provide grid stability services, namely voltage support (particularly relevant for isolated power systems with high penetration of renewables from Distributed Energy Resources) and peak-shaving functionalities. This is achieved by deploying a BESS at the low-voltage distribution network level, which is operated as a highly responsive storage backup to regulate events that may transcend some of the grid Quality of Service (QoS) thresholds.

The BESS control process is very similar to the one described in the previous section. In this case, the control algorithms trigger real-time events based on the grid status when selected metrics are outside predefined (and configurable) thresholds.
In Madeira, the solution is being deployed at a LV distribution sub-station that has a considerable amount of UPPs (i.e., generation units that, unlike UPACs, inject all the energy produced into the grid) connected to it. Here, the BESS works as a buffer for the grid:

- it stores excess production from UPPs in order to minimize the chance of voltage fluctuations due to the intermittency of renewable production; and
- is then discharged to respond to an unexpected increase in the demand, thus helping to flatten the load curve.

3.4.2 Target group

The main target groups for this solution are:

- Network operators such as DSOs.
- Companies providing flexibility services to DSOs and TSOs.

3.4.3 Components

Hardware:

- Grid quality analyzer.
- Gateway (optional).
- BESS.

Software:

- EMS back-end.
- EMS front-end (Figure 20).
- BESS control algorithm.

Figure 20. Interface providing information about (on the top) active and reactive power and (on the bottom) a set of additional quality parameters (e.g., power factor, frequency, voltage).

3.4.4 Requirements and limitations

Political-legal factors

With the 2019 Electricity Directive[1], network operators are not allowed to own and/or manage storage facilities in order to prevent any chance of market distortion. This was not an issue in Madeira, since the island benefits from an exception regime to this rule (article 66)[2]. However, this is an aspect that should certainly be considered as a limitation to replicating this solution. To avoid a regulatory breach on islands that do not benefit from such regimes of exception the system must be owned and managed by other market players (e.g., aggregators), which will then sell flexibility services to the DSO.

Economic factors

Besides the cost of a storage system, grid operators might have to make substantial improvements to existing infrastructure. For example, in the case of Madeira, before accommodating the BESS at the LV distribution substation, the local partners had to install additional components (e.g., an HVAC system to ensure the optimal temperature conditions for operating the battery) and replace existing ones (e.g., main electrical board was replaced with a smaller one in order to comply with the Portuguese Safety Regulation for Substations). These additional costs could impact the economic viability of this solution and should be taken into account before deciding whether to implement it or not.

Due to the relatively high cost of energy storage technologies**,** larger market players have a competitive advantage over smaller ones (limitation not relevant to Madeira – see *Political-legal factors* above).

[1] *2019 Electricity Directive*. https://www.europarl.europa.eu/doceo/document/TA-8-2019-0226_EN.html

[2] https://www.h2020smile.eu/wp-content/uploads/2020/05/D7.1_SMILE_final_rev1.pdf

Social factors
From a social point of view, there are no relevant requirements or limitations to report.

Technological factors
The minimum requirements for implementing this solution are:

- Reliable internet connection.
- Monitoring equipment (power quality and energy analyzer).
- Communication gateway (to communicate with the power quality and energy analyzer).
- Battery Energy Storage System.
- A set of grid quality or general heuristics provided by the DSO, which serve as an input to control the charge/discharge of the BESS.

Despite this solution (software-side) is highly compatible with several systems, the HW used should comply with the following requirements.

Monitoring equipment:

1. allow for real-time (1 Hz) data measuring and communication.
2. allow for high-frequency data storage (kHz) when a pre-configured event is detected.
3. allow for instant actuation (few milliseconds) on the Direct Current (DC) output relay signal when a certain pre-configured event is triggered.
4. capability to handle the nominal current and voltage requirements of the secondary winding of the substation transformer.
5. capability to measure the following data:
   - 5.1. Voltage (in volts).
   - 5.2. Current (in Amps).
   - 5.3. Real power (in Watts).
   - 5.4. Reactive Power (in Var).
   - 5.5. Apparent Power (in VA).
   - 5.6. Power factor (value from 0 to 1).
   - 5.7. Frequency (in Hz).

Communication gateway:

- allow the use of TCP/IP ModBus protocol.

BESS:

- Provide access to an interface (e.g., web APIs) for monitoring the BESS.
- Provide access to an interface (e.g., web APIs) for controlling the BESS.

Environmental factors
As in the previous solution (*DSM and BESS for optimizing self-consumption*), a potential environmental drawback is the processing power required by the computing and communication infrastructures needed to ensure real-time control of the storage devices. This limitation was not relevant to the Madeira case since the deployment of solution 2 involves only one LV distribution sub-station.

In more general terms, despite the benefits it could bring to the distribution network, the environmental impact of the energy storage system (which varies depending on the typology of battery used) is another potential limitation of this solution.

3.5 Solution 3: EVs smart charging

3.5.1 Value proposition and main functionalities

The third solution aims to provide smart charging mechanisms through non-intrusive and cheap systems. Specifically, two different systems have been deployed.

- The first one, from now on referred to as Tukxi system, is entirely based on off-the-shelf hardware components and targets small vehicles such as electric scooters. This system is being deployed at the garage of Tukxi Tours Madeira, which is a local sightseeing company operating a fleet of Ape Calessino[3].
- The second system, from now on referred to as EEM system, is being tested at the garage of the local electricity company (Empresa de Eletricidade da Madeira). Unlike the Tukxi system, the EEM system relies on custom-made hardware solutions and is intended for full-fledged EVs.

In both cases, smart charging is achieved by remotely turning ON/OFF the charging points according to a set of charging strategies.

The main advantages of this solution are:

- possibility of implementing several charging strategies (e.g., based on pricing, electricity demand, renewable availability, or aggregated energy consumption in the building) and manage the charging of multiple vehicles at the same time.
- access to feedback on energy consumption (via a web app) and charging status (via web-app and a mobile application).
- highly compatibility with different chargers and plugs - thus, it can be used to retrofit existing installations.
- The EEM system also allows end-users to manually control and schedule the charging via a user-friendly web interface (Figure 21).

Moreover, it offers the opportunity to:

- understand the charging characteristics of the vehicles' battery.
- provide demand response service to the grid.

[3] Piaggio - APE Calessino Electric, https://drive.google.com/open?id=0BwLg0bl6UTC7UnpVYTdBOGpQeUk

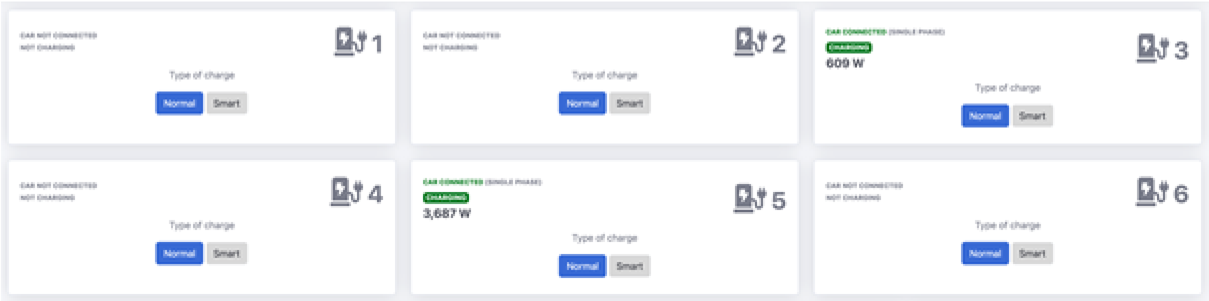

Figure 21. UI widgets to access the real-time information of each charging station and take control over the charging (e.g., switch from smart to normal charging mode).

Figure 22 illustrates the interface of the mobile app provided to the Tukxi's drivers. A description of the mobile app can be found in D4.12[4].

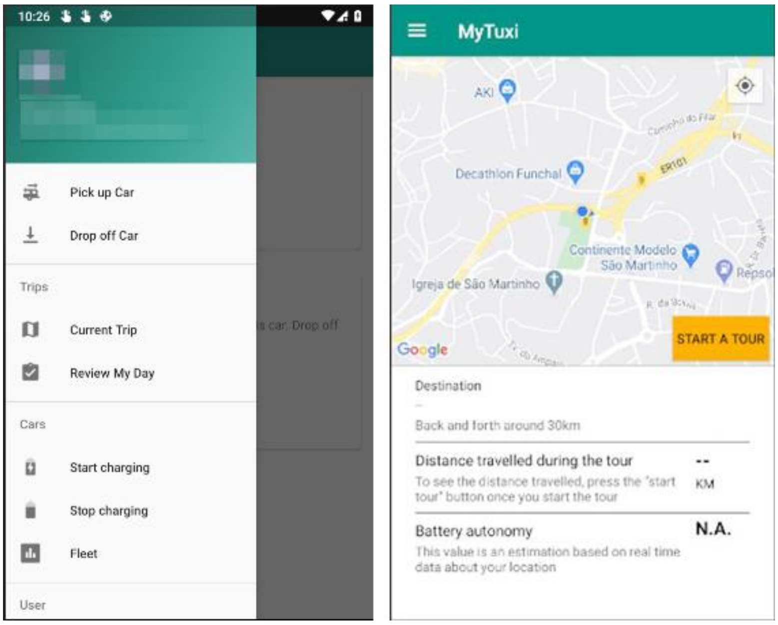

Figure 22. Interface of the MyTukxi application that is used by Tukxi Tours drivers.

3.5.2 Target group

- Businesses or public entities owning a fleet of full-fledged or small EVs.
- EVs owners.
- EVs charging station operators.

3.5.3 Components

Software:

- EMS back-end.
- EMS front-end.
- Smart charging algorithms.

[4] https://cordis.europa.eu/project/id/731249/results

- EV drivers' mobile application (provided to the Tukxi drivers to gather additional information about their driving behaviour and charging habits).

Hardware **(Tukxi system** – Figure 23**)**:
- energy meter to monitor aggregated consumption.
- smart plugs (PlugWise).
- a gateway, which allows querying consumption data from both the energy meter and the smart plugs and forwards the ON/OFF commands to the smart plugs.

Hardware **(EEM system** –Figure 24**)**:
- a set of chargers - the Control and Communication Modules (CCM).
- the Coordinator - i.e., a custom-made gateway which is used to aggregate energy data from all the charging stations and manage the command parameters at the site.

Figure 23. Energy Monitor and Gateway installation at TukxiTours (on the left) and Smart Plugs (on the right).

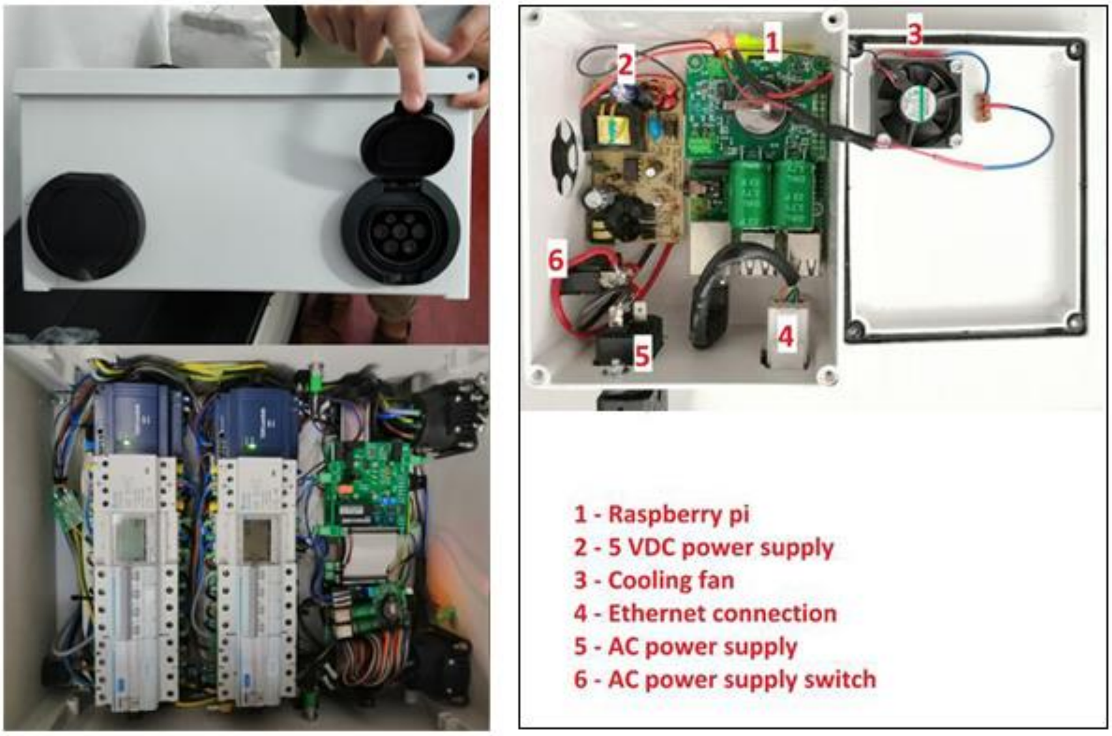

Figure 24. Control and Communication Module at EEM (on the left) and Coordinator gateway (on the right).

3.5.4 Requirements and limitations

Political-legal factors

This solution could bring additional benefits and provide grid support by performing vehicle-to-grid (V2G) services. Batteries of EVs can be indeed used to store excess energy and feed it back into the grid when needed. However, there are several legal voids concerning V2G. In Madeira, for example, it was not possible to implement any V2G smart charging strategies due to a regulatory barrier. Other islands interest in exploring this opportunity should carefully analyze the legal frameworks at the EU, national, and/or regional level.

Economic factors

This solution aims at achieving smart charging through non-intrusive and cheap systems. Therefore, from an economic point of view, it does not present any relevant limitations.

Social factors

The limited penetration of EVs and the fact that people are still not familiar with smart charging represent potential barriers towards the acceptance of the proposed solution. This barrier was particularly relevant in Madeira, since our is probably the first EVs smart charging pilot ever implemented on the island. EV drivers and garage staff at both Tukxi and EEM were concerned about the risk of a possible failure of the charging system and therefore showed some initial resistance towards its adoption. In order to overcome this barrier, the local partners conducted several visits to the pilot sites in order to train the garage staff in how to use the systems and address all their questions on the smart charging mechanism.

One other potential barrier (not pertinent to Madeira demonstrator but worth mentioning) is the fact that some smart-charging strategies might not be advantageous to all of the relevant stakeholders. For example, a strategy based on the availability of RES brings benefits to grid operators while could negatively affect energy consumers by resulting in an increase in the electricity bill.

Technological factors

The minimum requirements for implementing this solution are:

- Reliable internet connection.
- Monitoring equipment.
- Communication gateway.

Although this solution (software-side) is highly compatible with several systems, the communication gateway used should allow the use of ModBus protocol.

Environmental factors

Possible environmental limitations of this solution (not studied in Madeira due to the limited scale of our demonstrator) are:

- **the environmental impact of the storage devices** - e.g., what to do with the batteries once they are no longer good for an EV.
- **the potential environmental impact of a large-scale deployment** of this solution (i.e., the need for installing more and more ICT, chargers, etc.) should be assessed.

3.6 Samsø – Overview of the proposed solutions

Samsø is a small island with a population of 3,724, located eastward off the Jutland peninsula in the Kattegat, Denmark. The energy demand in the Ballen marina (Figure 25) is very inconsistent as it is dominated by the demand from berthed yachts and associated tourism. This results not only in significant fluctuations on a daily basis, but also significant seasonal variations as tourism has its peaks in the summer. While there is not yet an issue with curtailment of renewable generation in Samsø's energy system, there are several bottlenecks which present opportunities for better management of locally generated energy. Addressing these issues, by shifting peaks in energy demand for example, can help to stabilise and reduce energy prices for residents, as well as providing a valuable service for the local DSO by helping them to manage and balance the grid overall.

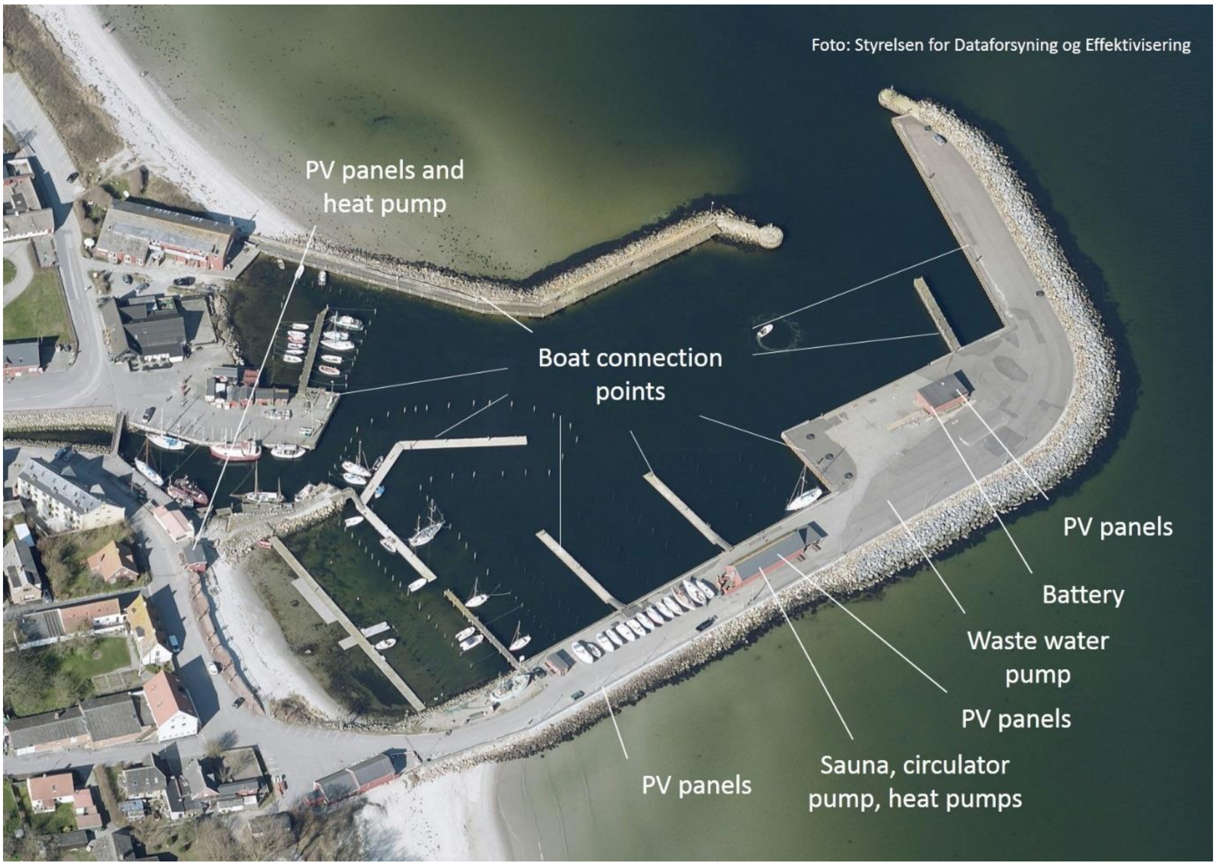

Figure 25. Ballen Marina in Samsø, Denmark.

A *solar battery* is the popular term for a hybrid power system that combines photovoltaic panels with a *battery energy storage system* (BESS). The objective is to store solar energy for later use (during the night for instance). It is attractive when the PV plant produces *excess energy*, that is, more energy than needed at the moment of production. A *grid connected* system can also exchange electric power with the public grid. When the buying price differs from the selling price, such a system opens an opportunity for trading at profitable moments, or *energy arbitrage.*

3.7 Solution 1: A grid connected solar battery for a marina

3.7.1 Value proposition and main functionalities

Compared to a stand-alone photovoltaic plant, adding a battery increases the renewable energy share and the economic viability. The marina saves on purchasing electricity from the public grid thanks to the PV plant. Figure 26 shows an overview of the system. The PV plant supplies energy for heating and cooling also, by heat pumps, so the system is a Smart Energy System. The sauna and the heat pump can be started and stopped remotely in order to optimise the renewable energy share or the economy.

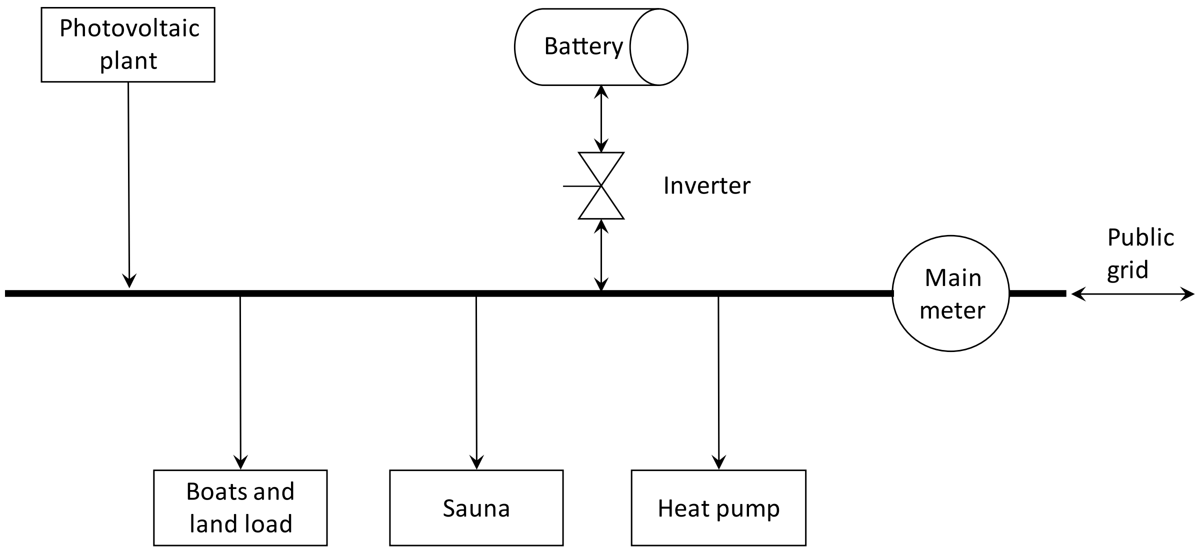

Figure 26. Internal grid on the marina. All components are connected to a common busbar, which is connected to the public grid. The battery stores excess PV production for later use. The upper part is the production side, and the lower part is the demand side.

3.7.2 Target group

The main target group for this solution are marina owners. On Samsø this is the municipality. The system increases self-sufficiency for the benefit of the island energy system. That benefits, in turn, all taxpayers on the island. The system is almost invisible, and tourism is unaffected. The visiting boat owners benefit from more sockets, more power (higher ampere fuses), better voltage, and a self-service payment system. The marina saves expanding the main fuse to the public grid.

3.7.3 Components

A battery (237 kWh), a specialised battery cabin, a PV plant (60 kWp), electric sockets for the boats (340), measurement equipment, Internet access. All components (table 1) are on the marina side of a single public meter.

Table 3. Factsheet of the different components.

Units	Specifications
46%	Estimated degree of self-supply with battery
26%	Estimated degree of self-supply without the battery
95%	Estimated own consumption of annual PV energy with battery
49%	Estimated own consumption of annual PV energy without the battery
237 kWh (Xolta BAT-79)	Nominal capacity of battery
225 kWh	Accessible capacity of battery
82%	System round-trip efficiency (AC-AC)
49 kW (ABB ESI-S)	Battery converter power
60 kWp (Eurener)	PV plant nominal power
49 kW (Fronius, Enphase Energy)	PV inverter power
56 000 kWh/year (Better Energy)	PV plant estimated annual yield
155 m2 (Better Energy)	PV plant area
105 000 kWh/year (NRGi)	Marina annual demand (2016)
340 (CompuSoft, Seijsener)	Sockets for the boats
(Compusoft, Seijsener)	Each socket has a meter and a remotely controlled switch
49 kW (KONSTANT Net A/S)	Max allowed export to the grid
5 (Daikin)	Number of heat pumps
18 000 kWh/year (Ballen-Brundby Fjernvarme amba)	District heating consumption of the service building
2 m3 (Xylem, Inc.)	Wastewater tank
15 kW (SAWO, Inc.)	Sauna in the service building
11 kW	Charging point for the harbour master's electric vehicle
16 amp (Lasses Auto)	Charging sockets for 3 rental electric vehicles

3.7.4 Requirements and limitations

Political-legal factors

The plant must be acceptable to the local citizens and it should have little or no environmental impact. It should be costless to the taxpayers and comply with the local urban planning. These are rather general requirements that are applicable on Samsø and may apply in other countries.

On Samsø the municipality cannot operate as a business. However, marinas are exempt being regarded as a non-profit service within the tourist sector. The PV plant must be isolated in a special-purpose company (in Denmark). The municipality cannot sell electricity to electric vehicle owners because that would compete with private enterprises. However, this may change in 2022, because all municipalities recognise a need to sell electricity to further the green transition.

Economic factors

The battery saves on buying electricity from the public grid. If the price of buying electricity from the public grid is high, the payback period is shorter. This is valid for all countries.

On Samsø the payback period should be 20 years or less. The lifetime of the PV panels is 30 years, while the lifetime of the battery is 15 years.

A battery system is relatively expensive at the moment, but prices on both PV panels and batteries are expected to decrease in the coming years. In perhaps five years, the solution could be economically viable without subsidies. Keeping the battery temperature around 20℃, with the use of an air conditioning e.g., will prolong its lifetime.

Social factors
The plant should not interfere with the urban planning. The plant can be a tourist attraction, at least for energy tourists, politicians, and journalists. This could be valid for all countries.

On Samsø, the marina offers a service to the visiting boats. Optimal service is more important than optimising the share of renewable energy. Therefore, the visiting boats should not have to bother with complex solutions, such as a tariff that changes by the time of day. On the contrary, the advanced technical solutions, such as buying and selling from the public grid at advantageous times of the day, should work in the background, invisible to the visiting boat owners.

Technological factors
The public grid must accept excess energy from the plant in the Ballen marina. This requirement is general for all countries.

On Samsø, the acceptable injected power is limited to 49 kW. Selecting the optimal size of the components requires extensive computations. On Samsø the renewable energy share is 45 percent. It would be higher with a larger PV plant, but space limits its size. The limit on the maximum acceptable injected power into the grid also limits the size of the plant.

Environmental factors
There is no noise or emissions, but the plant should not spoil the landscape or the view of the sea. This is likely valid for all countries. On Samsø, an envisaged wind turbine was abandoned and replaced with a larger PV plant. The battery is invisible, because it fits inside an existing building rather than an odd cabin.

3.8 Orkney – Overview of the proposed solutions

The Orkney Islands (Figure 27) are an archipelago with a population of approximately 20,000 people off the north coast of Scotland. While the smart grid installed by the local Distribution Network Operator (DNO) has increased the capacity available for new generation, there are still significant constraints which limit further development and reduce the output of operational generation. Because of the regulatory structure of the UK electricity sector, it is difficult for the DNO to directly implement additional energy storage or demand response and receive the full commercial benefit, as this could involve activities classes as generation or energy supply, which are forbidden for DNOs under the UK's fully liberalised energy system.

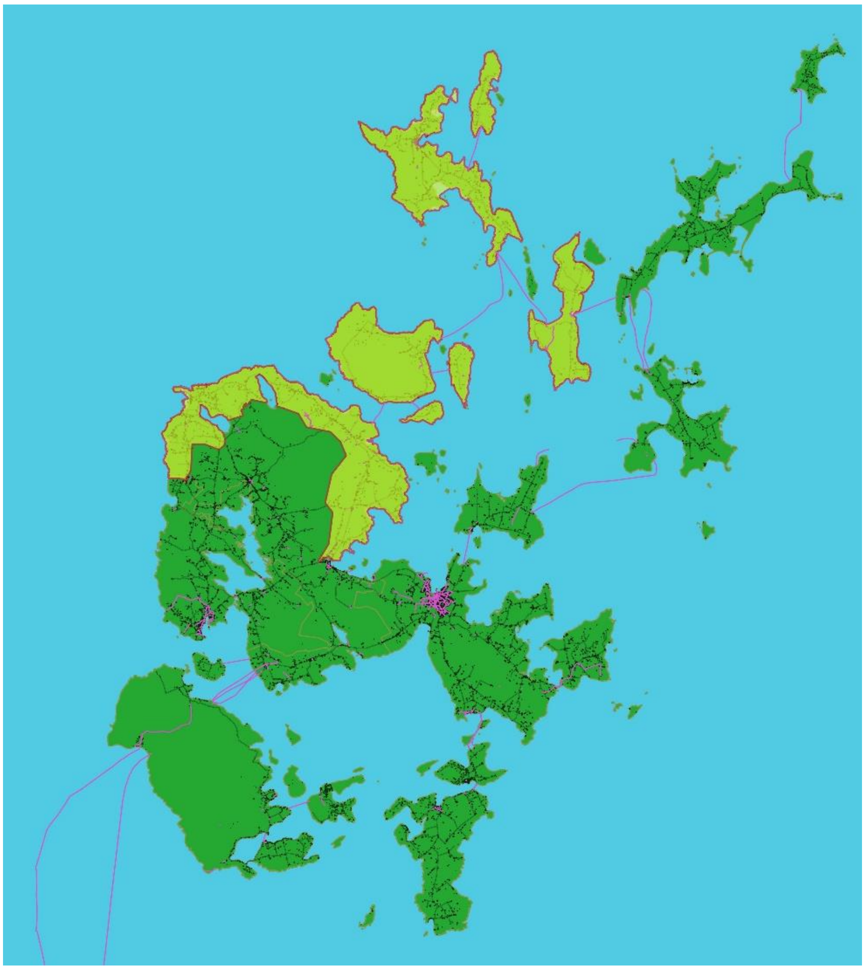

Figure 27. The Orkney Islands, United Kingdom

The Orkney demonstrator centres around the concept of increasing electrical demand at the time of curtailment events for local community-owned wind turbines. When curtailed, these wind turbines are stranded assets that do not financially contribute to the community. This loss of revenue is effectively an opportunity to invest in mitigation measures, such as those found in the SMILE project.

Within SMILE the Orkney demonstrator is hoping to demonstrate that by monitoring and proportionally responding in real-time that the turbines will be able to either be curtailed to a lesser degree, or be able to continue generating at full capacity for longer.

All proposed solutions used in the Orkney demonstrator are connected to the Kaluza's Energy Flexibility Platform , which manages the following three solutions:

- Solution 1, "*Heating and hot water optimization*", aims to closer marry the generation capacity of the wind turbines to the energy demands of the participating properties. The four different designs involved Sunamp, Lithium Balance and OVO Energy;
- Solution 2, "*EV charging optimization*", aims to make better use of the stationary EV batteries to increase the financial return on investment to the EV owner. The two different EV charging designed solutions involved Route Monkey and OVO Energy;
- Solution 3, "*Aggregated / Load Optimisation*", aims to quickly integrate large controllable loads to the flexibility platform to further improve revenue streams through assisting in the optimisation of a renewable energy asset.

Figure 28 illustrates the interconnectivity of the equipment present in the Orkney demonstrator.

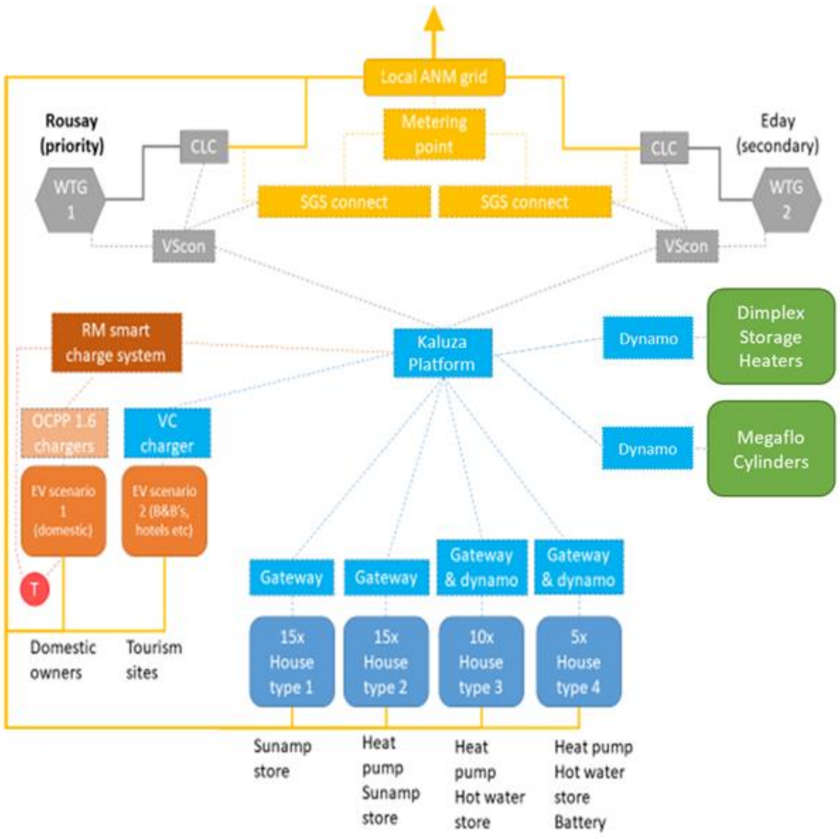

Figure 28. Interconnectivity of the different solutions demonstrated on Orkney.

The Kaluza platform, which was produced and managed by OVO Energy, is designed to monitor the various data streams from multiple smart devices spread across many properties. It is also responsible for monitoring the state of the wind turbine assets owned by community organisations. The Kaluza platform is capable of integrating directly with single devices, an API with another technology developer for singular devices, or the management system for another aggregated load.

3.9 Solution 1: Heating and Hot Water Optimisation

Four different designs were installed and tested under the heating and hot water solution. Figure 29 to Figure 32 below provide an illustrated demonstration of these four designs:

Type 1

This design tested an installed of two Sunamp PCM heat batteries, either operating independently or in conjunction with a previously existing boiler or heat pump.

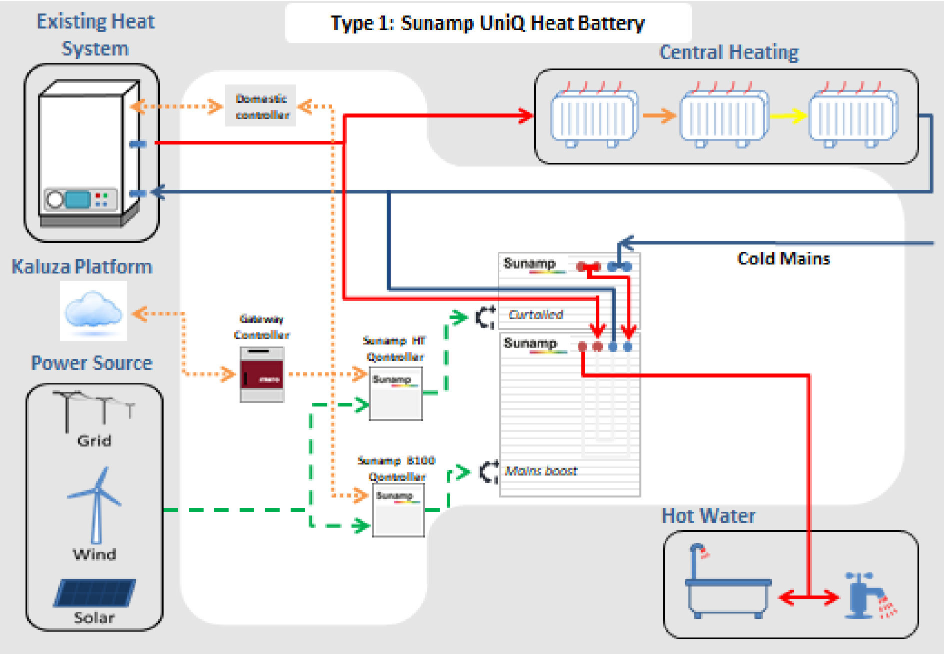

Figure 29. Sunamp PCM heat batteries only

Type 2

This design tested a configuration of five Sunamp PCM heat batteries along with an air to water heat pump. This provided storage for the hot water and central heating

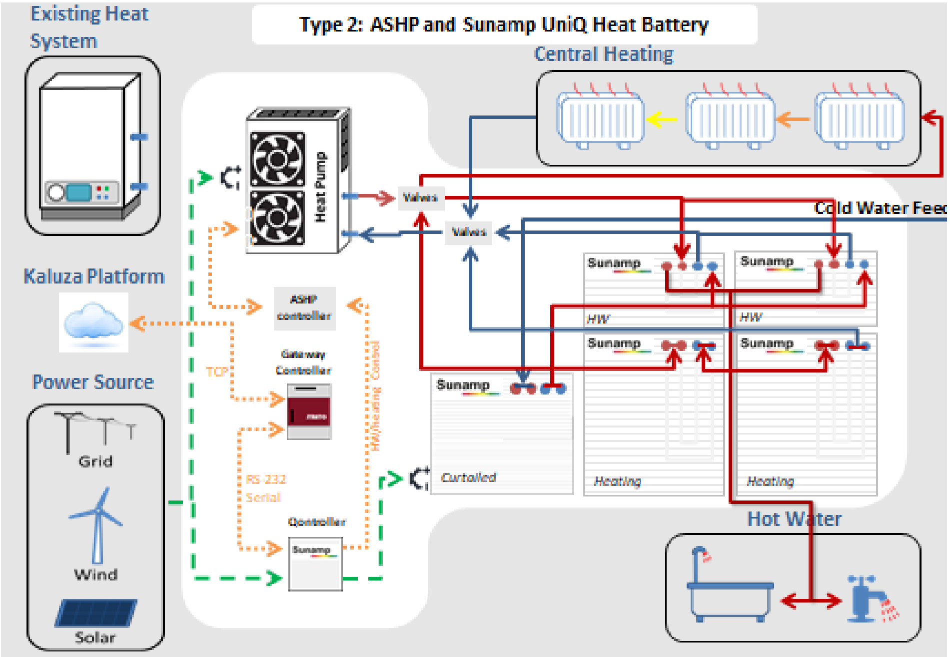

Figure 30. Sunamp PCM heat batteries and Heat Pump

Type 3

This design was to test the comparison against the Type 2 design. But hot water storage instead of PCM batteries.

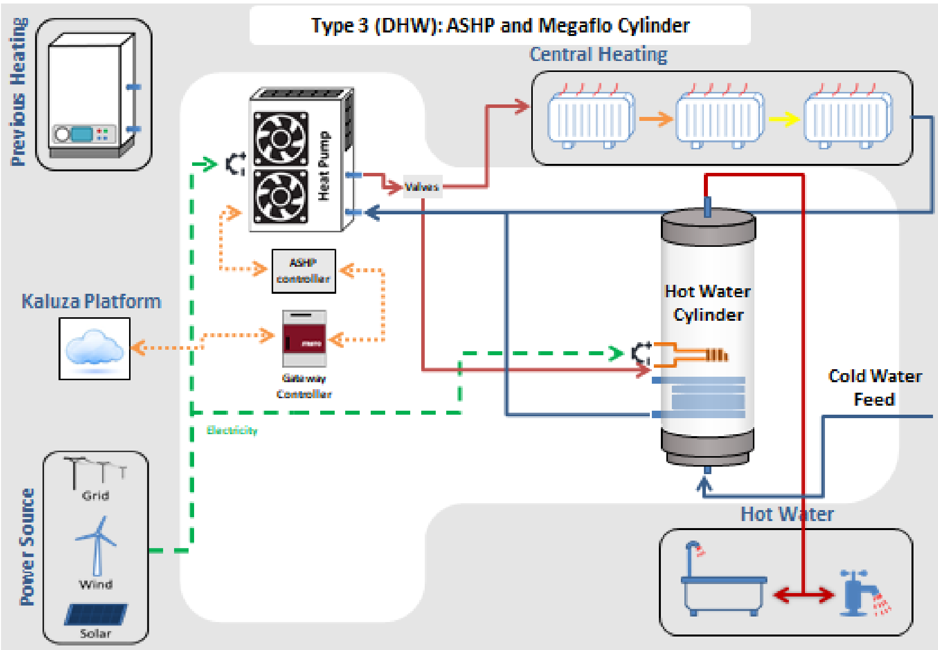

Figure 31. Heat pump and Hot Water Cylinder

Type 4
Was similar in design to Type 3, but offered lithium-ion battery operating in parallel with the heat pump, connected behind the meter. The battery charging during periods of curtailment and discharging when the heat pump was using power.

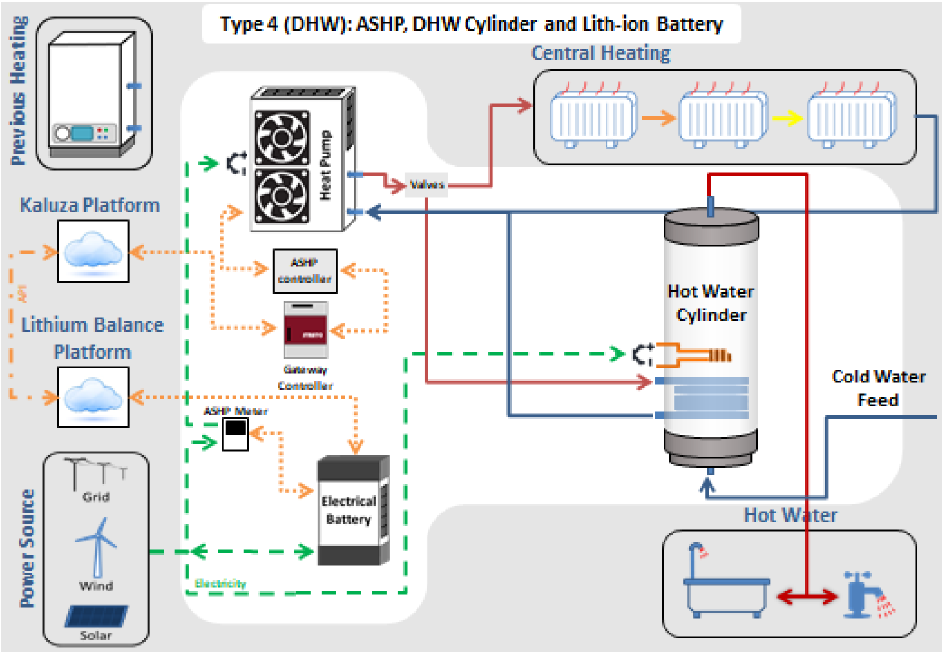

Figure 32. Heat Pump, Hot Water Cylinder and Battery Energy Storage System

3.9.1 Value proposition and main functionalities

The value of heating and hot water optimisation though the Kaluza platform is being able to closer marry the generation capacity of the wind turbines to the power demands of the participating properties. This is done by triggering an override of the smart technologies to draw power from the grid, but then storing the energy until the heat and hot water are required. The turbine operators benefit from the platform as it enables the turbine(s) to continue turning without day-to-day intervention from the participating properties. The participants should remain completely oblivious to the operation of the technologies, but continue to have access to the energy medias on demand while also contributing to revenue generation in the community.

A like for like comparative solution did not already exist. It is possible to operate on a single property bases diverting excess energy to a hot water cylinder. But on a "islanded" grid scale, this did not previously exist.

3.9.2 Target

This solution targets:

- Distribution System Operators;
- Renewable energy asset operators;
- Commercial prosumers;
    - Shops;
    - Hotels;
    - Self-catering accommodation;
    - B&Bs;

- Etc.
- Domestic properties:
  - Properties with wet heating systems
  - Properties with electric heating, but also has a hot water cylinder.

3.9.3 Components

This solution exists out of the following components:

- energy monitoring system back-end;
- Control algorithm;
- Renewable generation asset communications gateway;
- Server level API;
- Per property communications gateway and energy monitoring;
- Kaluza Energy Flexibility Platform
- According to the specific type, some of these components could be needed: Sunamp PCM based Heat Battery, Lithium Balance BESS, Heat Pump

3.9.4 Requirements and limitations

The principal heating and hot water DSM equipment have main requirements and limitations which include: economical requirements on high capital and operational costs; technical requirements on the compatibility of DSM loads; social limitations on the acceptance of non-typical domestic equipment, which presents hesitancy or a move away from high levels of innovation if not managed correctly; and legal requirements due to the amount of equipment in a property which does not belong to the homeowners and not completely in the control of the homeowner either.

Political-legal factors
In order for the solution to work there must exist legal contracts between the energy generator, consumer and aggregator platform manager. This is to cover the expectation of responsibilities of each party, and ownership of equipment. For example, equipment may be present in the property that will not belong to the property owner. A contract should outline which party is responsible for the equipment installation and maintenance. There should existing a distinction as to what equipment is and is not covered and the responsibility of the project operators within the property. But also, what is the role of the project when project covered equipment impacts non-project covered equipment.

Due to the high capital nature of the equipment, and the specific equipment required, it is unlikely for the time being, excluding financial incentives from external stakeholders (including generators and aggregators), that a homeowner would agree to pay for such equipment in order to access the functionality and any additionalities that come from such an aggregator platform. This is especially true as the market does not fully represent this capability yet. Political will to continue funding such demonstration projects is required to continue real-world demonstration before effective technical and financial models can be identified. For the time being, different potential business models have been proposed by the project.

There is a legal requirement to allow the installation of equipment to operate for the benefit of the homeowner, but which does not actually belong to the homeowner. A unified legal model for installing such equipment in a property which does not belong to the homeowner, but can be removed by the project operators, does no currently exist. Demonstrator projects, such as SMILE, are attempting to prove different models. But currently bespoke terms and conditions are required.

There is a general acknowledgement that properties need to be better insulated in order to make them either better suited for heat pump, or suitable at all. There exist mechanisms in place to retrofit insulation and draft exclusion measures, but there is not a high enough political will and effort to prioritise such measures, along with energy efficiency in general.

Throughout the length of the project, since it began in 2017, there has not been any significant change in the political or legal landscape relevant to the objectives for the Orkney demonstrator. However, there is an increased awareness of the shift to a net zero economy across all sectors; there is a growing focus on the adoption of zero emission technologies. But at the same time, there is reductions in funding available to cover capital costs for early adopters.

Heat pumps, and the intervention measure that might be required to make heat pumps suitable for a property, can be inaccessible for some lower income properties. Increased political importance put on energy efficiency measures will see greater support, and in turn more properties which can make the step towards cleaner technologies.

The solutions tested in Orkney are highly replicable. However, the legal contract required between all partners involved will be very complex. This should be prioritised from the beginning. However, the contract should be specific enough to cover as many eventualities as possible, but allow room for alterations to equipment while still remaining protected by the contract.

Economic factors

There needs to exist an economic requirement for the intervention provided by this solution. For example, an opportunity cost as a result of lost revenue. The principle economic limitation to the solution demonstrated in Orkney is the very high CAPEX and also significant OPEX. Without external incentives for the time being it is unlikely that this would be covered by the local operators of the community-owner turbines or the homeowners themselves.

Furthermore, in Orkney the significant portion of properties derive their heating and hot water from an oil-based (kerosene) system. Due to the average price point of heating oil, compared to the average cost of electricity, it is hard for heat pumps to be cheaper than and oil boiler; which will impact the interest in switching to such technologies.

The Orkney-based solution is highly dependent upon system which would be abnormal to an average property. The cost of then either installing this solution, or amending an existing to align with the solution requirements would be expensive and a significant barrier to being included.

Many economic factors have remained the same. For example, the cost of such equipment remains the same. This means that the entry price point for such a project remains high. A potential solution to overcome this is to focus on solutions that are accessible in homes currently, which require very little intervention and cost to implement.

A significant limitation to the economic factors would be the lack of a suitable market. Currently, it is not possible to be significantly compensated for presenting energy storage.

In order for the solution demonstrated to have been fully applicable to Orkney, the cost per property would need to be lower in order to either allow the entry point or cost of operations and maintenance to reduce the overheads compared to value to the turbine operators.

Currently there are a lot of properties in Orkney that would not be suitable for an air source heat pump. This is principally be down to the level of insulation or draft exclusion; both which would require capital to invest in. In order for a SMILE solution to be wide spread across Orkney, there would need to be a mechanism in place to allow for increasing insulation levels. Either directly through project funding, or teaming up with another organisation which could assist with such services.

The issue of capital and operational costs will be very translatable to any other situation or island. Focusing on the operational costs, the solutions tested did not prove to be robust enough to operate without semi-regular intervention; this increases the costs to the system. There exist multiple examples where budgeting for 4G wireless internet connection would have been more cost effective. The principal reasoning being that a lot of costs incurred, and reduced functionality, was due to the quality of the internet connection of the property.

Social factors

The Kaluza platform protects participants against running out of heating and hot water supply by ensuring the equipment meets minimum requirements without an internet connection, and that overriding the equipment is a secondary feature. This limits the potential for participants being unhappy with the equipment and the project's operation.

Due to the requirements if a property to make ASHPs effective, there were properties that registered interest that could not be selected. This made up a bracket of the demographic in Orkney which wished to make the change to a low emission heating system, but could not access it yet due to the need for additional expensive intervention measures. Along this trajectory, there is a risk of such demographics being "left behind".

Through testing the designed solutions in Orkney, the feedback from partners, contractors and participants have provided enough insight into where the systems could be changed in order to increase acceptance. The changes would principally be down to the level of control in the properties. This would increase the acceptance of the solutions, as well as the replicability.

For the solutions demonstrated in Orkney to meet the social requirements of the population in Orkney, there must be no degradation in the reliability of the equipment to provide heating and hot water on demand. Ideally, the systems would be able to provide increased comfort for a reduced cost. For example, stored thermal energy for hot water or central heating will have a faster response time than first allowing a heat pump to get to temperature before providing heat.

Technological factors

In order for a property to be a valid candidate to be connected to the aggregator platform, the minimum requirements of a participating property for implementing these solutions are:

- A reliable internet connection;
- Controllable compatible heat pump;
- Suitably sized energy storge for either domestic hot water or space heating requirements;
- Energy monitoring system, operating on a close to 1Hz frequency;
- Communication gateway, either operating in conjunction with or relaying energy monitoring.

Where direct integration with heating and hot water technologies is not required, but integration with another operators control system is, the following is required:

- A reliable internet connection with property and operator;
- Provide access to an interface for monitoring and control (e.g., web/server API).

A communications gateway is required at the renewable energy asset; a gateway that will allow the relaying of data to the control platform in order to perform discission making. The resolution of the data would need to be in the order of 1 Hz to allow for quick response times and to minimise the operation of smart technologies within properties outside curtailed periods.

The limitations to these requirements are that a lot of these can only be met with direct intervention to install specific equipment to allow for suitable energy storage, control and data telemetry. There does not currently exist standards on heating and hot water technologies that would allow for smart control of their operation.

With regards to the necessary internet connection, reliable broadband internet connection was found to not yet be widespread across the entire of the project area. Effort to replicate these solutions should also consider the important of the strength and reliability of the internet connection, and also backup 4G signal.

Additionally, since the beginning of the project, a number of the key technologies have either developed further or been replaced by newer versions. For example, the range of Daikin Altherma high temperature heat pumps have been replaced by models which take up less physical space but can reach the same temperature. This would have made more properties within the selection process suitable for deployment. Additionally, Sunamp Ltd have developed their heat battery controller ("Qontroller") further for increased control and data telemetry capacity.

In order for such a solution to be fully applicable to Orkney there should be options to integration that require very little interventions to change the existing equipment in the property where possible. Additionally, the extend in which quality broadband connections are guaranteed across the whole of the country would need to be increased.

Environmental factors

There are few environmental requirements or limitations relevant to the heating and hot water solutions tested in Orkney. However, governments around the world are beginning to schedule bans on burning fossil fuels and moving to lower/zero carbon technologies. As such, designed systems would need to meet these future requirements in order to have a roll after such bans. All the technologies designed, deployed and tested in Orkney meet the requirements and either only used zero emission technologies or enable properties to lower their CO2 footprint.

Furthermore, during the length of the SMILE project, the UK government has begun to outline plans to impose restrictions on the types of heating fuels available. An example of such is a planned ban on burning some solid fuels. This does not directly impact such solutions being tested in Orkney, but represents a requirement on UK homes that could turn to such equipment to avoid being negatively impacted from further planned restrictions on fossil fuels.

When considering the environmental factors, it is key to determine a baseline of energy/fuel consumption prior to intervention measures. Some of this information is hard to accurately quantify. For example, the rate of use of heating oil. The installation of additional equipment would be required to get accurate figures for modelling

As grid electricity is the fuel for the system, it cannot always be easy to determine an accurate CO2 intensity on the electricity used. But this is required in order to determine the life cycle analysis.

Steps which could be taken in order to further increase the chance of replication in Orkney, would be the further analysis of life cycle environmental impacts, and the publishing of the results as a marketing tool to promote the shift from traditional fossil fuel heating systems. Furthermore, these technologies could be replicated in a very wide range of international locations; the need for hot water is commonplace, and thermal storage can be replaced with cold storage medium for warmer climates.

3.10 Solution 2: Electric Vehicle Charging Optimisation

Figure 33 and Figure 34, below, illustrate the solution designed and tested by Route Monkey and OVO Energy respectively:

Type A:
This solution, designed by Route Monkey, paired a smart charger with a telematic unit within the participating vehicles. The telematics unit relaying information from the EV to the management system to allow for charging scheduling

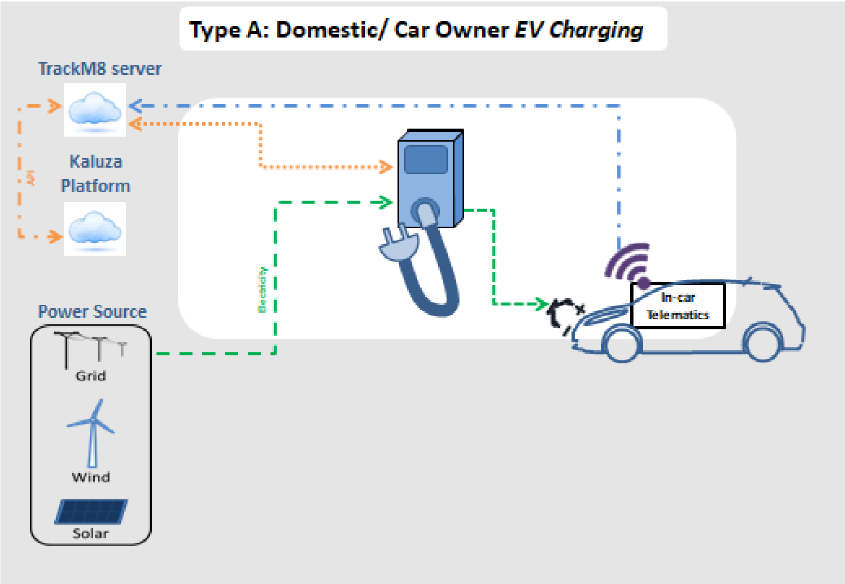

Figure 33. EV Charger and Telematics

Type B:
OVO Energy's designed solution for EV charging so the pairing of a smart charger and a user interface. The user interface would allow the participant to feed details to the aggregator system to allow scheduling of charging.

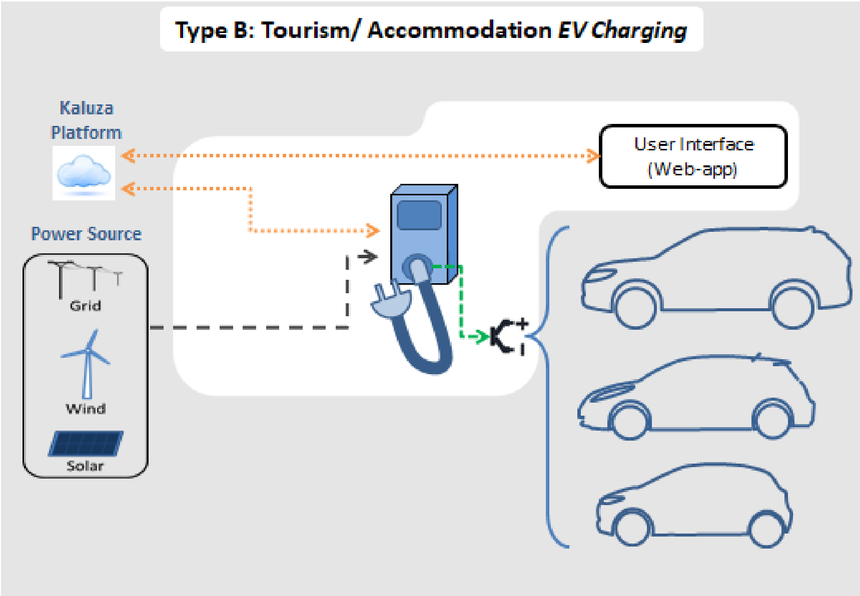

Figure 34. EV Charger and User Interface

3.10.1 Value proposition and main functionalities

The value of optimising electric vehicle charging through the Kaluza platform stems from the capacity of energy storage that exists within the car and the duration EVs are typically stationary for; making better use of the batteries during these times could potentially increases the financial return on investment to the EV owner. On scale, this can benefit communities and grid-scale operators.

The participants should remain completely oblivious to the operation of the technologies, but continue to have access to the drivable miles on demand while also contributing to revenue generation in the community.

Products on the market currently allow for excess energy on a property scale be diverted into a plugged in EV. But it is still uncommon for grid-scale EV charger optimisation to be rolled out. It is also currently common to see smart chargers optimised for flexible tariffs which adjust on a half-hourly basis. But it is still uncommon to see EV chargers respond to the requirements of a particular portfolio of renewable energy assets.

3.10.2 Target

This solution's target:

- Distribution System Operators;
- Renewable energy asset operators; and
- Commercial and domestic prosumers.

3.10.3 Components

This solution exists out of the following components:

- Energy monitoring system back-end;
- Control algorithm;
- Renewable generation asset communications gateway;

- Web/Server-level API;
- Smart EV charger with industry standard control protocols (e.g., OCPP 1.6 or above);
- Additional interface with driver or EV is required to understand state of charge of the batter. Either direct integration with EV, 3rd-party telematics or mobile app.
- Kaluza Energy Flexibility Platform

3.10.4 Requirements and limitations

The minimum requirements for the implementation of this solution are primarily technical in nature. A compatible smart charger, compatible EV, a reliable internet connection, and an interface with the control platform. The following PESTEL analysis covers the technical and non-technical requirements and limitations to the Orkney-based EV charger solutions.

Political-legal factors

The main political requirement the solution demonstrated in Orkney is an emphasis on deploying smart chargers which can be integrated in aggregator platforms, instead of "dumb" chargers. This is something that has already been in place for some time. As such, there do not exist political hurdles, beyond the promotion and incentivising of electric vehicle rollout.

In order to support the use of existing smart chargers, the standards being adopted by the sector must be recognised across all manufacturers, and regulated/monitored where appropriate. Currently the sector responsible for the production of smart chargers does not recognise a single standard to follow. The Open Charge Point Protocol (OCPP) has changed from 1.5 to 1.6 and then to 2.0. It was found that not all charger manufacturers are aligning with the standards before declaring their product do. Increase regulation of the sector could see this better forced transparency from the manufacturer.

During the project the adoption of smart charges under the UK governments funding support became mandatory. Even though this did not directly apply to the funding demonstration. It would allow for easier replication due to higher number of smart-enabled chargers across the country.

Further political changes during the project are both the UK and Scottish government's planned banning of the sales of new petrol and diesel vehicles. This represents a future requirement upon personal and business vehicle owners, which itself is an opportunity for these solutions in Orkney to be rolled out further. It is political legislation such as this that will be required to make adoption of low emission vehicles validated, and in time also mandatory.

The solution demonstrated in Orkney will be directly translatable to other location/islands. As electric vehicles become wider spread, so will the chargers installed to support them. Solutions like those tested in Orkney are highly replicable. The only political and/or legal factors which would promote this potential is the continued promotion of EVs, the rollout of smart chargers, compared to the older "dumb" charger models, and the banning of fossil fuelled vehicles.

Economic factors

There needs to exist an economic requirement for the intervention provided by this solution. For example, an opportunity cost as a result of lost revenue. The requirements for as big a business model compared to heating and hot water optimisation is not the same for EV charging, as the EV and the EV charger would typically already be present, minimising the requirement for capital expenditure.

Currently the market is catching up to the ability and potential of smart chargers to balance the grid (I.e., 30-minutely agile tariffs). This trend could be adopted by more energy providers as one solution to realise this potential. Additional market mechanisms would be required to allow further incentivising of EV and smart charger adoption.

During the length of the demonstrator in Orkney, the cost of second-hand EVs continued to drop; this was especially true in 2020/21. The rate of ownership in the county increased. If this had occurred during the recruitment phase of the project, this could have resulted in creased participant registered interest.

In order for the solutions tested in Orkney be fully applicable in Orkney, there would need to be a means to the control platform both understanding the state of charge of the vehicle as well as when the vehicle is required; the two solutions tested in Orkney perform one of the two requirements. Also, there would need to exist a mechanism where the cost of the telematics was not passed to the vehicle owner.

The solution demonstrated in Orkney will be directly translatable to other location/islands. As electric vehicles become wider spread, so will the chargers installed to support them. Solutions like those tested in Orkney are highly replicable.

Social factors
A social factor that must be accepted and minimised against is the possibility of a vehicle be without charge either because charge is being delayed for a particular scenario, or because the control platform has malfunctioned. This can be minimised through ensuring a minimum level of charge before optimisation, or an alert system to the vehicle owner.

Another requirement to being part of this solution is having an EV and a smart charge. Both still have high entry price points. This makes the technologies less accessible to those with lower incomes. Furthermore, smart chargers are only available to those with off street parking, which high proportions of the population in Orkney, and the world, do not have access to.
No social factors have significantly changed during the length of the project. However, the entry price point for EVs continues to drop every year, making it easy to adopt. EVs remain financial inaccessible for many.

In order to make such a solution fully applicable to Orkney, and see a larger rollout of the solutions, it would be necessary to see higher adoption of EV.

The solution demonstrated in Orkney will be directly translatable to other location/islands. As electric vehicles become wider spread, so will the chargers installed to support them. Solutions like those tested in Orkney are highly replicable. Due to the project zone for the Orkney solutions, there was very little inclusion of built-up areas (I.e., towns or villages). This meant there was very few properties without off-street parking; a key limitation to nationwide adoption. As such, the Orkney trials are not able to offer replication results in this area; presenting the risk to being less inclusive to those with no private off-street parking.

Technological factors
The minimum requirements of a participating property for implementing this solution are:

- A reliable internet connection;
- Controllable EV charger;
- A compatible EV which can have charge withheld, but woken by the charger when required;

- Energy monitoring system, operating on a close to 1Hz frequency;
- Communication gateway, either operating in conjunction with or relaying energy monitoring.

Where direct integration with an EV charger is not required, but integration with another operators control system is, the following is required:

- A reliable internet connection with property and operator;
- Provide access to an interface for monitoring and control (e.g., web/server API)

A communications gateway is required at the renewable energy asset; a gateway that will allow the relay of data to the control platform in order to perform discission making. The resolution of the data would need to be in the order of between 1 Hz in order to allow quick response times and minimise the operation of smart technologies within properties outside curtailed periods.

The management of EVs charger will principally rely on the data connection via broadband internet connections. This presents a limitation to this requirement. Operating on an aggregated platform requires the working condition of multiple points; every single internet connection must be working in order for every charger to be online and manageable.

Orkney has seen a relatively high uptake of EVs in the last 10-years compared to many parts of the UK. As such, Orkney represents a good representation and test bed for mass adoption of low-emission vehicles. This extends to the need for methods to manage the power demand of EV chargers. Even if Orkney's grid was to continue to be upgraded to meet this demand, there will exist a need for smart control of EV chargers.

Also, during the project, standards for EV charger have been updated. The Open Charge Point Protocol (OCPP) has changed from 1.5 to 1.6 and then to 2.0. It was found that not all charger manufacturers are aligning with the standards before declaring their product do. The sector needs to adopt a signal standard with assurances that these will be adhered to.

The requirements on stable internet connections have not changed throughout the length of the project. The demonstration of the project in Orkney has highlighted how difficult this requirement is. There exist areas of Orkney where a stable high speed internet connection is still not available. However, during the length of the project more internet solutions have been available. This is allowing more properties to be reached, but more infrastructure reinforcement is required before such solutions are viable for every property in Orkney.

For this solution to be fully applicable to Orkney as a whole, a technological solution would be required for properties where off-street park was not available.

Environmental factors

There are very few environmental limitations to the solutions tested in Orkney. The optimised EV chargers were programmed to allow the same level of charging that would have been used anyway, but schedule to more preferred times. There is very little new equipment to be installed, limiting the materials required to allow the innovation. However, as scheduled international bans be fossil fuel vehicle come into action in the coming decades, EVs will become ubiquitous, and there will be requirements on such mechanisms to allow for local grid balancing while charging vehicles to meet demand. But this is a technical requirement with environmental advantages.

The only other limitations on the environmental factors of the EV-based solutions is based on the principals that rare earth materials go into the production of EVs. The optimised EV charger solution demonstrated in Orkney is very replicable. There are no environmental limitations to the replicability of such a solution; both EVs and smart chargers will become common place.

3.11 Solution 3: Aggregated / Load Optimisation

Figure 35 below, illustrates the aggregated DSM loads used within SMILE.

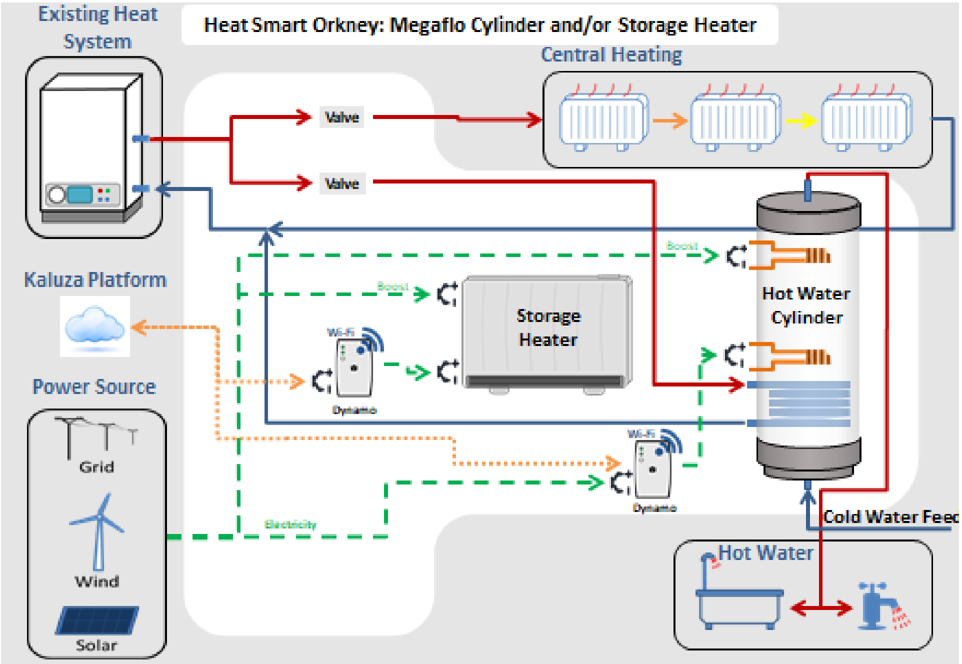

Figure 35. Aggregated Heat Smart Orkney Assets

The aggregated load controlled within the SMILE aggregator were a combination of control electric storage heaters and hot water cylinders in approximately 70 properties. These aggregated DSM assets were from a Scottish Government funded project called Heat Smart Orkney.

3.11.1 Value proposition and main functionalities

The value of the Kaluza platform to integrate with either a large industrial load or 3rd-party aggregated load is that a large controllable asset can be added to the portfolio quickly. While the principal operators of these assets potentially get access to a further revenue stream through assisting in the optimisation of a renewable energy asset.

A like for like comparative solution did not already exist. It is possible to operate on a single property bases diverting excess energy to hot water cylinder. But on a "islanded" grid scale, this did not previously exist.

3.11.2 Target

This solution's target:

- Distribution System Operators;
- Renewable energy asset operators; and

- Commercial and domestic prosumers.

3.11.3 Components

This solution exists out of the following components:

- Web/server-level API for integration to aggregated load;
- Communications gateway for industrial load, to allow data telemetry and control signalling.
- Renewable generation asset communications gateway;
- Kaluza Energy Flexibility Platform
- storage heaters and hot water cylinders

3.11.4 Requirements and limitations

The principal requirements and limitations of the aggregated load demonstrated in Orkney include: economic requirements for capital costs and operational costs, including a rebating mechanism; social limitations on the level of intervention and inconvenience introduced to the homeowners as a result of the level of innovation; and technical requirements on the communications and control equipment which allow for the high resolution of data and DSM loads.

Political-legal factors

The principal requirement for an aggregated load is similar to that of the other loads tested in Orkney. A legal contract is required for all parties involved to ensure that the expectations of each is follow known and understood. These contracts should detail what is and is not covered, to details individual liabilities.

There also needs to be mechanisms to protect each party from malpractice of the other parties, the recovery of equipment where necessary, and the cost recover of damaged equipment.

There have not been many changes in the political or legal factors relevant to aggregated loads or DSM industrial loads. However, the political awareness of smart grids has continued to increase. But his does not directly relate to the Orkney demonstrations.

In order for an aggregated load, as which was demonstrated in Orkney, to be fully realised, energy efficiency in the domestic setting should be made a higher political priority to ensure the support structures are in place to allow those with lower incomes to benefit from such solutions, that could lower their cost of energy.

The solutions tested in Orkney are highly replicable. However, the legal contract required between all partners involved will be very complex. This should be prioritised from the beginning. However, the contract should be specific enough to cover as many eventualities as possible, but allow room for alterations to equipment while still remaining protected by the contract.

Economic factors

In order for a load to have DSM functionality, there will typically need to be cost involved. This cost will either need to be covered by the party control the load, or by the owner of the load(s). This cost will only be covered with the return is greater. For aggregated domestic properties, where DSM loads are not fitted as standard, this is many individual costs that would be needed in each property.
The aggregated load demonstrated in Orkney was a secondary heating system; operating in parallel to the properties existing and main heating system. As such, without financial payback or contribution

towards energy costs, the homeowner would have higher energy costs. As such, the rebate mechanism used in conjunction with the aggregated load would be recommended.

The economic factors relevant to such aggregators or industrial loads have not significantly changed since the beginning of the SMILE project in 2017. There already existed early mechanisms for large loads to be turned down/off to assist the grid. But there still does not exist a matured market for aggregator platforms.

The aggregator demonstrated in Orkney is highly replicable, but from the years of testing the platform, the complexity of the equipment has significantly impacted the cost effectiveness of the platform. Because of this complexity the control equipment was not always proven to be reliable under test conditions. This translated into higher costs for every kW of DSM load.

Social factors

The requirements on any DSM load, relevant to social factors, are that the access to the energy from the load is not negatively impacted as a result of its altered operation. For example, a property still has access to heating and hot water. In the case of the Orkney-based aggregator, the heating provided was secondary to the equipment's primary function. As a result, the homeowners were not impacts by either the operation or lack of operation.

Due to the nature of the project, there was a high dependency upon the homeowners actively contributing the operation of the aggregated loads. This put the homeowners in the participant category. In order for this system to be fully applicable to Orkney, the level of intervention per property would need to be dropped considerably by having equipment which was more consistent in its operation and connectivity.

During the length of the project the COVID-19 lockdown restrictions caused an altered used of energy as homeowners were instructed to remain home as much as possible. This saw a higher demand on energy in the properties, but not a change in the requirements of the equipment. In order for the solution tested in Orkney to be fully realised, in line with social requirements, the control equipment would require to be more reliable. Due to technical limitations, homeowners were required to intervene and attempt to help get equipment reconnected to the control platform. This could be seen to limit the acceptance of the innovation in the face of inconvenience. Furthermore, in some cases unreliable communications equipment resulted in less discounted heating and hot water being provided to homeowners; again, impacting the acceptance of the equipment and innovation.

Technological factors

The minimum requirements of an aggregated load for implementing this solution are:

- A reliable internet connection;
- Energy monitoring system, operating on a close to 1Hz frequency;
- Communication gateway, either operating in conjunction with or relaying energy monitoring;
- An energy storage medium, to allow the changing of power demand from the grid without negatively impacting production, output or access of energy.

Where direct integration with a singular industrial load is not required, but integration with another operators control platform is, the following is required:

- A reliable internet connection with every asset in the portfolio;
- Provide access to an interface for monitoring and control (e.g., web/server API);
- Clear documentation of control protocols to retrieve data and send commands.

The resolution of the data generators would need to be in the order of 1 Hz in order to allow quick response times and minimise the operation of smart technologies within properties outside curtailed periods.

The main requirement for making either an industrial load or aggregated load (primarily the latter) fully applicable to Orkney, is the necessity for good quality and reliable internet connections or backup 4G signals. Such systems are highly replicable, as long as data connection options are reliable and provide the necessary bandwidth.

Environmental factors

The aggregated load ,integrated into SMILE in Orkney, built upon the concept of using technology that would normally be found in a property, but introducing an altered method of operation to see stranded wind turbines operating to capacity more often. In this way there is a mutually beneficial relationship between the loads on the aggregator and wind turbines. As such, the equipment in the properties must be electrical storage by necessity. This is a technical requirement with environmental benefits.

There are no specific environmental requirements upon the DSM-loads within the aggregated load. However, as international efforts move towards renewable technologies there will be a growing demand/market for such aggregated loads to assist in balancing the local grid. Bans on traditional fossil fuels will see requirements on wind and solar farms, and it is this requirement that will see platforms such as this aggregated load replicated. Hot water cylinders are very common in domestic properties and are a form of energy storage already available; this factor alone contributes towards the highly replicability of this aggregator.

4 Replication on Greek shadow islands

In order to strengthen replication, selected Greek Islands will act as shadow islands for the SMILE pilots. Solutions tested in SMILE pilots will be selected and adapted to the needs of Greek islands. The procedure of island selection and the way SMILE solutions will be adapted to them are described in this chapter adjusting the tested SMILE solutions to Greek islands creating new opportunities for cooperation between pilot islands and technology providers, in future projects. The procedure followed is illustrated in Figure 36.

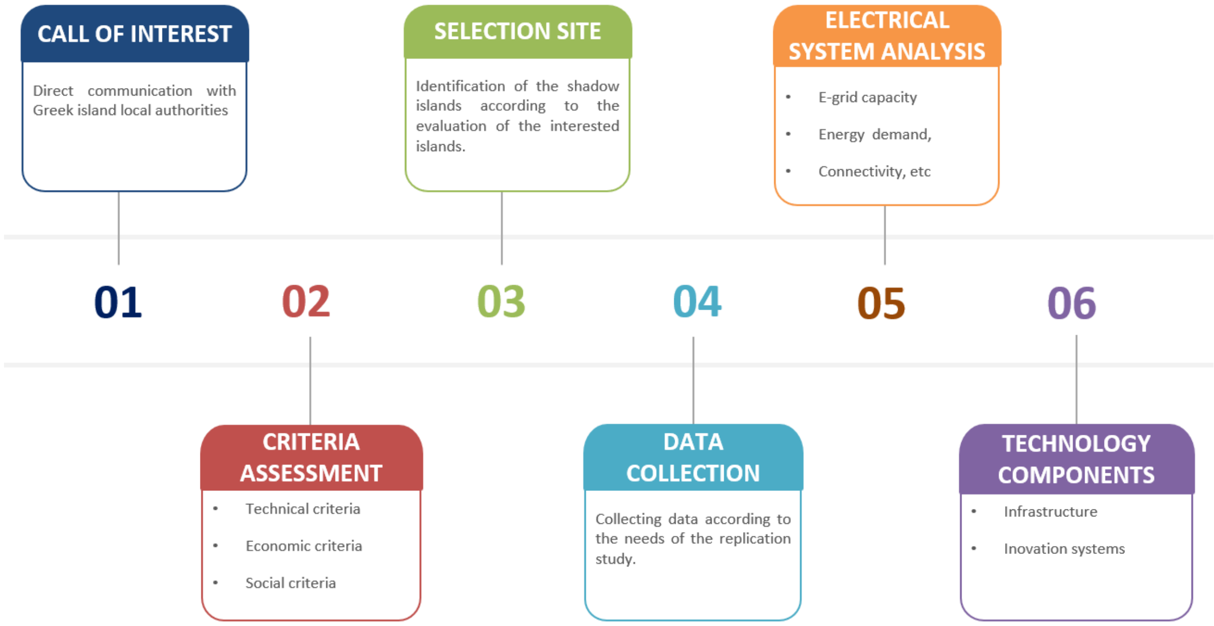

Figure 36. Replication methodology

4.1 Call of Interest and Identification of Shadow Greek Islands

As a first step, DAFNI Network prepared a catalogue in Greek language with the contribution of SMILE partners. It describes the integrated technological solutions applied to the SMILE demonstrators. In the catalogue, it is highlighted how the solutions implemented are tailored to the specific characteristics of the energy system of each island. The scope of the work is to introduce SMILE solutions to the Greek islands' local authorities, members of DAFNI Network of Sustainable Greek Islands. The catalogue accompanied the "call of interest" for replication in order to map the interested Greek islands. The catalogue can be found on the H2020 SMILE website under Press & Downloads. As a motive to engage, local authorities were informed of the concept note that would be delivered to them showcasing the SMILE replication potential in their territories.

In total fourteen island municipalities were interested as illustrated in Figure 38.

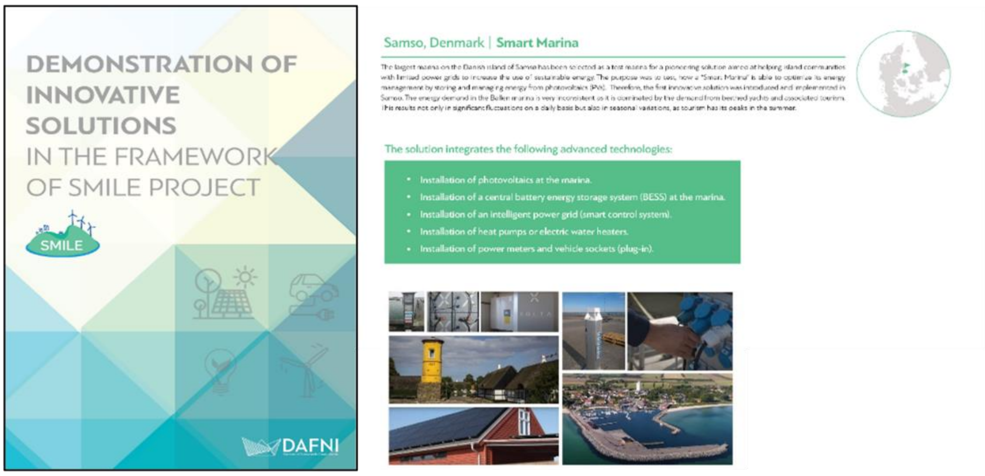

Figure 37. SMILE Catalogue

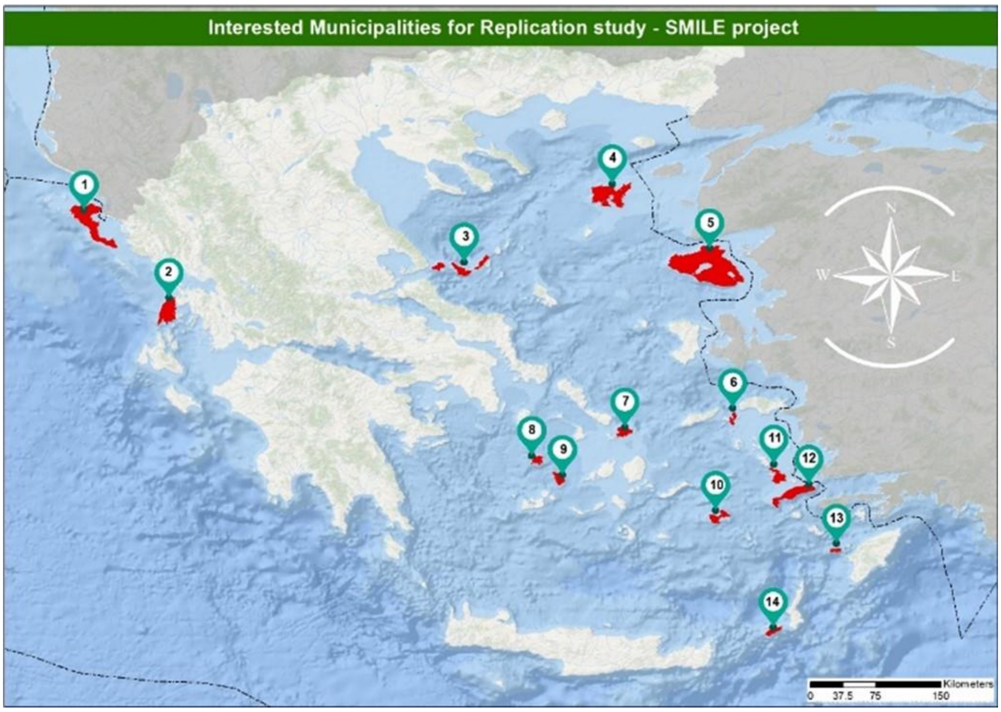

Figure 38. Interested Greek islands for replication

Table 4. Interested Greek islands for replication

#	Island	#	Island
1	Corfu	8	Serifos
2	Lefkada	9	Sifnos
3	Sporades	10	Astypalaia
4	Limnos	11	Kalymnos
5	Lesvos	12	Kos
6	Fourni	13	Chalki
7	Mykonos	14	Kasos

The next step was the selection of the islands which align with the requirements of the SMILE technologies. The assessment stage considers **technical**, **economic**, and **social** aspects which differentiate based on the demonstrator. The main criteria applied to the interested Greek islands are given in Table 5 below categorized per pilot.

Table 5. Main criteria for the interested Greek shadow islands

SMILE Demonstrator	Criteria
Samsø	A. Existence of touristic marina
	B. Level of seasonality
	C. Interconnectivity with mainland
Madeira	A. Level of EVs and PVs penetration
	B. Level of E-grid balancing issues
	C. Non-interconnected island
Orkney	A. High dependency on fossil fuels
	B. Need for heating and cooling
	C. Interconnected island complex

Supplementary horizontal criteria taken into account were: Islands Involved in other projects aimed at RES, RES potential, public acceptance, and information availability. The selected islands are depicted in the Table 6.

Table 6. Beneficiary for replication Greek

#	Greek shadow island	Pilot replicating
2	Lefkada (Kastos and Kalamos)	Samsø
7	Mykonos	Madeira
6	Fourni	Orkney
13	Chalki	
11	Kalymnos	
14	Kasos	

4.2 Greek shadow Islands and possible SMILE replication

4.2.1 Chalki – Orkney shadow island

The municipality of Halki includes the island of Halki and nearby uninhabited islands. Halki is one of the smallest islands of the south-eastern Aegean Sea, in the Dodecanese Island complex, with 478 inhabitants. It is located 5 miles west of Cape Armenistis of Rhodes, south-east of Tilos, the north-eastern part of the Carpathian Sea. The surface area of the island is 28 km^2 with a coastline of 34 km. Halki has only one port that serves the movement of residents and tourists. Halki is interconnected via ferry with Rhodes, and it is 2 hours from the main port of Rhodes. It is also served by a passenger ship that leaves from the port of Piraeus and operates a barren line passing through various Aegean islands such as Karpathos, Kasos, Crete, etc. The island of Halki does not have an airport.

The general aspect of Halki is characterized as mountainous and small or large lowland areas. The highest peak is 593 m in the north-eastern part of the island. The coasts are mostly steep and rocky with small sandy and pebble beaches. The whole island is included in the Natura 2000 network as a special protection zone. Residents are engaged mainly primary sector and specifically with livestock and fishing. Halki offers nature trails and has important historical monuments. It is also the ideal place for fishing and hiking. At the port is the settlement of Niborio, with houses of neoclassical architecture too.

4.2.1.1 Energy system of Chalki

The Rhodes – Chalki electric power system consists of the islands of Rhodes (1.401,46 km^2) and Chalki (26,99 km^2). The twin underwater electric power cable of 5 MVA capacity connects the two autonomous grids from the western part of Rhodes to the eastern part of Chalki.

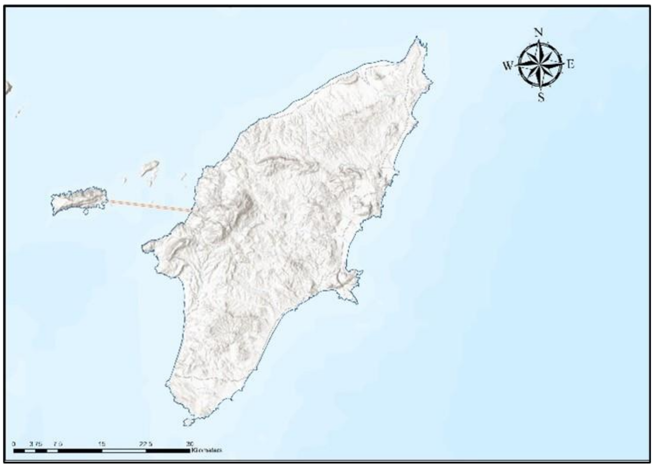

Figure 39. Map of Rhodes-Chalki power system

The installed power of the energy generation units is listed in Table 7 while in Table 8 the load and production level is illustrated.

Electrical system overview

Table 7. Electrical system overview of Rhodes-Chalki system

Year	Average load (MW)	Peak load (MW)	Electricity demand per year (GWh)	Load factor	RES electricity (MWh)	Thermal electricity (MWh)	RES Penetration (%)
2017	95	206	838	46%	164,650	673,140	14%

Table 8. Installed capacity (MW) of power plants in Kos-Kalymnos power system (2018)

Electric Power Systems	Wind Parks	PVs	Rooftop PVs	Net-metering PVs	Thermal Units
Rhodes-Chalki	48.55	18.16	1.21	0.19	232.93

The total contribution to the energy production of 2017 for Rhodes – Chalki electric power systems is depicted in Table 7. The production variability and the low rate of exploitation of RES, as well as the constraints that are imposed by the operator, are the main reason why the percentage between installed power and delivered energy is relatively different.

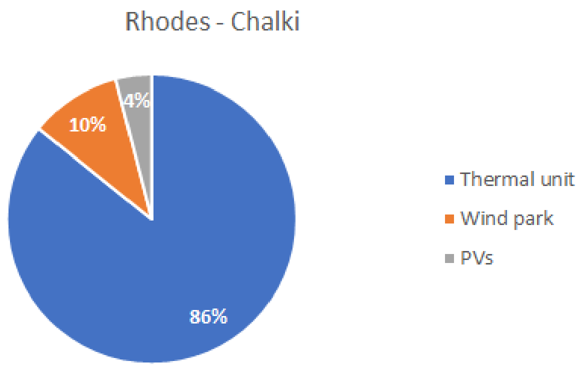

Figure 40. Contribution of each technology to energy production

Today, in the electric power systems of Rhodes – Chalki participate twelve electricity suppliers making them the second most represented non interconnected electric power systems in Greece in terms of electricity suppliers.

Thermal station

The only thermal station of the Rhodes – Chalki electric power system is located 2.5 km northeast of the community Soroni and 23 km southwest of the city of Rhodes. The total area of the station is 171.200 m^2 and the fuels consumed by its units are heavy fuel oil and diesel oil. A new thermal plant in South Rhodes is in operation since 2019, with a total capacity of 115,44 MW consisting of seven internal combustion engines, consuming heavy fuel oil and diesel oil.

The thermal units included in the Rhodes thermal station are:

- Two steam turbines, each with an installed capacity of 15 MW.
- Five internal combustion engines, from which two of them rated at 12,3 MW and the rest three of them each at 23,5 MW.
- Four gas turbines with capacities varying from 21 to 28 MW.
- Twenty generating sets, with a total installed capacity of 25,5 MW, are included in the system only in the summer months, without the possibility of change in their load.

The average total and variable cost of production from the conventional units of the Rhodes - Chalki system as developed monthly is illustrated in Figure 41.

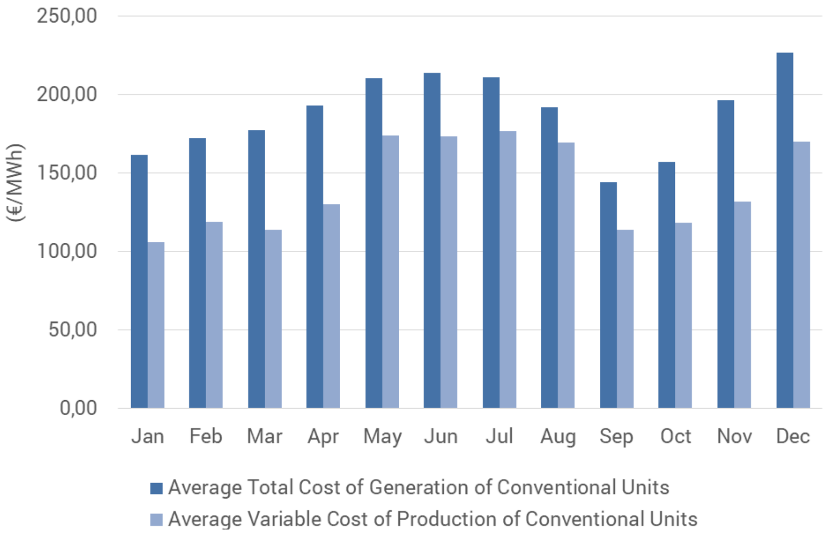

Figure 41. Cost of production of thermal unit Rhodes - Chalki system (2017)

4.2.1.2 Interventions at Chalki' Buildings

The municipal buildings presented in Table 9 are considered to replicate the Orkney SMILE solution. The school complex of the Municipality of Halki consists of two buildings, the building of the Secondary-Kindergarten and the building of the Primary School of Halki. The complex of buildings is located in the central settlement of Halki, near the eastern end of the settlement.

Table 9. Municipal buildings on Chalki

	Building	Area sqm	Heating and cooling	Estimation of consumption [kWh/m2]	Estimation of Consumption (Primary energy) [kWh]
	Secondary and kindergarten	306	60%	207.9	63,650
	Primary school	107	58%	316	33,810

4.2.1.3 Description of the existing situation of the buildings

Secondary school-Kindergarten

The autopsy on the building took place in February 2020. The location of the building favors the sunbathing of all aspects of the buildings in all directions. However, there are not enough openings in the building. At the same time, the openings are considered sufficient for the natural lighting of the

Secondary School rooms, while in the cases of the Kindergarten and the computer room located on the ground floor, the openings are considered insufficient.

Building's characteristics

Shell: The shell of the building consists of stone construction while the external frames of the building are wooden, with single glazing without thermal break.

Heating systems: The building does not have a central heating system. Heating is done through split-type air conditioners.

Lighting: The lighting of the building is mainly done by square lamps with T8 fluorescent lamps and compact fluorescent lamps. The lighting operation is controlled manually.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied

The energy certificate of the aforementioned building is illustrated in Figure 42.

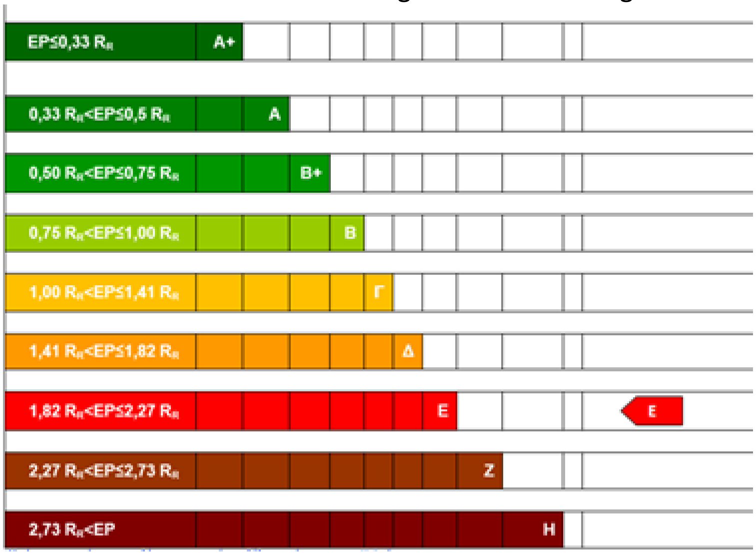

Figure 42. Energy certificate of Secondary and kindergarten

The energy behavior of the building is generally considered bad. The lack of thermal insulation, the lack of central heating-cooling system in the space, the old lighting systems degrade the comfort of using the space, while the draft existing solutions are characterized as particularly energy consuming. The energy behavior of the building can be significantly improved, with interventions in its openings and E / M systems.

In addition to SMILE solutions, the following interventions are proposed:

1. Installation of a central system for heating and cooling via a heat pump in combination with wall-mounted fan coil terminals
2. Replacing light bulbs with more energy efficient ones
3. Installation of BEMS system
4. Replacement of Frames with more energy efficient
5. Thermal insulation of the roof under a non-thermally insulated roof

Primary school
The autopsy on the building took place in February 2020. The location of the building favors the sunbathing of all aspects of the buildings in all directions. However, there are not enough openings in the building.

Building's characteristics
<u>Shell</u>: The shell of the building consists of coated brickwork with insufficient thermal insulation (exterior walls). The external frames of the building are wooden, with single glazing without thermal break.

<u>Heating systems</u>: The building does not have a central heating system. Heating is done through split type air conditioners. The building has very high heating needs during the winter months given its use. In addition, the lack of modern automation and energy saving equipment leads to high energy consumption.

<u>Lighting</u>: The lighting of the building is mainly done with T8 fluorescent lamps and compact fluorescent lamps. The lighting operation is controlled manually.

<u>Energy Inspection</u>: The Energy Inspection was carried out in accordance with the revised Regulation of Energy Efficiency of Buildings (KENAK) of 2017, while for the calculation of the energy efficiency of the building the 4M computer tool (4M-KENAK) was used.

The energy certificate of the aforementioned building is illustrated in Figure 43.

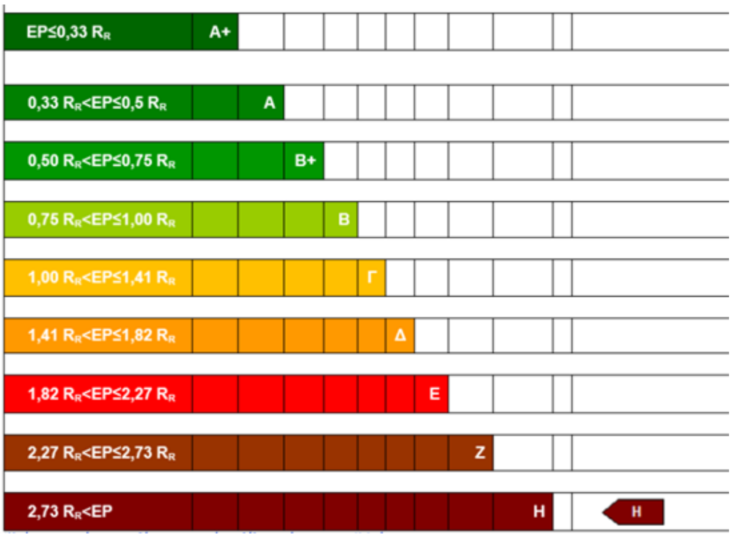

Figure 43. Energy certificate of Primary school

The energy behavior of the building is generally considered bad. The lack of thermal insulation, the lack of heating-cooling system in the space, the old lighting systems degrade the comfort of using the space, while the existing solutions are characterized as highly energy consuming. The energy behavior of the building can be significantly improved, with interventions in the shell and its E / M systems.

In addition to SMILE solutions, the following interventions are proposed:

1. Installation of a central system for heating and cooling via a heat pump in combination with wall-mounted fan coil terminals
2. Replacing light bulbs with more energy efficient ones
3. Installation of BEMS system
4. Replacement of Frames with more energy efficient
5. External Thermal Insulation of Masonry
6. Thermal insulation of the roof under a non-thermally insulated roof

4.2.2 Kalymnos - Orkney shadow island

The municipality of Kalymnos includes the island of Kalymnos, the nearby islands of Pserimos Telendos and Plati as well as the surrounding uninhabited islands. The island of Kalymnos belongs to the Dodecanese Island complex and is located in the southeast Aegean Sea, between the Icarian (northwest) and the Carpathian (southeast) Seas. It is the fourth largest island of the Dodecanese with an area of 109,67 km^2. The capital of the island is Pothia and is located on the south side of the island. According to the latest census, the population of the island reaches 16,140 people and includes 16 settlements.

Kalymnos has a main port located in the settlement of Pothia and is directly connected by ferry with Piraeus, Rhodes, Kos, Samos, Patmos, Leros, Astypalaia, Nisyros, Tilos, and other smaller islands. It is also connected to Athens by air, with daily flights. The total arrivals reached 11,703 in 2017. The terrain of the island is relatively rocky mountainous with small plains. The mountains of Kalymnos are treeless with the highest peak of Prophet Elias, with an altitude of 760 m.

Of the primary sector industries, fisheries are prominent on the island of Kalymnos. It is traditionally the island of sponge divers and sponge fishermen. Seafood trades, especially sponging, have made the island famous all over the world. Agriculture in Kalymnos is not developed due to the great scarcity of arable land and water. The tertiary sector is the most developed on the island with tourism and trade be prominent.

4.2.2.1 Energy system of Kalymnos

The Kos – Kalymnos electric power system is significantly more complicated as it connects a total of nine Dodecanese islands, specifically it consists of the islands of Kos (287.61 km^2), Kalymnos (110.58 km^2), Tilos (61.49 km^2), Leros (54.05 km^2), Nisyros (41.26 km^2), Leipsoi (15.84 km^2), Pserimos (14.62 km^2), Telendos (4.65 km^2) and Gyali (4.56 km^2). The capacities of the twin electric underwater power cables vary from 5 to 10.4 MVA. They connect the nine autonomous grids between them to form the electric power system in question.

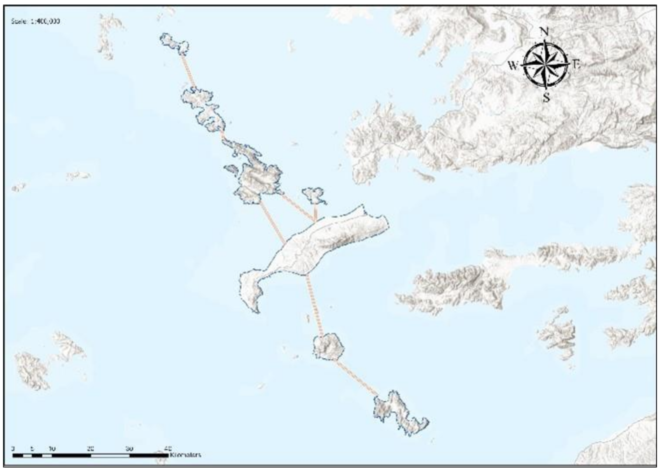

Figure 44. Map of Kos-Kalymnos power system

Future aspects

Interconnection of the Dodecanese with mainland Greece is the new major island interconnection that is part of the new preliminary Ten-Year Development Program of the Independent Power Transmission Operator for the period 2020-2029. In particular, the interconnection of the Dodecanese, with a budget of 1,5 billion €, to be completed in 2027, provides for the interconnection of Kos with the mainland transmission system through the new Extra High Voltage Center in Corinth via an underwater DC cable with a length of 380 km and a capacity of 900 MW. The direct interconnections of Kos with Rhodes and Rhodes with Karpathos will then follow. Thus, this long-awaited interconnection will allow for the reliable supply of the Dodecanese by the mainland system and the utilization of the RES potential, with significant environmental and socio-economic benefits.

Electrical system overview

Table 10. Electrical system overview of Kos-Kalymnos system

Year	Average load (MW)	Peak load (MW)	Electricity demand per year (GWh)	Load factor	RES electricity (MWh)	Thermal electricity (MWh)	RES Penetration (%)
2017	43.28	98.20	384,811	44.2	56,495	328,316	14.68%

The installed power of the energy generation units, listed in Table 11, represents energy production profile in the current system.

Table 11. Installed capacity (MW) of power plants in Kos-Kalymnos power system (2018)

Electric Power Systems	Wind Parks (4)	PV station (92)	Rooftop PVs	Net-metering PVs	Thermal Units
Kos-Kalymnos	15.2	8.78	0.7	0.07	133.66

The total contribution to the energy production of 2017 for Kos – Kalymnos electric power systems is depicted in the next Figure 45.

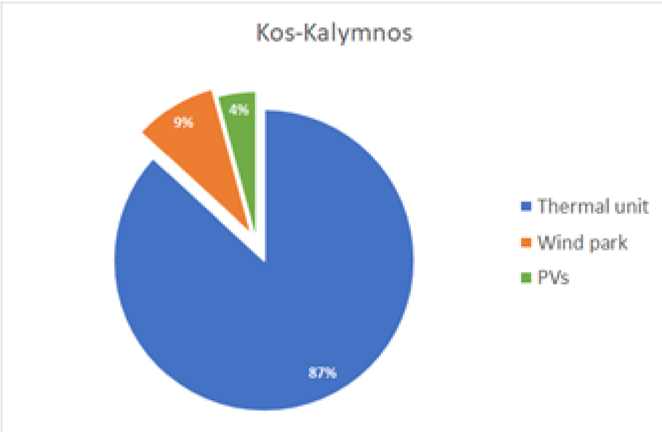

Figure 45. Contribution of each technology to energy production

Thermal stations

There are two independent thermal stations in the Kos – Kalymnos electric power system, consuming heavy fuel oil and diesel oil. The first is located in central-western Kos, 5 km southwest from Mastichari and it consists of:

- Sixteen internal combustion engines, varying in sizes and capacities, with a total installed capacity of 87 MW
- One gas turbine rated at 16 MW
- Three generating sets, with a total installed capacity of 5 MW

The second is located in southern Kalymnos, 1.5 km east of the main port and it consists of:

- Five internal combustion engines, from which one rated at 8.5 MW, one at 2.7 MW, and the other four with 1.8 MW installed capacity each.

Cost of production

The average total and variable cost of production from the conventional units of the Kos – Kalymnos system as developed monthly in the previous year is depicted in Figure 46.

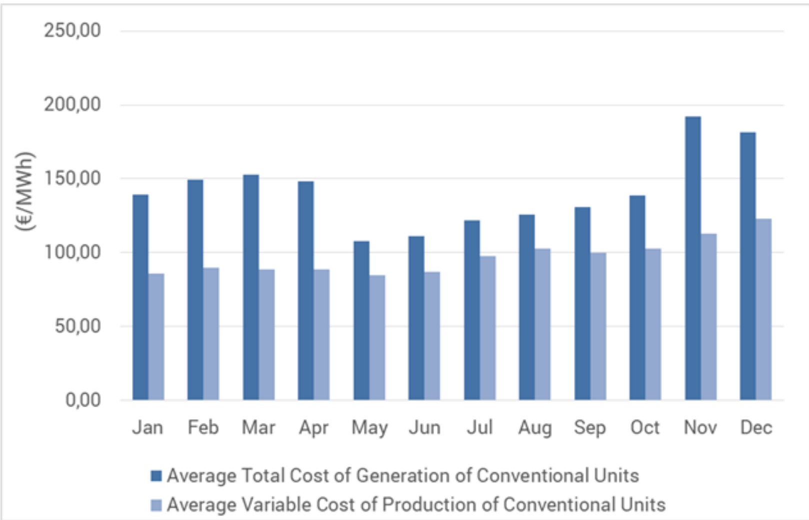

Figure 46. Cost of production of thermal unit Kos – Kalymnos system (2017)

4.2.2.2 Interventions at Kalymnos' Buildings

The municipal buildings presented in the next Table 12 are considered to replicate the Orkney SMILE solution.

Table 12. Municipal buildings on Kalymnos

	Building	Area sq m	Heating and cooling	Estimation of consumption [kWh/m²]	Estimation of Consumption (Primary energy) [kWh]
	Primary School of Kalymnos (3 units)	1,363	57%	495	675,000
	Primary school of Bathy	362.84	58%	206	75,745
	Hospital of Kalymnos	4,149	54%	706	2,930

4.2.2.3 Description of the existing situation of the buildings

Primary school of Kalymnos

The autopsy on the complex took place in June 2018. The primary school complex consists of 3 buildings. The position and orientation of the buildings favor the sunbathing not only of the roof but also of the vertical views of all the floors. The buildings do not meet modern energy efficiency standards as they were constructed based on old non-applicable standards.

Buildings' characteristics

Shell: Filling walls: Exterior masonry with a total thickness of 25cm, from corrugated brickwork - insulation - street brickwork coated inside and out with lime-cement mortar, without thermal insulation (Ut1 = 2.20 W / m2, ^{O}K).

Bearing body: Exterior concrete (beams and columns) with a total thickness of 35cm, made of reinforced concrete, coated inside and out with lime-cement mortar, without thermal insulation (Ut2 = 3.40 W / m2, ^{O}K).

The average heat transfer coefficient, U-value, of the exterior surfaces was calculated as a weighted average in proportion to the percentage of concrete / filler walls.

- Roof: Flat passable reinforced concrete roofs without thermal insulation (UR = 3.05 W / m2, ^{O}K)
- Floors: on the ground with any coating, the coefficient was exported as UF = 3.10 W / m2, ^{O}K)
- Windows: Metal frames (20%) with single glazing Uw = 6.0 W / m2, ^{O}K.
- Exterior doors: Metal frames without glass UD = 3.5 W / m2, ^{O}K

Heating systems: The production of hot water for the heating of the school complex takes place in a central boiler room in the main building K2, from a boiler with a capacity of P = 140 kW (120,000 kcal / h) with a two-stage oil burner, from where the distribution networks start. For each building there is an independent circuit (supply-return) with a constant speed circulator that operates manually ON-OFF.

Lighting: All buildings are illuminated by 85% of the floor area, through natural light. In Artificial Lighting, they have luminaires with twin fluorescent lamps T8 - 36W, for the main lighting, with manual ON-OFF function.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned buildings is illustrated in Figure 47.

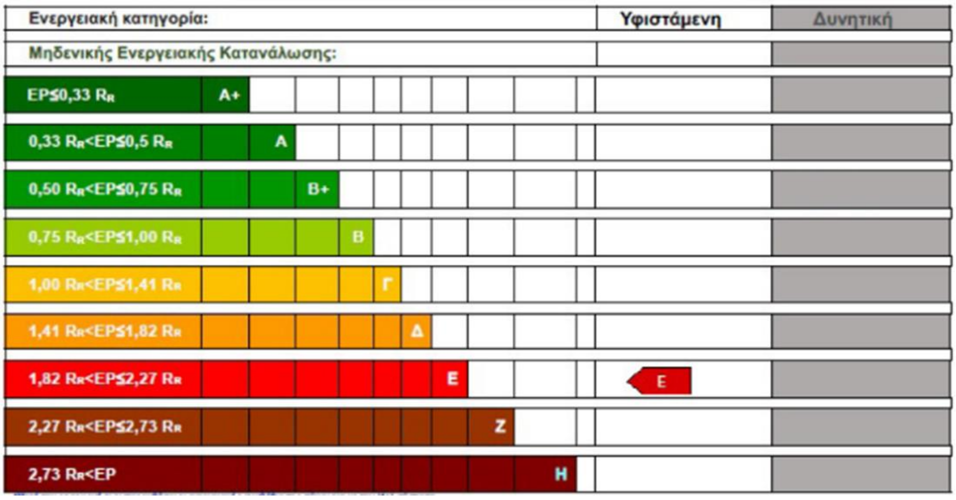

Figure 47. Primary School of Kalymnos

Both the active and the passive energy behavior of the buildings of the complex are judged as "unacceptable" based on the criteria of KENAK categorized in category: "E". It is considered that the improvement of the active energy components (E / M installations) will bring equivalent significant energy savings.

In addition to SMILE solutions, the following interventions are proposed:

1. Installation of air conditioning system (heating - cooling) with autonomous units for direct air-water heat dissipation of high temperatures.
2. Replacing light bulbs with more energy efficient ones
3. Installation of BEMS system
4. Independent operation control per space.
5. Frame replacement

Primary school of Bathi

The autopsy on the building took place in June 2018. The initial part of the school was built in 1930. The building of the Primary School occupies a total area of 362.84 m^2 and consists of the initial building, while in 2000 an extension was constructed.
The position and orientation of the buildings favor the sunbathing not only of the roof but also of the vertical views of all the floors.
The buildings do not meet modern energy efficiency standards as they were constructed based on old non-applicable standards.

Buildings' characteristics

Shell: The external walls of the "new" part of the school are made of brickwork 0.25 m. with coating inside and outside, with insufficient thermal insulation protection according to the Thermal Insulation Regulation of Buildings. The façade of the building has a southeast orientation (SE). The initial part of the school has a 0.65 m thick stone structure with internal and external coating, without thermal insulation protection. The façade of the building is southwest (SW).

Heating systems: The school premises have a central heating system with oil boiler, power 40kW of moderate efficiency.

Lighting: The school has luminaires with linear T8 fluorescent lamps in the teaching areas, incandescent in the toilets and the boiler room and in the auxiliary areas. The lighting needs are particularly high due to the nature of the building and in general, the lighting of the building is a critical element in the operation of the school.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned building is illustrated in Figure 48.

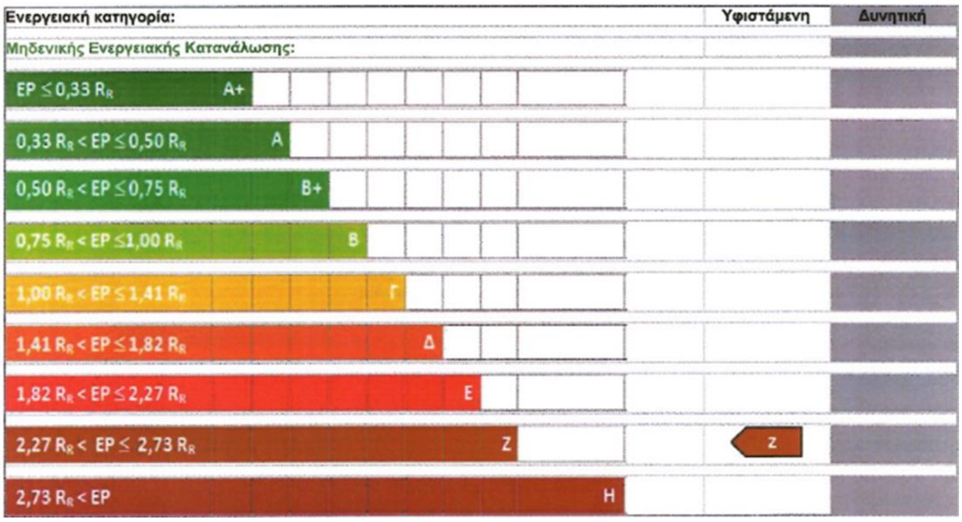

Figure 48. Energy certificate of primary school of Bathy

The energy behavior of the building is generally considered bad. The installed heating system is old technology, showing increased energy consumption, while the old lighting system is very energy consuming. The energy behavior of the building can be significantly improved, with interventions in the shell and its E / M systems.

<u>In addition to SMILE solutions, the following interventions are proposed:</u>

1. Installation of air conditioning system (heating - cooling) with autonomous units for direct air-water heat dissipation of high temperatures.
2. Replacing light bulbs with more energy efficient ones
3. Installation of BEMS system
4. Frame replacement

Hospital of Kalymnos

The General Hospital of Kalymnos "To Vouvaleio" was built in 1926 with modifications-renovations and additions in the 70's to meet the ever-increasing needs for health care in Kalymnos, co-housing its clinics as a Health Center until today.

The building of the hospital has been characterized as a "historic building of special architectural interest" according to the decision of the Council of Architecture of the Regional Unit of Kalymnos.

The building facilities of the hospital occupy a total area of 4.149 m^2 and consists of one (1) building (thermal zone) which has been constructed in two phases.

The building is located in a relatively sparsely structured urban environment and borders adjacent plots on the southwest, southeast and northeast side, while on the south and north it adjoins provincial roads. The entrance of the building is located on the north and south sides.

The position and orientation of the building complex favor the sunbathing, not only of the roof but also of the vertical views of all the floors.

The building does not meet modern energy efficiency standards, as it was built based on old non-applicable standards. The autopsy on the building took place in April 2018.

Building's characteristics

<u>Shell</u>:

- Filling walls: Old section: Exterior masonry with a total thickness of 60 cm., Made of stone and brickwork, with internal and external plaster coatings with insufficient thermal insulation protection according to the Thermal Insulation Regulation of Buildings. New section: Exterior masonry with a total thickness of 25 cm., Made of brickwork, with internal and external coatings of plaster with insufficient thermal insulation protection according to the Thermal Insulation Regulation of Buildings.

- Bearing structure: Old section: Self-supporting construction made of stone, coated internally and externally with plaster, without thermal insulation. New section: Reinforced concrete (beams and columns) with a total thickness of 35 cm, coated internally and externally with plaster, without thermal insulation.
- Roof: Flat passable reinforced concrete roofs without thermal insulation (UR = 3.05 W / m2, ^{O}K)
- Floors: On the ground with any coating, the coefficient was exported as UF = 3.10 W / m2, ^{O}K.
- Windows: Old section: Wooden (20%) with double energy glazing. New section: Wooden frames with single U-value high glazing which negatively affects the energy behavior of the building.
- Exterior doors: Old section: Wooden frames with energy glass. New section: Wooden and metal frames UD = 3.5 W / m2, ^{O}K.

<u>Heating systems</u>: The production of hot water for the heating of the hospital of Kalymnos is made in the central boiler room by a boiler with a capacity of P = 500 kW with a two-stage oil burner, from where the distribution networks start. For the building there is a circuit (supply-return) with a constant speed circulator that operates manually ON-OFF.

<u>Lighting</u>: The buildings are illuminated by 85% of the floor area, through natural light. In Artificial Lighting, they have luminaires with fluorescent lamps T8 – 36W, for the main lighting, with manual ON-OFF function.

<u>Energy Inspection</u>: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned building is illustrated in Figure 49.

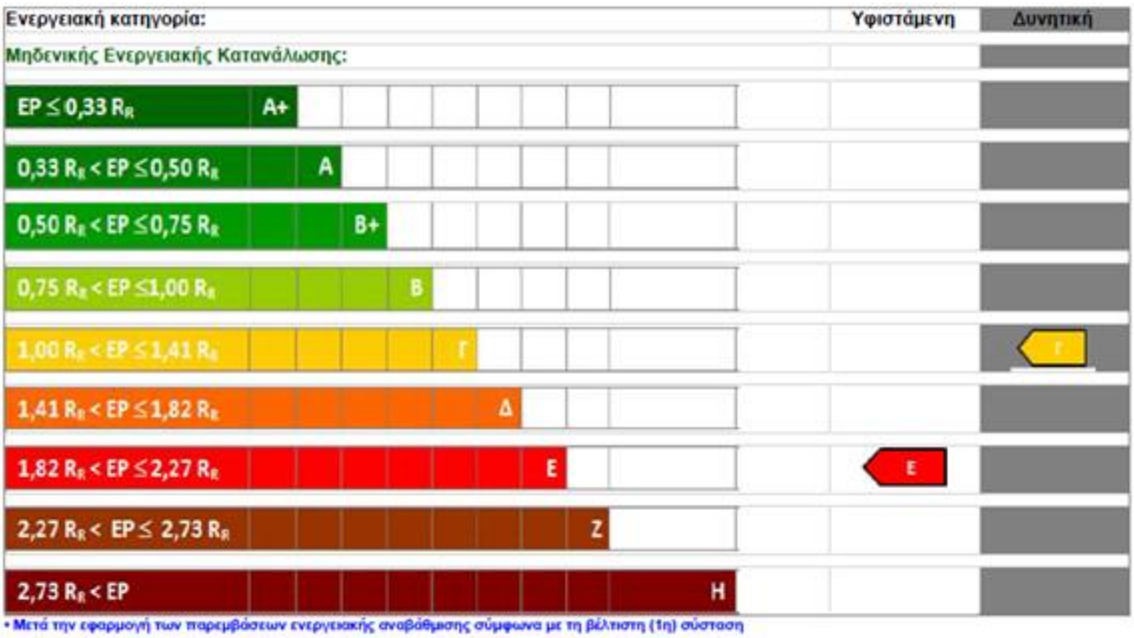

Figure 49. Energy certificate of Kalymnos' hospital

The energy behavior of the building is generally considered bad. The installed heating system is old technology, showing increased energy consumption, while the old lighting system is very energy consuming. The energy behavior of the building can be significantly improved, with interventions in the shell and its E / M systems.

The highlighted area below refers to the hospital building plan.

Figure 50. Architecture plan of Kalymnos' hospital

<u>In addition to SMILE solutions, the following interventions are proposed:</u>

1. Installation of DHW production system with autonomous unit for direct air-water heat dissipation of high temperatures.
2. Replacing light bulbs with more energy efficient ones
3. Roof thermal insulation
4. Internal thermal insulation system of external walls

4.2.3 Fourni – Orkney shadow island

The Municipality of Fourni Korseon is a municipality of the North Aegean region that includes the complex of Fourni -a cluster of barren small islands- consisting of the islands of Fourni, Thymena, Agios Minas, and some smaller uninhabited islands. Their location is west-southwest of Samos and east of Ikaria. Administratively they belong to Samos. Fourni is the largest island of the cluster with an area of 30.5 km^2 where the capital with 1,120 inhabitants is located. The island of Fourni is populated with 1,320 inhabitants.

The island of Fourni contains one port, which serves the transport of residents and tourists. Fourni island is networked by a ferry connection with the ports of Piraeus, Ikaria, Kalymnos, Samos, and other islands of the Aegean Sea. The island has no airport infrastructure. However, the level of seasonality on the island is high since the population rapidly increases during the summer due to tourism.

The cluster of Fourni islands is characterized by steep rocky coasts and it belongs to the Natura 2000 network. The permanent residents are mainly occupied with fishing activities taking place in the surrounding sea. The main occupation is related to activities taking surrounding sea. Also, Fourni island is famous for its honey production. Honey is produced from thyme, heather, and other plants. For most of their history, the islands have been uninhabited or pirate haunts. The scarce archaeological material suggests that in antiquity Fourni may have been inhabited during the Archaic and Classical periods, while it is certain that they were inhabited during the Hellenistic and Roman periods.

Energy system of Fourni

The power system of Samos consists of the three (3) islands of Samos, Fourni, and Thymaina. It is a non-interconnected archipelago located in the North Aegean Sea. The power system together with the power capacities of submarine three-pole power cables of 5 MVA is illustrated in Figure 51.

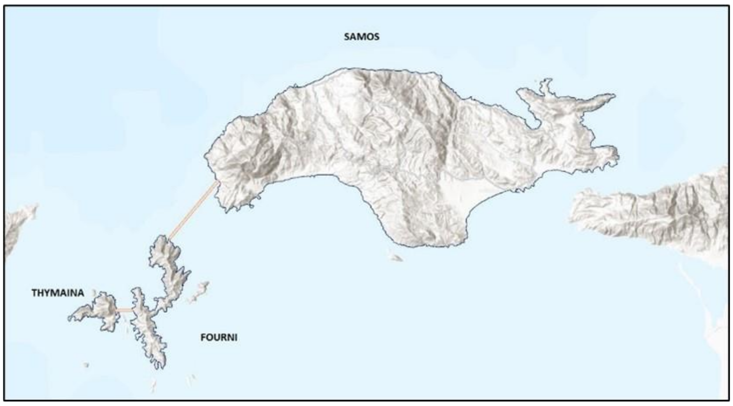

Figure 51. Map of Samos power system

The Samos - Fourni interconnection is carried out with two cables. In case one of the cables is cut off, then the transmission capacity is limited to 3,013 MW. The simultaneous peak of Fourni and Thymaina islands is estimated at 1,32 MW, so the case of cutting one cable does not cause an electrical problem on Fourni and Thymaina islands.

Future plans

The power system of Samos will be extended by the interconnection with the islands of the North Aegean through submarine high voltage cables. The project will begin with the interconnection with Ikaria Island through Samos in order to be achieved a significant reduction in the total cost of electricity for Ikaria. In addition, in Ikaria Island is cited a hydraulic station which will facilitate the RES penetration across the interconnection, even before the interconnection with the North Aegean islands.

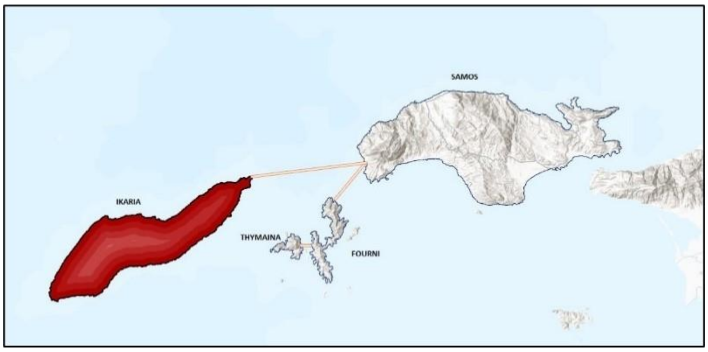

Figure 52. Map of future plan of Samos power system

The electrical system of Samos covers the needs of electricity of a total amount of 34.446 inhabitants. The demand for the power system of Samos reached 31.8 MW in 2017. The wide variation in daily and seasonal demand proves that the features of the system are demanding. The load factor of the Samos power system in the last five years is between 50.2% and 54.4%, which is quite high revealing that the load of the system is maintained at relatively high levels, even during the winter months.

Electrical system overview

Table 13. Electrical system overview of Samos system

Year	Average load (MW)	Peak load (MW)	Electricity demand per year (GWh)	Load factor	RES electricity (MWh)	Thermal electricity (MWh)	RES Penetration (%)
2017	15.92	31.8	143.6	50.2%	25,901.8	117,725.7	18.03%

The installed power of the power plants is listed in Table 13 which represents the power generation profile in the system. The photovoltaic units that function under the program of virtual net metering are partially excluded because they do not directly contribute to the grid.

Table 14. Installed capacity (MW) of power plants in Samos power system

Electric network	Wind farms (6)	PV stations (63)	Thermal plants (6 units)
Samos Power System	8,375	4,373	47

The total contribution to the energy production of 2017 for the power system of Samos is shown in the following Figure 53. Similarly, like the other islands, the variability of production, the low rate of exploitation of RES, as well as the restrictions that may be imposed by the system administrator, are the main reasons for the low level of penetration of renewable energy sources.

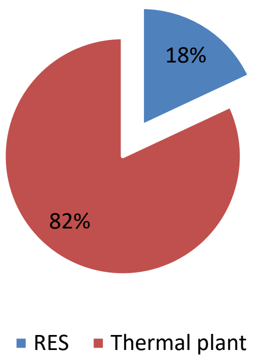

Figure 53. Energy mix for Power system of Samos (2017)

Thermal station

The thermal station operates with heavy fuel oil while its electromechanical equipment has been periodically updated. The total thermal installed capacity in Samos equals 47 MW. It is worthy to mention that the power of the largest thermal unit in the Samos power system equals 11 MW, at the rate of 35% of the peak of the system, which does not facilitate the absorption of energy from RES.

Cost of production

The average total and variable production costs of thermal units in the power system are shown in Figure 54, as they developed monthly in 2017.

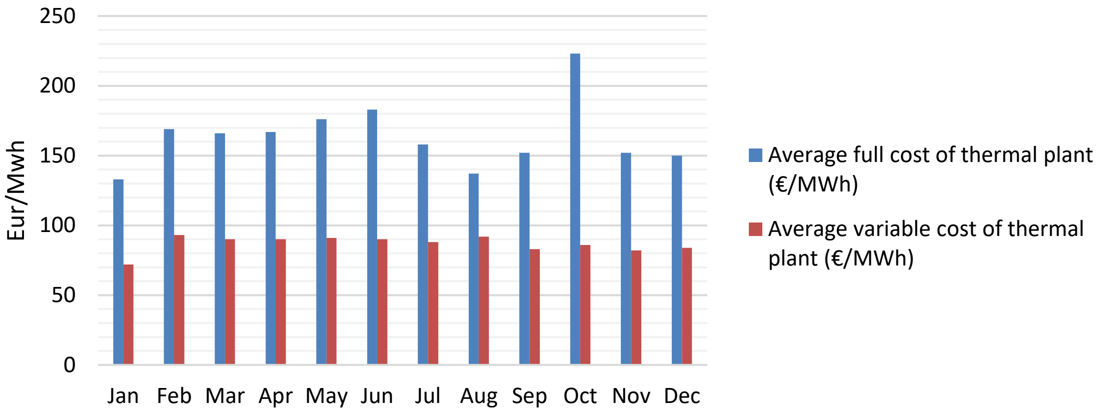

Figure 54. Cost of production of thermal unit Samos power system (2017)

4.2.3.1 Interventions at Fourni' Buildings

The municipal buildings presented in the next Table 15 are considered to replicate the Orkney SMILE solution.

Table 15. Municipal buildings on Fourni

	Building	Area m^2	Heating and cooling	Estimation of consumption [kWh/m^2]	Estimation of Consumption (Primary energy) [kWh]
	Primary school of Fourni	635.60	57%	282.50	180,000
	Primary school of Thimena	56.75	58%	200.70	11,400
	Primary school of Chrisomilia	136.91	77%	244.90	33,550

4.2.3.2 Description of the existing situation of the buildings

Primary school of Fourni

The building that houses the primary school is located in the center of the settlement of Fourni Korsea. It consists of two buildings constructed in different time periods. The first building was built in 1950 and is on the ground floor with a total area of 208.5 m^2 while the second building is two storey and has a total area of 427.1 m^2 and was built in 1985. The old primary school building is developed on the East-West axis and has a north orientation while the latter building has a West one.

Building's characteristics

Shell: Since the construction of the buildings that house the primary school was completed in 1950 for the first building and in 1985 for the second, it is understood that there is no thermal insulation in any part of the shell in the first building, while the application of insulation is considered incomplete for the second. The construction of the shell in the old building consists of 70 cm thick stonework and has a wooden roof with a tiled roof, while for the second building the construction consists of a load-bearing structure of reinforced concrete and filling masonry of perforated bricks. A percentage of the building shell is covered by openings. The openings consist of wooden opening frames with single glazing with rather poor airtightness. During the energy inspection it was found that the condition of the window frames and the windows in the Primary School of Fourni is bad and in fact they contribute significantly to the increase of heat losses in an area with very low temperatures.

Heating systems: The heating of both buildings is done with heat accumulators of power about 2KW per terminal unit while it was estimated that there are four bodies per room. The heat accumulators are very old with very poor emission and it is judged that they are not sufficient due to reduced efficiency to cover the thermal losses of the buildings.

Lighting: As the building has several openings but also due to its orientation, the natural light in a large part, and in a large percentage of the hours of use is considered sufficient to cover the lighting needs for lighting intensity of 300lux.

Artificial lighting: To meet the lighting needs, the buildings mostly use incandescent lamps. The condition of the luminaires is considered moderate. According to the measurements, however, the natural light is sufficient to ensure the required level of lighting for the use of the building. Thus, in most areas, it is not necessary to use artificial lighting during most of the operation time of the buildings.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned building is illustrated in Figure 55.

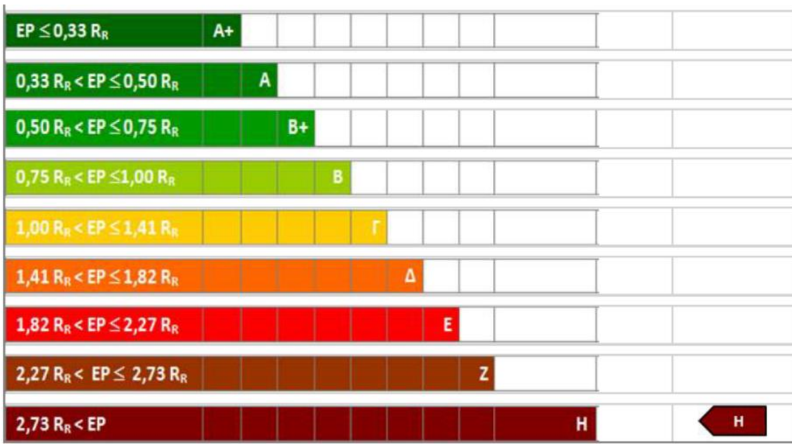

Figure 55. Energy certificate of Fournoi's Primary school

The energy behavior of the building is generally considered bad. The lack of thermal iinsulation application in the shell of the building has significant heat losses and this is recorded in the consumption of fuel for heating. Furthermore, the lighting is done mainly with the use of artificial lighting, despite the fact that in many rooms, natural lighting values were measured, sufficient for their use needs. The energy behavior of the building can be significantly improved, with interventions in the shell and its E / M systems.

In addition to SMILE solutions, the following interventions are proposed:

1. Addition of thermal insulation to the shell and the building
2. Replacement of the frames with newly certified ones
3. Replacement of luminaires and the installation of light sensors
4. Installation of a geothermal system

Primary school of Thimena

The building that houses the primary school is located in the center of the settlement of Thimena in the municipality of Fourni Korsea and is a ground floor with a total area of 63 m^2. The building is developed on the North-South axis and has a west orientation. The construction of the building was completed in 1950, several years before the implementation of the thermal insulation regulation.

Building's characteristics

Shell: The construction of the shell consists of a stone structure 70 cm thick and has a wooden roof with a tiled roof. No structural element of the building has insulation. A percentage of the building shell is covered by openings. The openings consist of wooden opening frames with single glazing with rather poor airtightness. During the energy inspection it was found that the condition of the frames and the windows in the Primary School of Thimena is bad and in fact they contribute significantly to the increase of heat losses in an area with very low temperatures.

Heating systems: The heating of the building is done with two heat pumps, one for the classroom and one for the teachers' office with thermal power of 18,000 BTU each. Heat pumps have recently been installed and operate relatively efficiently.

Lighting: As the building has several openings but also due to its orientation, the natural light in a large part, and in a large percentage of the hours of use is considered sufficient to cover the lighting needs for lighting intensity of 300lux. Artificial lighting: To meet the lighting needs of the building they mostly use fluorescent lamps. The condition of the luminaires is considered moderate. According to the measurements, however, the natural light is sufficient to ensure the required level of lighting for the use of the building. Thus, in most areas it is not necessary to use artificial lighting during most of the operation time of the buildings.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned building is illustrated in Figure 56.

Figure 56. Energy certificate of Thimena's Primary school

The energy behavior of the building is generally considered bad. The lack of thermal insulation of the shell together with the old frames result in increased energy consumption, while the old lighting system is very energy consuming. The energy behavior of the building can be significantly improved, with interventions in the shell and its E / M systems.

In addition to SMILE solutions, the following interventions are proposed:

1. Addition of external thermal insulation to the shell and the building
2. Replacement of the frames with newly certified ones
3. Replacement of luminaires and installation of light sensors

Primary school of Chrysomilia

The building that houses the primary school is located at the highest point of the settlement of Chrysomilia in the municipality of Fourni Korsea. It consists of two buildings built in different time periods. The first building was built in 1950 and is ground floor with a total area of 63 m^2 while the second building is two storey and has a total area of 74 m^2. Both buildings are developed on the North-South axis and have a West orientation.

Building's characteristics

Shell: The construction of the buildings that house the primary school was completed in 1950, several years before the implementation of the thermal insulation regulation. Therefore, no structural element of the building has insulation as shown by the detailed measurements using a thermal camera. The construction of the shell consists of 70 cm thick stonework and has a wooden roof with a tiled roof. A percentage of the building shell is covered by openings. The openings consist of wooden opening frames with single glazing with rather poor airtightness. During the energy inspection it was found that the condition of the window frames and the windows in the Primary School of Chrysomilia is bad and in fact they contribute significantly to the increase of heat losses in an area with very low temperatures.

Heating systems: Central heating: The heating of both buildings is done with three heat pumps, one for the older building and two for the newer thermal power of 18,000 BTU each. Heat pumps have been installed relatively recently and operate relatively efficiently.

Lighting: As the building has several openings but also due to its orientation, the natural light in a large part, and in a large percentage of the hours of use is considered sufficient to cover the lighting needs for lighting intensity of 300lux.

Artificial lighting: To meet the lighting needs, the buildings mostly use incandescent lamps. The condition of the luminaires is considered moderate. According to the measurements, however, the natural light is sufficient to ensure the required level of lighting for the use of the building. Thus, in most areas, it is not necessary to use artificial lighting during most of the operation time of the buildings.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned building is illustrated in Figure 57.

Figure 57. Energy certificate of Chrisomilia's Primary school

The energy behavior of the building is generally considered bad. The lack of thermal insulation application in the shell of the building has significant heat losses and this is recorded in the consumption of fuel for heating. Furthermore, the lighting is done mainly with the use of artificial lighting, despite the fact that in many rooms, natural lighting values were measured, sufficient for their use needs. The energy behavior of the building can be significantly improved, with interventions in the shell and its E / M systems.

In addition to SMILE solutions, the following interventions are proposed:

1. The addition of thermal insulation to the shell and the building.
2. The replacement of the frames with new certified ones
3. Replacement of luminaires and installation of light sensors

4.2.4 Kasos – Orkney shadow island

The Municipality of Kasos is located in South Aegean and it includes the island of Kasos and 14 neighbouring uninhabited islands. Kasos is located at the southernmost tip of the East Aegean, in the Dodecanese region, between Crete and Karpathos. The Municipality of Kasos together with the Municipality of Karpathos form the Regional Unit of Karpathos. Kasos has a population of 1085 people and has an area of 64 km^2 and a coastline of 59 km. The capital of the municipality is Fri which is also the only port on the island. The island is connected by ferry with Crete, Piraeus, Karpathos, Rhodes, Chalki, and the islands of Cyclades. It is also connected to Athens by air via Crete, Rhodes and Karpathos.

The island of Kasos is mountainous and rocky, with little arable land. It has a maximum altitude of 597 m. On the island, there are no areas classified as forests, but in the last 20 years, the municipality follows a reforestation plan. The primary sector of Kasos is limited, with a significant part of the parcels of land remaining uncultivated. There is a low level of crops while livestock farming is the most important sector of the primary sector. The existence of numerous bays and islets, the rich relief of the seabed, and the existence of favourable sea currents have contributed to the great fishing wealth of the area in which they flock professional fishing vessels from other islands. The secondary sector of Kasos is limited.

Its ecclesiastical and cave wealth refers to the traditional settlements with the local lifestyle (music, gastronomy, house architecture), the island's great historical tradition and the natural environment are important factors in attracting visitors. It appears that Kasos attracts an alternative mild tourism, that responds to the natural and cultural characteristics of the island.

Energy system of Kasos

The power system of Kasos consists of the two (2) islands of Kasos and Karpathos. It is a non-interconnected archipelago located in the South Aegean Sea in close distance from Crete Island. The power system interconnection is made with two cables while in case of one is cut off then the transmission capacity is limited to 3,949 MW. The peak of Kasos is estimated at 2 MW.

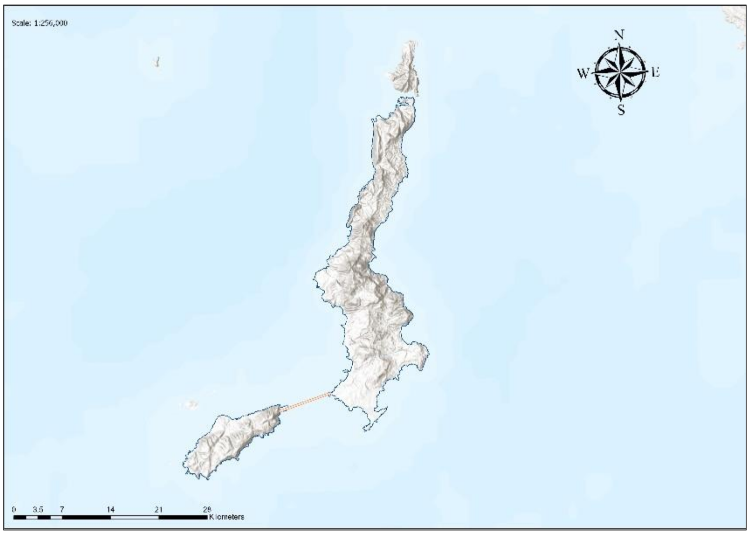

Figure 58. Map of Karpathos and Kasos power system

Future plan

According to the ten-year development program of the Hellenic Electricity Transmission System (ESMIE), the interconnection of the Dodecanese is part of the implementation program after 2023. Specifically, as mentioned before, the project of the interconnection of the Dodecanese concerns the interconnection with the National Transmission System Energy of several Southeast Aegean islands (Rhodes, Simi, Kos-Kalymnos, Patmos and Marathi). As an optimal solution for the electrification of the aforementioned Non-Interconnected Islands (MDNs) of the Southeast Aegean, it is planned to connect them directly from the ESMIE with a HVDC connection capacity of 2 x 450 MW, in the long-term horizon, which will facilitate the penetration of RES.

Electrical system overview

The demand for electricity in the Karpathos - Kasos system is seasonal, due to the significant increase of the population during the summer period and the integration of the tourist infrastructure, which during the winter period remain inactive.

Table 16. Electrical system overview of Karpathos-Kasos system

Year	Average load (MW)	Peak load (MW)	Electricity demand per year (GWh)	Load factor	RES electricity (MWh)	Thermal electricity (MWh)	RES Penetration (%)
2017	4.32	11.18	38,526	37.9%	4,512	34,015	11.7%

The installed power of the energy generation units, listed in Table 17, represents energy production profile in the current system.

Table 17. Installed capacity of power plants in Karpathos-Kasos system

Electric network	Wind farms (3)	PV stations (17)	Thermal plants
Karpathos-Kasos Power System	1,225	1,162	16.65

The total contribution to the energy production of 2018 for the power system of Karpathos-Kasos system is shown in the following Figure 59.

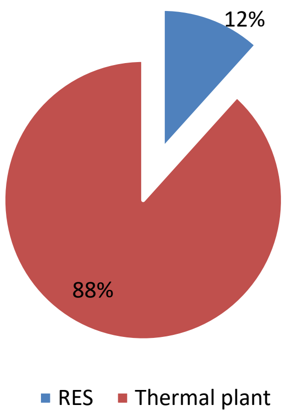

Figure 59. Energy mix for Power system of Samos (2017)

Thermal station

In Karpathos-Kasos power system are installed:

- Two conventional WARTSILA W12V32 Units, with a total capacity of 5 MW which consume fuel oil.
- One AC / DC DAIHATSU 8DV-26 with a capacity of 1.8 MW, a portable PC WARTSILA VASA 8R22MD and two portable MITSUBISHI PCs of the "Portable PC Bank" of 1 MW each, and two portable MITSUBISHI PCs of 1 MW each, which consume diesel fuel.

Cost of production
The monthly average total and variable production costs of thermal units in the power system in 2017.are shown in Figure 60.

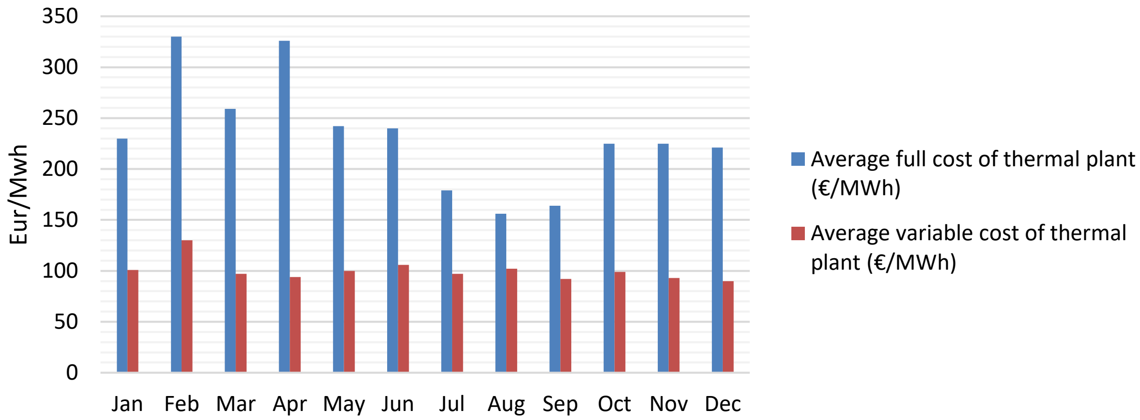

Figure 60. Cost of production of thermal unit Karpathos-Kasos system (2017)

4.2.4.1 Interventions at Kasos' Buildings

The municipal buildings illustrated in Table 18 are considered to replicate the Orkney SMILE solution.

Table 18. Municipal buildings on Kasos

	Building	Area sqm	Heating and cooling	Estimation of consumption [kWh/m2]	Estimation of Consumption (Primary energy) [kWh]
	Secondary and high school	969	60%	136.9	157,00

4.2.4.2 Description of the existing situation of the buildings

Secondary and high school
The building that houses the secondary and primary school consists of a two-story building. It has a total area of 969 m^2.

Building's characteristics
The building characteristics regarding the shell, heating system, and lighting were not available for this building.

Energy Inspection: The Energy Inspection was carried out in accordance with the revised national Regulation of Energy Efficiency of Buildings, while for the calculation of the energy efficiency of the building the associated national software was applied.

The energy certificate of the aforementioned building is illustrated in Figure 61.

Figure 61. Energy certificate of Kasos' secondary and high school

The energy behavior of the building is generally considered bad. The lack of thermal insulation, the old lighting systems degrade the comfort of using the space, while the draft existing solutions are characterized as particularly energy consuming. The energy behavior of the building can be significantly improved, with interventions in its openings and E / M systems.

4.2.5 SMILE Technical Proposal – Orkney Replication

The technical solution description below refers to Orkney replication islands and can be replicated on other islands with similar electrical grid constraints. The current analysis took into account the characteristics of the Greek shadow islands of Orkney which are Chalki, Kasos, Kalymnos, and Fourni.

4.2.5.1 Technical Description

Aggregation and Control Platform (ACP)

The ACP would, at all times, collect data from the relevant renewable generation production sites with regards to the level of production and the expected renewable capacity thresholds at a site level or the entire island system. It would also be collecting localized generation/weather forecast data - and using both sets of data to build a prediction model for estimating the excess production event (known as "Capacity Excess Event").

When the ACP determines the above and there's a likely capacity to excess in the next 15 minutes, it will instruct the XOLTA battery, all the Electric Vehicle Supply Equipment (EVSE chargers), and the Sunamp thermal storage to start charging so that they absorb the predicted excess until the renewable production is operating at a desirable capacity threshold.

Regarding the charging hierarchy: XOLTA batteries would be the highest priority to be charged, then the thermal storage from Sunamp, and the EVSE chargers will follow. Once the capacity excess event has ended, at times with no capacity excess event:

- Sunamp thermal storage would be used to manage the thermal load in the building.
- XOLTA batteries would be used to load match the electrical need of the building.
- EVSE chargers' electrical needs would be fulfilled as part of the general building load - and they would be charged to a default off-peak electricity time schedule.

Thermal batteries
The provision of controllable thermal storage can be used to assist balance peaks and troughs providing a more predictable and level electricity load demand. Unlike in Scottish islands that were part of the SMILE project, the Greek island peak electricity demands are created by the requirement of cooling thermal energy. Thus, the cooling thermal batteries will interface with the electricity grid, the building's renewable electricity generation and cooling system to provide decoupling of generation and supply of demand, for enabling grid electricity balancing and occupant thermal comfort.

Occupancy of the thermal batteries:
- During the winter months, heating will be occasionally required, and therefore a reversible chiller has been recommended with hot thermal batteries for demand shifting.
- During the summer months, waste heat from the chiller can be captured to provide hot water in the hot thermal battery. In the winter this would be charged directly from the reversible chiller.

Figure 62 and Figure 63 illustrate the conceived architectures and the aforementioned operations.

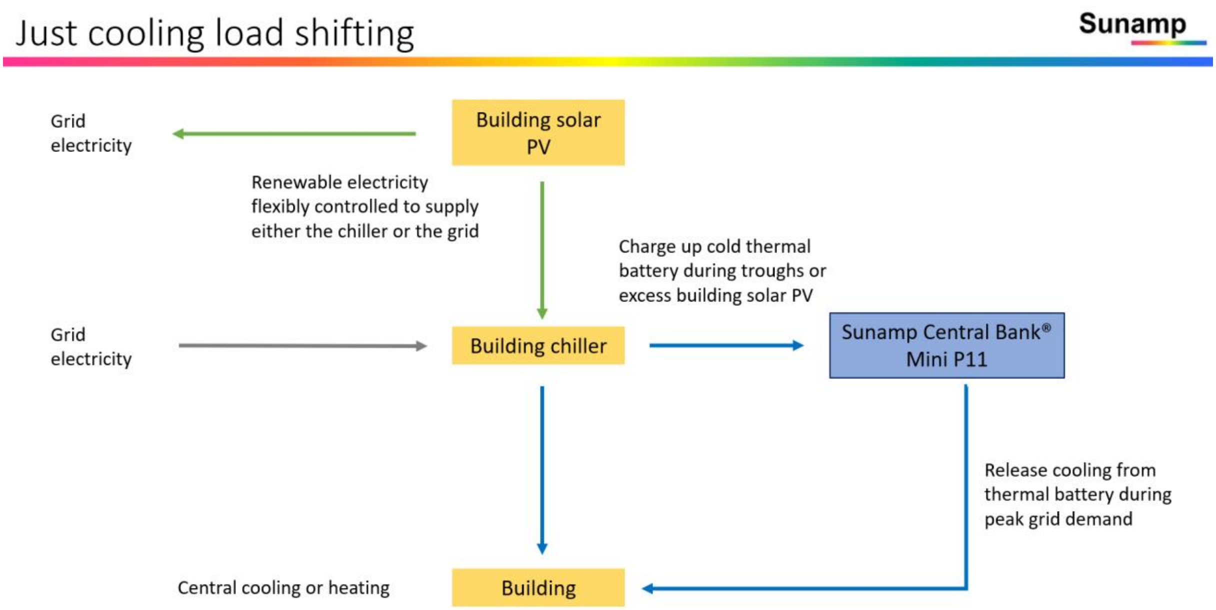

Figure 62. Operation at cooling providing load shifting

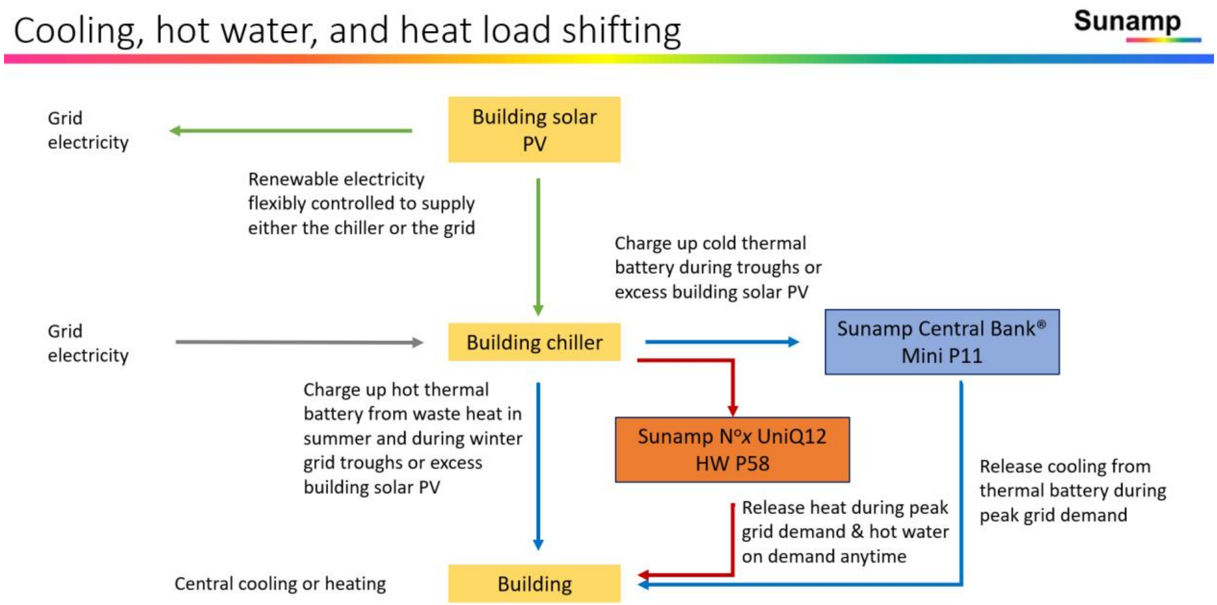

Figure 63. Operation at cooling, hot water, and heat load providing load shifting

Technical components

The flexibility solution consists of the following components, for each commercial building in consideration.

- A series of Libal / XOLTA 75 kWh / 50 kW battery system (BESS) - Sized according to the expected demand in the building.
- A stack of Sunamp electrically charged only, “Dual Cell” thermal batteries - that has both a cold thermal store and a hot thermal store.
- A series of 7 kW Indra Smart and Electric Vehicle chargers.
- Aggregation and Control Platform (ACP) developed by OVO Energy (Kaluza)
- Integration between the Aggregation and Control Platform and the above components.
- Devices that collect data on renewable energy generation at the various renewable power generation stations.
- Integration with an external wind and solar irradiation forecasting system.

The overall technical architecture of the solution is depicted in Figure 64.

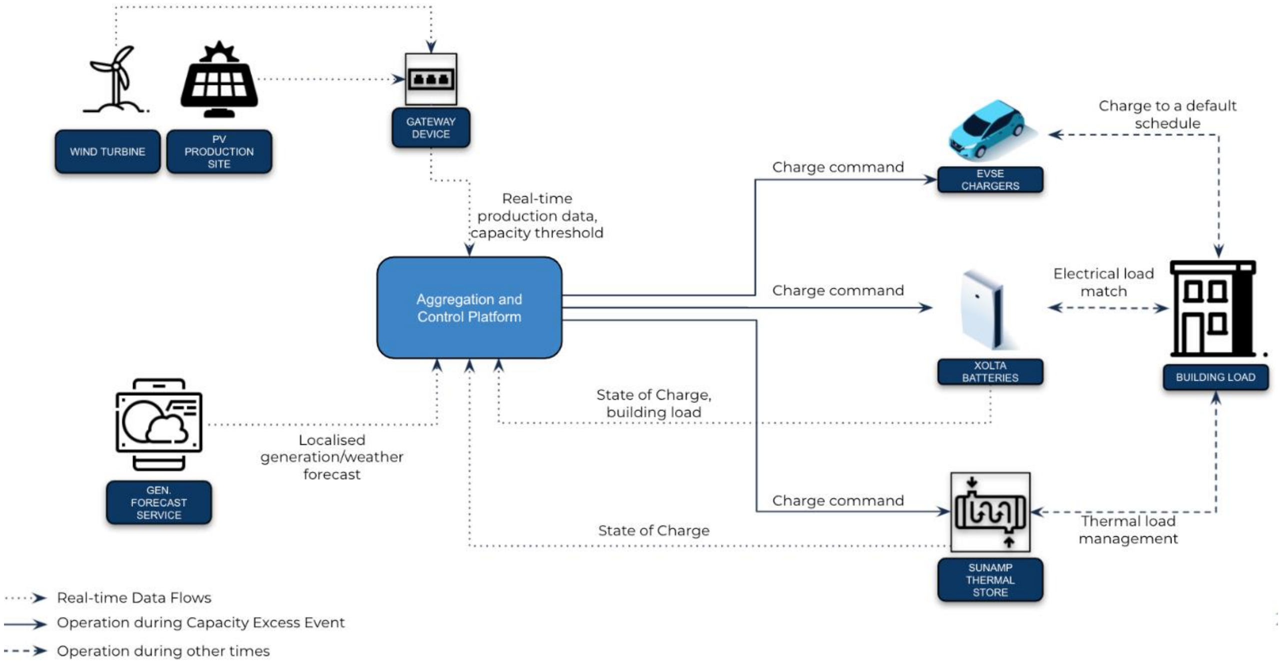

Figure 64. Overall Technical architecture

Estimated costs

The costs for the aggregation system to serve the systems are described over a period of 5 annually. The per annum cost of deployment depends on the number of devices and number of generators it is intended to serve. Table 19 illustrates these estimated costs for various combinations of generators and devices. The cost changes according to the generators and it does not include capital costs of the system neither costs for maintaining the devices (e.g. internet connectivity to the devices or any other maintenance costs). All such DR device costs would need to be added on top. However, it is included the capital cost of hardware and installation for the devices that maintain the connection with the PV and wind generation sites to collect data for the aggregation platform.

The lifetime of the deployment is assumed to be 5 years. In particular, the costs of any software development and maintenance are assumed to be recovered linearly over a 5-year horizon. The total cost over a 5 years' time horizon, coming up from the multiplication of the annum cost by 5. It is important to mention that the variable cost component relating to DR devices is associated with scaling by devices and operational maintenance.

Table 19. Estimated cost of the service

		Number of generators						
		1	2	5	10	20	50	100
Number of devices	**1**	€225,000	€225,000	€235,000	€260,000	€310,000	€425,000	€630,000
	10	€225,000	€225,000	€235,000	€260,000	€310,000	€425,000	€630,000
	50	€225,000	€225,000	€235,000	€260,000	€310,000	€425,000	€630,000
	100	€225,000	€235,000	€250,000	€260,000	€310,000	€425,000	€630,000
	200	€225,000	€235,000	€250,000	€270,000	€310,000	€425,000	€630,000
	400	€250,000	€260,000	€270,000	€295,000	€330,000	€450,000	€650,000
	1000	€285,000	€295,000	€310,000	€330,000	€365,000	€485,000	€685,000

Table 20 and Table 21 illustrated the estimated costs regarding the thermal Heat Batteries.

Table 20. Estimated costs for cooling load shifting solution

Technical component	Costs
Thermal battery	€19,150
Reversible heat pump	€3,000
Total	**€22,150**

Table 21. Estimated costs for hot water and heat load shifting

Technical component	Cost
Thermal battery	€19,150
Reversible heat pump	€3,000
UniQ12 HW P58	€3,600
Total	**€25,750**

More specifications on the technology components can be found in the current document in chapter 2.2 for Thermal batteries, chapter 2.6 for the Aggregation and Control Platform (ACP), and chapter 2.5 regarding the Battery Energy Storage System. In addition, the related SMILE pilot solution that took place in Orkney is described in chapter 3.8.

4.3 Lefkada (Kastos and Kalamos islands) – Samsø replication

Kalamos and Kastos are two municipal entities, that administratively belong to the Municipality of Lefkada. These municipalities include, respectively, the islands of Kalamos and Kastos. The island of Kalamos is located south-east of Lefkada, between the islands of Meganisi, Kastos, and the coast of Akarnania. The island has a surface area of 25 km^2 and a length of 12 km. Kalamos has a population of 495 people. Kastos is a small island of the Ionian Sea with a surface area of 5.1 km^2, opposite the west coast of Aitoloakarnania and south of the island of Kalamos. Kastos is the smallest inhabited island of the Ionian Islands and its population is 80 people.
The island of Kalamos is connected by ferry with Mytikas. Likewise, the neighboring Kalamos, Kastos is connected to the coast of Aitoloakarnania by boats, from and to the opposite village of Mytikas. Kastos has two ports for mooring boats. Neither Kastos nor Kalamos have an airport.

Kalamos has two settlements and two smaller villages. The economy of the island is based on livestock farming, olive growing, and fishing, while the young people traditionally follow the profession of a sailor. On the island, there is a pine forest, which is a habitat for many species of birds. The island of Kastos has a homonymous seaside settlement. The settlement has very traditional characteristics, with the stone houses, the olive groves, the old olive mills and the windmill which maintains its mechanism. The inhabitants of Kastou are engaged in fishing, the cultivation of cereals and grapes, and the production of wine.

Energy System of Kastos and Kalamos
Kastos and Kalamos are interconnected with Lefkada which is connected to the mainland system. They are located at the Ionian Sea in close distance from the mainland. There are no renewable energy systems installed in the aforementioned islands, except for residential PVs of 66 kWp in Lefkada. Figure 65 illustrates the two islands highlighting their main marinas.

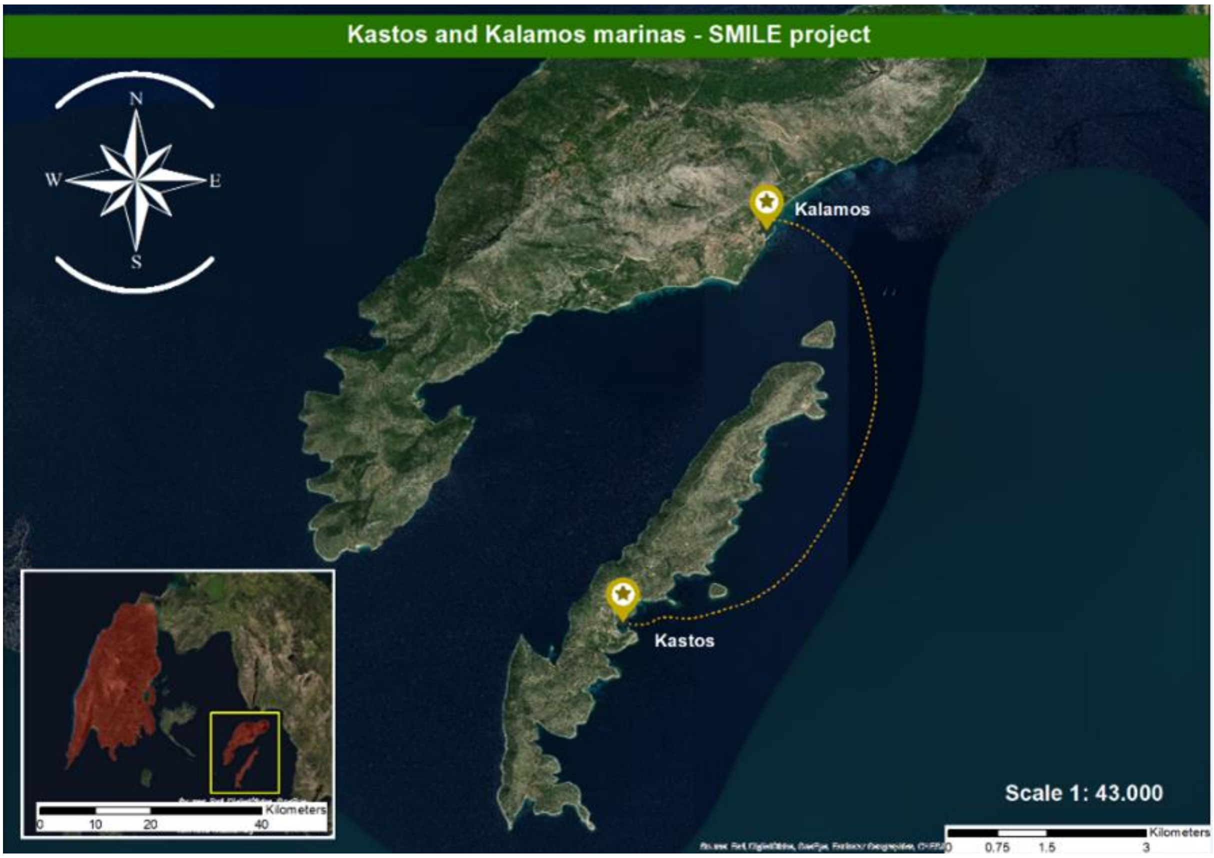

Figure 65. Map of Kastos and Kalamos

4.3.1 Technical Proposal – Samsø Replication

The technical solution description below refers to Samsø replication islands and can be replicated on other islands with similar seasonal marinas. The current analysis took into account the characteristics of the Greek shadow islands of Samsø which are Kastos and Kalamos. Three marinas in total will be converted to smart ones, two marinas in Kalamos island (Kalamos and Episkopi) and one marina in Kastos island.

Figure 66. Kastos' marina

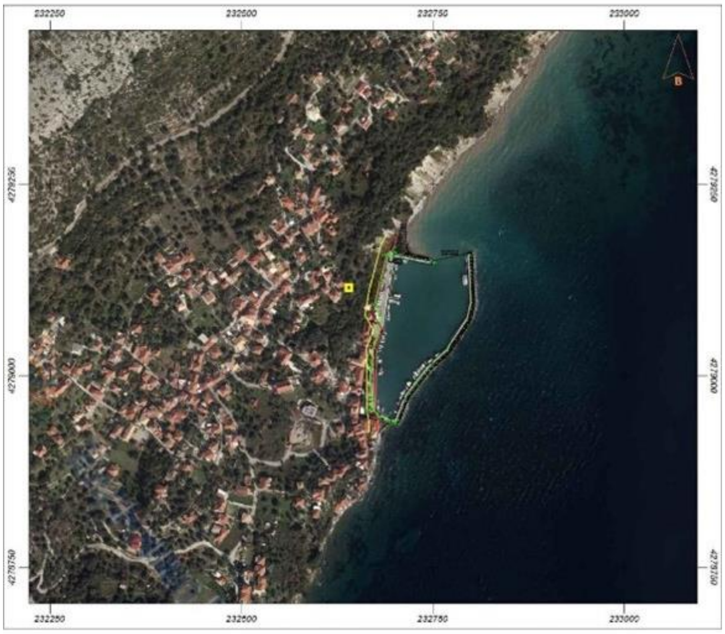

Figure 67. Kalamos' marina

Figure 68. Episkopi's marina

4.3.1.1 Technical Description

Currently the three marinas offer zero services. For their upgrade basic infrastructure needs to be created in order for the marinas to be able to offer electricity and water plus a small building to host toilets, showers, and the harbor master station. The smart marinas will be identical to the one in Ballen in all three Greek ports. The components proposed are the following:

PV: Installation of photovoltaics at the marina to cover the electric power consumption of boats, electric vehicles and that of buildings on the marina. Due to the higher electricity consumption during the summer months, and low production during the winter, PVs power generation will end up covering approximately 1/3 of the yearly energy use at the marina.

BESS: The purpose is to level out fluctuations derived from the variable RES power generation and load peaks. Storage capacity should be sufficient to buffer the local day-to-day energy consumption. This way it will be possible to use electrical energy generated by PVs also during evening and night time where most boats are docked in the marina and energy consumption is high (it peaks around 23:00 during the high season). In other words, the battery stores energy for later use, so marina's consumers can make use of solar power even after sunset, while it ensures a stable power supply based on sustainable energy.

Smart Grid: The fluctuations in power production, which are a natural consequence of using solar power, are managed accordingly minimizing their impact. For example, tasks can be postponed that require a lot of power until a time when the battery state-of-charge is plentiful.

EVC: Sockets will be installed to provide electricity to each boat and plug-in cars. The meters measure accurately the amount of energy consumed by each socket. Consequently, a pattern of demand load is created which assists the energy management of the marina, predicting power consumption.

Operation of Smart Marina

The battery system on both marinas will be grid connected, which means it can exchange power with the public grid. In the default mode, the photovoltaic plant will produce electricity for boats and other electric loads. The battery will store excess electricity on sunny days. The battery will deliver it back during periods of shortage, for instance during the night. In default mode the battery operates as a one-day buffer storage. Due to the intermittent nature of PV production and the unpredictable future demand the battery and the grid both will act as balancers in the power balance equation. In case that the PV production differs from the demand, they will both react equalizing the load.

The demand is originated from yachts, motorboats, and utility loads such as streetlights and pumps. Also, the smart marina will cover the demand from the nearby municipal service building with an A/C. In Figure 69, real-time operation of Ballen smart marina in terms of demand and PV production is shown.

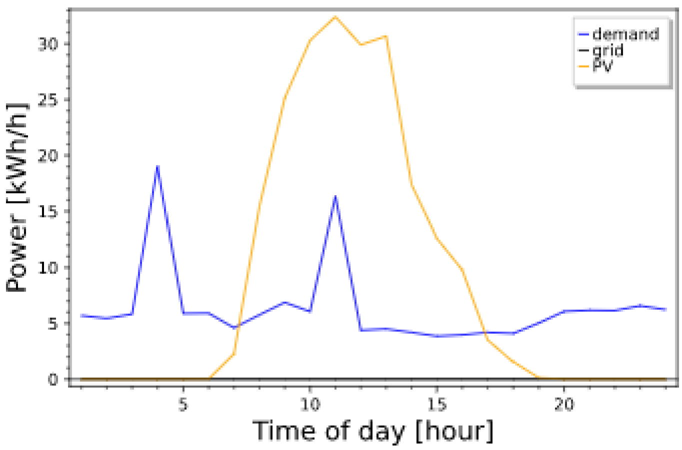

Figure 69. Demand and PV production on a sunny day.

Figure 69 shows a grave mismatch between solar production and load. The PV production is the highest around eleven o' clock that day. The municipal service building causes two distinct peaks in the consumption. The PV production increases during the sunny hours of the day, where the production exceeds the consumption. The figure illustrates two situations: shortage of PV – when the PV supply is lower than the demand, and excess PV when the PV supply is higher than the demand.

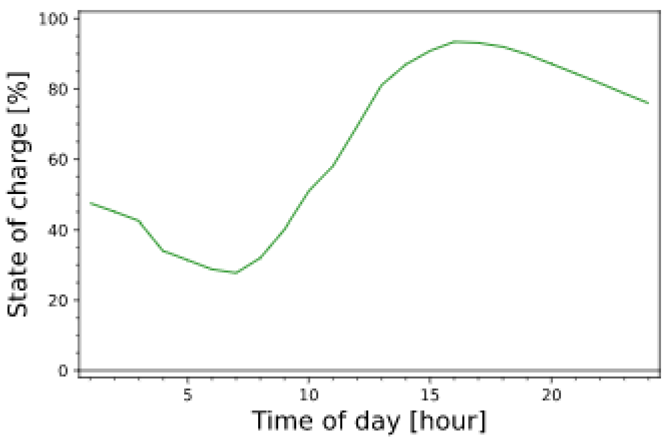

Figure 70. The battery's state-of-charge on the same day.

The generated excess power (kW) is over time stored as energy in the battery (kWh). Figure 70 shows the battery's state-of-charge (SOC) on the same day. It is noted that the end state is higher than the initial state thanks to excess PV energy.
In case of PV shortage, the battery level decreases; opposite in the case of PV excess. The first crossing point between PV and demand (Figure 69) is the time instant where the battery starts to increase (Figure 70). The second crossing point (Figure 69) is where the battery starts to decrease (Figure 70). A plot of the inverter flow would show the flow changes its sign. The battery level at time 01:00 results from previous days' history. All times refer to the end of the hour. For instance, the SOC at 01:00 is the result of the SOC at midnight and the flow streams between midnight and 01:00. The plot covers 24 hours, so it starts at 01:00, and it ends at 24:00.
In the mentioned above simulation, the battery meets its objective because the marina does not exchange power with the public grid at all. The system has a supply side and a demand side (Figure 71). The inverter controls the flow between the two sides. Even the demand side is controllable, to some extent. It is possible to control the service municipal building and one heat pump, remotely. They are controllable loads that can be turned on or off at times, when it is useful. Another option is to preheat the municipal building early in the morning, if the weather forecast predicts excess PV energy during the following afternoon.

Technical components

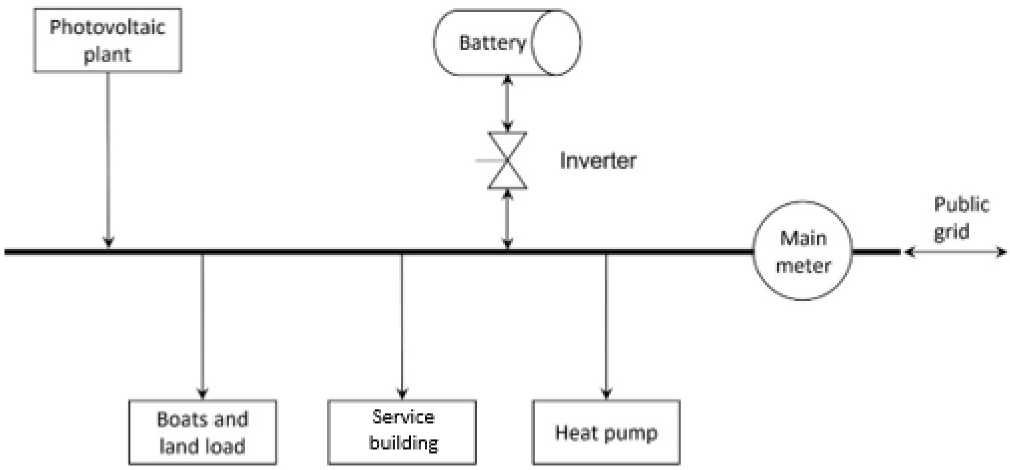

Figure 71. Overview of the solar battery system for Kastos and Kalamos marinas.

All components will be connected to a common busbar on the marina side of the public meter. The upper part, above the busbar, is the supply side, and the lower part, below the busbar, is the demand side. The inverter acts as a two-way valve for the battery. It controls whether to charge, discharge, or leave the battery idling.

The smart marina solution consists of the following components, for each marina in consideration.

Table 22. Components marina's Kastos, Kalamos, and Episkopi

Components	Kastos	Kalamos	Episkopi
Photovoltaic plant (kWp)[5]	E_1*0.8	E_2*0.8	E_3*0.8
Battery Energy Storage System (kWh)	E_1*1.1	E_2*1.1	E_3*1.1
Heat pump	1 X 5 kW	1 X 5 kW	1 X 5 kW
Electric Vehicle Chargers	2X 11kW	2X 11kW	2X 11kW
Pillars	6 (3 X16A)	9 (3 X16A)	9 (3 X16A)
Land Load streetlights	36 X 40 W	35 X 40 W	25 X 40 W
Smart Meters	✓	✓	✓
Public grid	✓	✓	✓

Table 23. Estimated costs of the main technical components

Technology component	Estimation of cost	Unit
Photovoltaic plant	€ 800 – € 1,200	kWp
Battery Energy Storage System	€ 350 – € 550	kWh
Heat pump (5 kW)	€ 3,000 – € 4,000	Unit
EV charger cost	€ 3,500	Unit

Figure 72, Figure 73, and Figure 74 illustrate the electrical installations of the EV charger, the lights and the pillars are depicted.

[5] *E_1, E_2 and E_3 are the annual consumption in MWh*

Figure 72. Electrical installation of Kastos marina

Figure 73. Electrical installation of Episkopi marina

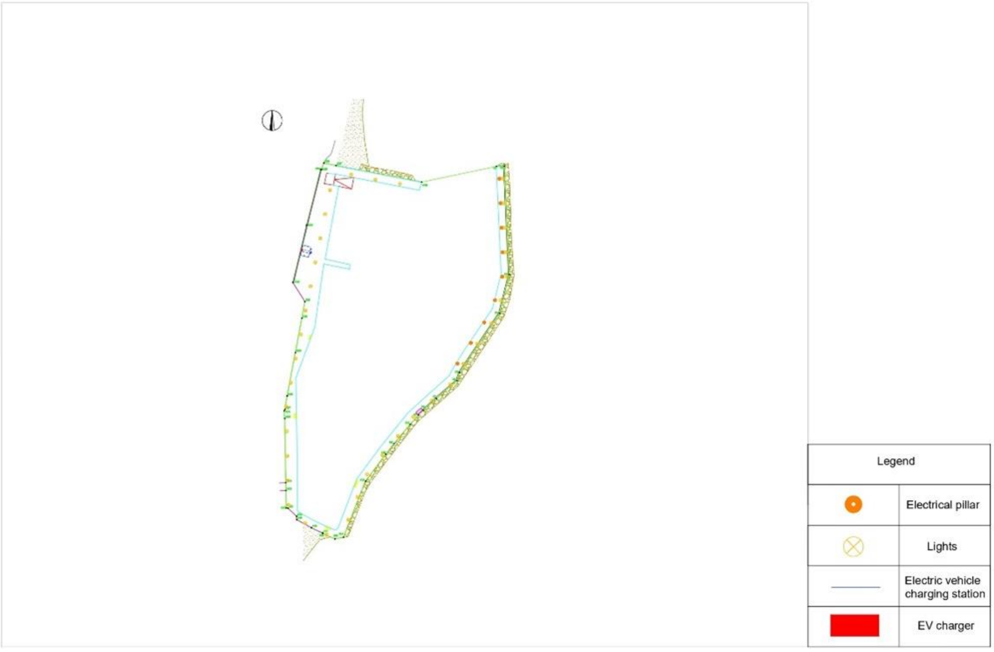

Figure 74. Electrical installation of Kalamos marina

More specifications regarding the related SMILE pilot solution, that took place in Samsø, can be found in chapter 3.6.

4.4 Mykonos – Madeira replication

Mykonos belongs to the Cyclades region which includes 24 islands located in the South Aegean Region. The Municipality of Mykonos consists of Mykonos, Rineia, Delos, and the surrounding islands (rocky islets). The capital of the island is Chora, located on the western side of the island. The municipality of Mykonos consists of two municipal Communities: Municipal Community of Mykonos and Municipal Community Ano Meras. The municipality of Mykonos has a population of 10,135 people, of which 10,110 reside on the island of Mykonos, and the rest in Delos. Mykonos extends in an area of 106 km^2 and it has a coastline of 89 km.

Mykonos was one of the first Greek islands to be developed for tourism. As early as the 1960s, the island developed high tourism activity while today arrivals overcome 387,310 in one year period. Mykonos has two ports in operation. The old port of Mykonos is in the center of the island and the new port is located 3.5 km north of the island, in the area of Tourlou. There are daily routes to the island of Mykonos from Piraeus, Rafina, Crete, and other islands of Aegean. Mykonos airport operates on the island, which is located 4 km from the town of Mykonos. It serves flights from/to domestic and European metropolitan destinations due to the island being a popular leisure destination.

The small island cluster of Mykonos, Delos, and Rhineia is certainly one of the most prominent areas of the planet over time, not only because of modern tourism and its cosmic traffic but because this zone was inhabited, developed, and became a cultural pole from ancient times. The oldest buildings date back to 5,000 BC, in the Neolithic era.

The soil of Mykonos is mostly rocky. There are two mountains, both of moderate height, both of which are gibbous: Anomeritis (east) and Vorniotis (north). The highest peak of both is called Profitis Ilias with an altitude of 341 m. Mykonos is devoid of forests and has little plantation with correspondingly limited cultivation mainly of wheat, grapes, and figs. It has many streams and no rivers. Today the water supply needs are covered by the desalination plant, which operates in the area of Korfos, and by the two dams, Marathi and Maous.

Energy System of Mykonos

The power system of Mykonos is located in the Cyclades region of the Aegean Sea. It is interconnected with the mainland indirectly from Lavrio port (108 km) and with two neighboring islands which are Syros (34 km), and Naxos (20 km). The power capacities of submarine three-pole power cables with 140 MVA and AC of 150 kV, as shown in Figure 75.

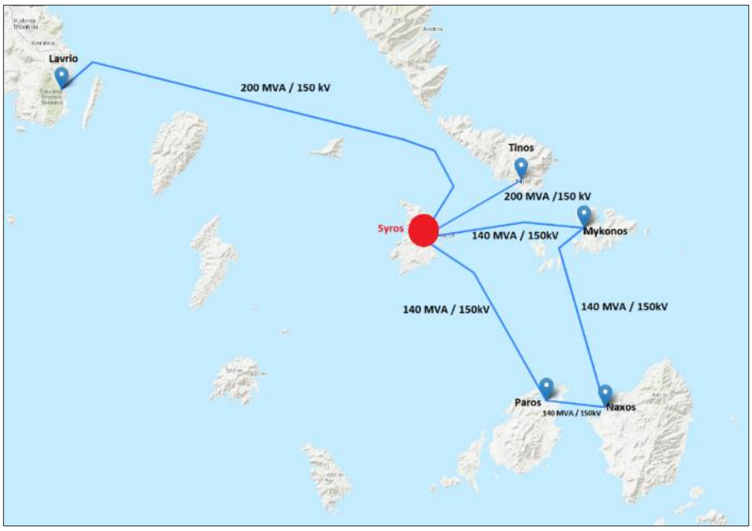

Figure 75. Interconnections of Mykonos power system

Table 24 below shows the individual cables that connect Mykonos with the mainland.

Table 24. Underwater interconnection cabling

From	To	Type and cable cross-section (mm^2)	Cable length (km)
Syros	Mykonos	Cu/XLPE – (3X) 300 mm^2	35
Naxos	Mykonos	Cu/XLPE – (3X) 300 mm^2	44.7

Mykonos interconnection is part of the interconnection of Cyclades Islands, a technically complex project, which ensures the reliable, economic, and sufficient supply of electricity to the islands Syros, Paros, Tinos, Mykonos, and Naxos islands for the next 30-40 years. More specifically, phase A was comprised of the connection of Mykonos Island indirectly with Lavrio (mainland) and the neighboring islands of Naxos and Tinos. Phase B consisted of the connection of Paros Island with Naxos Island and the connection of Naxos Island with Mykonos Island. Phase C was incorporated of the second interconnection between Lavrio (mainland) and Syros Island. The project was completed in October 2020.

Future plans

The interconnection of the Cyclades region with mainland Greece is part of the ten-year island interconnection development program of the Independent Electricity Transmission Operator. The next phase (4th) of the electrical interconnection of Cyclades completes a large-scale project aimed at the energy integration of the island complex in the mainland system, with benefits both the islands and the national economy. The start of this phase of the electrical interconnection of the Cyclades was launched by the announcement in 2020 of the tender for the interconnection of Naxos with Santorini, which poses the most important part of the amount of the islands to be interconnected since it will supply electricity radially. More specifically, the interconnection of the Cyclades region, with a budget of 385 million euros, will be completed in 2024. It includes the interconnection of Serifos with the mainland transmission system through the new high voltage station in Lavrio via an underwater AC cable connection with a capacity of 200 MVA. It also involves the direct connections of Milos with Folegandros and then with Thira. Thus, the interconnections will allow the reliable electricity supply of the Cyclades from the mainland system and the utilization of the RES potential, with significant environmental and socio-economic benefits.

***Electrical system overview*[6]**

The electrical system of Mykonos covers the needs of electricity of a total amount of 10,134 inhabitants. The wide variation in daily and seasonal demand proves that the features of the system are quite demanding. The demand on the island of Mykonos reached 49 MW in 2018, showing an increase of 12.9% compared to the peak of 2017 and 38.4% compared to the peak of 2013.

Table 25. Electrical system overview of Mykonos

Year	Peak (MW)	Electricity demand per year (GWh)	Load factor	RES electricity (MWh)	Thermal electricity (MWh)	Area (km^2)	Population
2017	49	144,000	37.5%	4,093	139,986	106	10,135

The installed power of the power plants is listed in Table 26 which represents the power generation profile in the system. The photovoltaic units that function under the program of virtual net metering are partially excluded because they do not directly contribute to the grid.

Table 26. Installed capacity (MW) of power plants in Mykonos

Electric network	Wind farms	PV stations	Thermal plants
Mykonos	0.9	1,044	54.45

The total contribution to the energy production of 2018 for the power system of Mykonos is shown in Figure 76. The variability of production, the low rate of exploitation of RES, as well as the restrictions that may be imposed by the system administrator, are the main reasons for the low level of penetration of renewable energy sources. Nowadays, the energy mix of Mykonos is considered to be similar to mainland Greece and it is as shown in Figure 77, since it is an interconnected island.

[6] before to interconnection

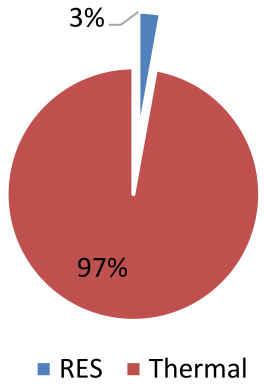

Figure 76. Energy mix prior to Mykanos interconnection - Contribution of each technology to energy production

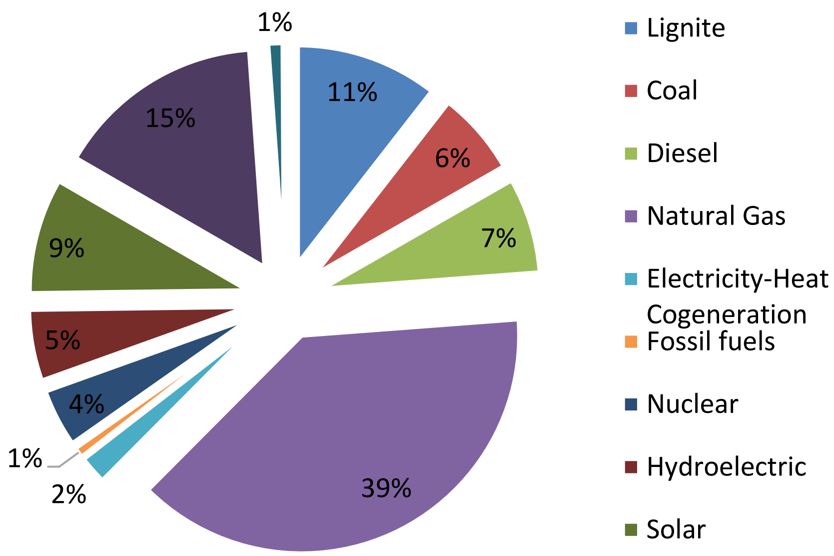

Figure 77. Greece's energy mix 2020

Thermal station

It operates with heavy fuel oil while its electromechanical equipment has been periodically updated. Before 2018 – the year of Mykonos interconnection – the thermal station used to cover the energy needs of the island, operating in cooperation with the local wind farms and solar PVs. However, the completion of the interconnection of Mykonos with the mainland network forced the oil plant to function only in cases of emergencies as a reserve. The total thermal installed capacity in Mykonos equals 54.45 MW.

Cost of production

The average total and variable production costs of thermal units in the power system are shown in Figure 76 as they developed monthly in 2017 before its interconnection with the mainland and neighboring islands.

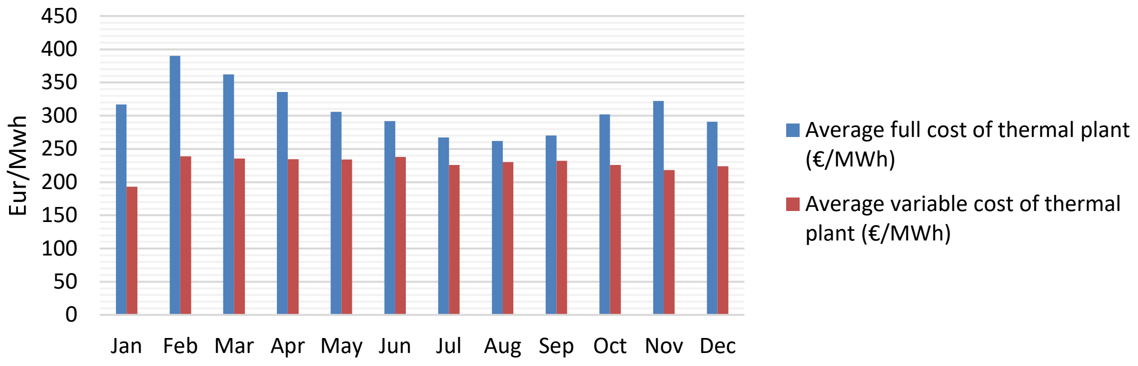

Figure 78. Cost of production of thermal unit Mykonos (2017)

4.4.1 Technical Proposal – Madeira Replication

The technical solution description below refers to Madeira replication islands and can be replicated on other islands with similar characteristics. Mykonos is extremely touristic and as most Greek islands, its electrical grid needs extended upgrades in order to facilitate the clean energy transition on the island while also covering the highly seasonal electricity demand. However, with the uptake of e-mobility, EV chargers will need to be installed in several places of the island and especially near beaches with high number of visitors. To this end and to relive pressure on the grid, the Madeira solutions will be applied. Another interesting option would be to install EV charging services in hotel garages, without the need for a complete overhaul of the grid. Smart charging could also be a good solution to this issue.

4.4.1.1 Technical Description

The system provides a non-intrusive, cheap smart charging solution for full-fledged electric vehicles. It consists of both software and custom-made hardware and is intended to enable fine-grained control of EVs charging. Smart charging is achieved by remotely turning ON/OFF the charging points according to a predefined charging strategy. The system provides a non-intrusive, cheap smart charging solution for full-fledged electric vehicles. It consists of both software and custom-made hardware and is intended to enable fine-grained control of EVs charging. The final solution was able to control the duty cycle of the charging with a granularity of 5% of the duty cycle.

Two are the main strengths of this solution:

- it provides the possibility of implementing several charging strategies (e.g., based on pricing, electricity demand, renewable availability, or aggregated energy consumption in the building) and managing the charging of multiple vehicles at the same time.
- it is highly compatible with different chargers and plugs and therefore can be used to retrofit existing installations.

In the scope of the solution proposed for Mykonos, the smart charging approach would be implemented based on:

- Renewable availability: the charging can be controlled based on generation from PVs installed on-site, thus avoiding or reducing the impact of charging the EVs directly from the grid.
- Electricity demand on the island: this scenario is particularly relevant when we consider a future situation with a much higher number of EV's in the grid. In such a situation, charging the EVs can be considered a way of implementing demand-side management strategies to avoid issues with grid stability.

Components of the system

Software:

- Energy Management System (EMS) developed by PRSMA
- Smart Charging Algorithms developed by Route Monkey

Hardware:

- Adapter - composed of; (i) gateway, (ii) Carlo Gavazzi EM340 and (iii) Contractor.

System requirements

The minimum requirements for implementing this solution are:

- Reliable internet connection.
- Monitoring equipment.
- Communication gateway.

Estimated costs

Table 27. Estimated costs

Components	Cost estimation (per unit)	Units	Frequency
Hardware components[7]	€ 1,800	12	Once
Software components - EMS	€ 1,500	n/a	Yearly
Software components - Smart Charging Algorithms	€ 420 - € 624	378 (EVs)	Yearly
Installation costs associated with the deployment of the hardware components	€ 200	12	Once
Average estimated value of the annual maintenance expenses to ensure the proper functioning of the deployed solution (software side)	€ 400	n/a	Yearly

Currently there are no cost estimations yet for using Route Monkey's Smart Charging Algorithms because this is not a fully developed commercial product yet. However, some rough estimates could be derived from Route Monkey's algorithm (software) charges for fleet optimisation and routing.

Figure 79 illustrates the sites of the EV charger installation at Mykonos island. In each spot is considered to be installed two-double EV chargers which in total equal 24 plug-in sockets.

[7] Cost per smart charging station.

Figure 79. EV charger installation in Mykonos island

The total number of electric vehicles was estimated based on the data of the existing fleet on the island, combined with a projection of the replacement rate with electric vehicles with a time horizon of three years. The methodology is briefly descripted in the next section.

4.4.1.2 Methodological approach of PEVCS

A bottom-up methodology was developed for the calculation of the number of Public Vehicle Charging Stations (PEVCSs), drawing on data regarding mobility in Mykonos as well as on technical characteristics of the vehicles and charging stations expected to be installed on the island. The estimate of the number of EVs has been made over three years based on the assumption that 15% of the vehicles will have been replaced by the end of the aforementioned period. For the development of the charger's installation plan, a linear increase in the number of electric vehicles is then assumed. The equation below calculates for the number of electric vehicles of each type that do not have a private charging station ($1\text{-}P_N$), the days they will need to be charged periodically, taking into account the flexibility of charging in more than one period per day. This calculates, per vehicle type, the required number of chargers C, which, if added up for all types, results in the required number of publicly accessible charging stations in Mykonos. A breakdown of how each variable was estimated is provided below.

$$C = \sum \frac{Q_N \frac{L_N}{A_N} \bullet 1 - P_N}{F_N}$$

Where:
C: Required number of charging stations[8]
N: Type of vehicles
Q: Number of vehicles to be served by PEVCS
L: Mean summer daily driving distance (km/day)
A: Autonomy (km)
F: Charging flexibility (morning-afternoon-evening)
P: Percentage of vehicles with private charging stations (%)

4.4.1.3 Analysis of the variables

Vehicles type (N)
As technical characteristics of vehicles, such as autonomy (A) and battery capacity (B), vary from vehicle to vehicle, three separate categories of passenger vehicles mini e-cars, e-cars, e-SUVs were considered. In addition to these, it was considered appropriate to include as a separate category the commercial vans (e-VANs), which are used on the island both for the transport of goods and the transport of visitors mainly to hotels from the ports and the airport.

Number of vehicles (Q)
The total number of electric vehicles was estimated based on the data of the existing fleet on the island, combined with a projection of the replacement rate with electric vehicles with a time horizon of three years.

- The existing number of private passenger vehicles on the island based on data from the national statistical service (2,470 vehicles) of which it was estimated that 15% will be replaced with EVs in three years, i.e. **370 EVs**
- For the estimation of the number of professional vehicles, referring to the e-VANs, it was assumed that the 50 existing professional vehicles (field inventory data) circulating on the island will be replaced at a rate of 15%, thus adding **8 e-Vans**, which are expected to be charged from the public chargers.

Finally, the total number of passenger electric vehicles estimated according to the above was allocated to the first three vehicle types, based on estimations. The apportionment percentages as well as the final results for the estimated number of vehicles Q to be served by the PEVCSs, for each vehicle type N, are presented in Table II below.

[8] The calculations are for charging stations with one charging point

Table 28. Estimated number of vehicles Q per vehicle type N

Type of EV	Quantity	Percentage allocation by type	N: Type of vehicle	Q: Number of vehicles
Passenger vehicles	370	25%	E-Cars (small)	93
		50%	E-Cars	185
		25%	E-SUVs	93
Professional vehicles	8	n/a	E-VANs	8

Distance estimation (L km/day)

The variable L is calculated as the approximate average distance travelled by vehicles during the peak summer season, based on data obtained from a survey of existing traffic on the island of Mykonos. This estimate also takes into account the length of the existing primary and secondary road network of Mykonos.

Charging flexibility (F)

The variable F describes the flexibility that vehicles have to charge from one to any period of the day. It was assumed that using 11 kW charging stations even in the extreme case (e-SUVs) the full charging time does not exceed 8 hours. Thus, and with the application of countermeasures (e.g. application of a financial penalty in case of staying on the charging station for more than 8 hours), 3 possible charging periods per day are estimated. The F-factor, therefore, takes values from 1 to 3. Mini-car electric vehicles have the flexibility to be charged at any time of the day due to their small battery capacity, which results in short charging times. The same would be the case with "e-VANs", but it is considered that a period of the day is reserved strictly for business use. The intermediate vehicle types are assumed to be able to charge 2 of the available periods per day.

Percentage of vehicles with a private charging station (P)

The P percentage of vehicles that are considered to have a private charging station was based on an estimation, originating from interviews with local municipality's representatives. Therefore, based on the above assumptions, the variables L, F and P take for each vehicle type the values summarized in Table 29.

Table 29: Variables L, F and P values

N: Type of vehicle	Q: Number of vehicles	L: Mean summer daily driving distance (km/day)	F: Charging flexibility (morning-afternoon-evening)	P: Percentage of vehicles with a private charging station
E-Cars (small)	93	25	3	14%
E-Cars	185	30	2	8%
E-SUVs	93	35	2	14%
E-VANs	8	40	2	30%

Autonomy (A km)

Autonomy (A) is given values referring to driving under real-world conditions, which are estimated as 60% of the equivalent of the autonomy in a standard WLTP cycle (AWLTP), in each case. Factors taken into account in reducing the actual range of an electric vehicle are driving behaviour, road conditions and ambient temperature. Note that the AWLTP variable was derived from technical characteristics of indicative vehicles per vehicle type. Variable A is assigned for each vehicle type the values summarized in the Table below.

Table 30: Vehicle Autonomy

N: Type of vehicle	A_{WLTP}: Autonomy WLTP (km)	A: Autonomy (km) [60% A_{WLTP}]
E-Cars (small)	260	156
E-Cars	340	204
E-SUVs	400	240
E-VANs	130	78

4.4.1.4 Results

The results of the calculated number of charging stations is shown in the table below.

Table 31. Number of charging stations

N – Vehicle type	Q – Number of vehicles	C – Number of charging stations (sockets)
E-Cars (small)	93	4.3
E-Cars	185	12.5
E-SUVs	93	5.8
E-VANs	8	1.3
Total	**378**	**24**

Two indicative EV charging stations in official dimensions are illustrated in Figure 80, and Figure 81.

Figure 80. Megali Ammos EV charging point

Figure 81. Korfos EV charging point

5 Conclusions

The scope of this report is to describe all relevant technological and non-technological information needed for an effective replication of the developed technologies (products and services) for the 3 SMILE demonstrators.
Actually, this document provided a clear overview on the different SMILE technologies, how these technologies are combined into specific solutions and demonstrated on Samsø, Madeira or Orkney (including technical and non-technical characteristics) as well as on replicability guidelines and how these solutions could be replicated on other islands using Greek shadow islands as an example. In fact, to showcase the feasibility of replicating the SMILE solutions on other islands a high level replicability assessment has been performed.
With respect to the SMILE technologies, a catalogue describing the different key enabling technologies developed by the SMILE partners was provided by including in each technology description the following elements: 1) customer segments, 2) value propositions and main functionalities, 3) components, 4) requirements, 5) limitations, and 6) technical specifications.

The key enabling technologies of SMILE are:

- Energy Management System
- Thermal Energy Storage
- Predictive Algorithms
- Battery Energy Storage System
- Energy Flexibility Platform

By combining the SMILE technologies, different solutions were developed and tested on the SMILE large-scale demonstration sites, for this reason an overview of the different main SMILE solutions demonstrated on Orkney, Samsø, and Madeira was provided including their: 1) value proposition and main functionalities, 2) target group, 3) components, and 4) requirements and limitations taking into account technical and non-technical aspects based on different political-legal, economic, social, and environmental factors.
This part of the report presented replication guidelines for the following SMILE solutions:

- Madeira: “DSM and BESS for optimizing self-consumption”
- Madeira: “Voltage control and peak-shaving”
- Madeira: “EVs smart charging”
- Samsø: “A grid connected solar battery for a marina”
- Orkney: “Heating and Hot Water Optimisation”
- Orkney: “Electric Vehicle Charging Optimisation”
- Orkney: “Aggregated / Industrial Load Optimisation”

Then the focus was moved on the methodological approach towards the identification of the Greek shadow islands and their selection. The selected Greek islands were introduced pointing out their features and their energy power system characteristics and then a contextual technical solution was proposed briefly, for each SMILE demonstrator.
More in details, the analysis carried out in Chapter 4 reveals extensive replicability potential for SMILE solutions in the Greek Shadow Islands. More specifically, the steps followed during the replication procedure led to very useful conclusions presented below:

- The great positive response from Greek island authorities to the SMILE open call for interest confirms the popularity of smart grid applications (such as smart marinas, demand response, and electromobility combined with RES) among islands, strengthening the notion that islands can be ideal testbeds for innovative solutions.

- The analysis performed about the shadow islands existing situation and energy system reveals great similarities with the SMILE pilots. Therefore, cooperation and exchange of knowledge and good practices among EU islands can lead to fast adaptation of innovation.
- Island infrastructure is very often obsolete whether it comes to buildings, ports, or mobility. This fact creates the need for disruptive changes and adaptation of novel solutions leading to great market opportunities for new products and services

Key aspects for adopting SMILE practices:

- Social: the small scale of the solutions combined with the local authorities' eagerness to adopt them shows that they possess high social acceptance and would be easily adopted by the local communities.
- Technical: technical adequacy will probably not be a problem since the solutions seem easy to be applied by local technicians. Grid limitations regarding electromobility is rather an issue for consideration especially though in non-interconnected islands.

Recommendations for future replication:

- Regulatory: Demand-side management is supported in Greek legislation in a very limited way making the sustainability of these solutions unclear. Further Greek policy analysis and recommendations could be a useful asset.
- Financial: Limited resources of the local authorities lead to the need to investigate for funding from either European or national financing schemes.

Island networks seem ideal partners for replication activities since they provide access to a large number of island stakeholders, increasing the project's visibility. Under proper coordination, the replication methodology within SMILE including a call for interest to island authorities and the creation of replication studies for them seemed to be a very effective replication strategy as confirmed by the participation of both island authorities and the contribution of SMILE partners, especially focusing on the technology providers willingness to adapt their solutions to the Greek island context.

The objective of this Replication Plan was to demonstrate the replicability potential of the SMILE solutions and to foster their market introduction. It can be concluded that, in the right circumstances and with the correct adjustments, the SMILE solutions can be replicated on other European islands with similar topographic characteristics but with different policies, regulations and energy markets e.g. However, further research is required before installing any of the SMILE technologies on the Greek shadow islands or any other islands. This document has solely demonstrated the replicability potential of the SMILE technologies and illustrated guidelines on how to replicate them.

Furthermore, this document has illustrated the important role smart grid technologies can have in realizing a clean energy transition on European islands, and how others can learn from the best practices and lessons learned throughout the SMILE project.

The replicability guidelines illustrated in this document can be used by other islands as stepping stones towards the implementation of a clean, affordable, and reliable energy system.