RE-EMPOWERED

Renewable Energy EMPOWERing European & InDian Communities

Deliverable 7.1: Deployment and demonstration plan

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R Document, report	**PU** Public
DEM Demonstrator, pilot, prototype	**CO** Confidential, only for members of the consortium (including the Commission Services)
DEC Websites, patent fillings, videos, etc.	**EU-RES** Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
OTHER ETHICS Ethics requirement	**EU-CON** Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
ORDP Open Research Data Pilot	**EU-SEC** Classified Information: SECRET UE (Commission Decision 2005/444/EC)
DATA data sets, microdata, etc	

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Executive Summary

The “RE-EMPOWERED” project aims to foster efficient, reliable, and flexible energy systems with increased renewable energy sources (RES) penetration. Moreover, it aims to provide local communities with tools for economic and social development, through sustainable energy systems. To achieve these goals, the project will deliver a suite of “ecoTools,” deploy them at four demo sites across the EU and India, and thereby demonstrate their value in energy systems at different scales and levels of maturity. This deliverable provides a detailed deployment and demonstration plan to guide the work on implementing the various ecoTools at their respective demo sites.

For each of the demo sites, the existing energy system infrastructure is reviewed, and planned upgrades related to the RE-EMPOWERED project are described. The ecoTools applicable to each demo site are described, and detailed plans for their deployment are provided, focusing on the integration of the various tools into the existing and upgraded infrastructure. Primary and secondary use cases (UCs) were mapped onto the individual demo sites in RE-EMPOWERED Deliverable D2.1 [1], and in this deliverable these UCs are further detailed into concrete actions, tailored to each demo site. Concrete demonstration plans for each demo site are presented, split up into two demonstration rounds: a first, testing-focused round, followed by any adaptations and adjustments necessary, and then a second, operations-oriented round. Additionally, the role of the involved partners to the demonstration activities for each demo, is highlighted. These demonstration plans directly support the achievement of the overall objectives of the RE-EMPOWERED project. Finally, for each demo site, the business models, regulatory, and social considerations related to deployment and demonstration actions are described.

The results of this work will serve as the foundation for the remaining work in WP7, specifically Tasks 7.2–7.4, related to the deployment of new equipment and ecoTools at the four demo sites, the demonstration activities, and data gathering during the demonstration rounds. Finally, this work will impact the work in WP8, concerned with the business models resulting from the project, assessment of the demonstrations, and reporting on the advancement in technological readiness level (TRL) achieved through the ecoTools and corresponding demonstrations.

Keywords:

Use Cases, Demonstration, Smart Grids, Energy islands, Local Energy Systems, Bornholm, Kythnos, Ghoramara, Keonjhar, ecoEMS, ecoMicrogrid, ecoPlanning, ecoDR, ecoMonitor, ecoPlatform, ecoCommunity, ecoResillience, ecoConverter, ecoVehicle

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Acronyms

Acronym	Description
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
BESS	Battery Energy Storage System
CHP	Combined Heat and Power
DER	Distributed Energy Resources
DH	District Heating
DHN	District Heating Network
DSO	Distribution System Operator
EB	Electric Boiler
EMS	Energy Management System
EV	Electric Vehicle
ILC	Intelligent Load Controllers
IoT	Internet of Things
KSI	Kythnos Smart Island
LES	Local Energy System
MGCC	Microgrid Central Controller
NII	Non-Interconnected Island
PPC	Partial Power Converter
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Source
SCADA	Supervisory Control and Data Acquisition
SLAM	Smart Low-cost Advanced Meter
SOC	State of Charge
TSO	Transmission System Operator
UC	Use Case
WTP	Willingness to Pay

1. Introduction

1.1 Purpose and scope of the document

The deployment and demonstration plan is designed in detail according to the defined use cases set in Deliverable D2.1 [1]. SGAM analysis was utilized as a systematic approach to mode the UCs and more information can be found in Deliverable D2.3 [2]. First, in the frame of this deliverable, an updated description of the ecoTools is provided, including the refinements that have been made since the preceding [1]. Moreover, this report presents the revised mapping of ecoTools to the demo sites and the revised list of UCs to be deployed in each demo site. Additionally, the Gantt Chart with the timeline of the high-level phases take place until the demonstration activities, is given.

The main parts of the work carried out for Task 7.1 are the planning of the deployment and demonstration of the ecoTools in each of the demo sites. The method followed for the planning of the deployment is related to the following: first, the upgrades of the existing infrastructure that are utilized and are related to the deployment of the RE-EMPOWERED ecoTools, are determined. Then, a detailed action plan is provided for the deployment of ecoTools' UCs to each demo site. Similarly, the method for the demonstration planning includes the determination of the functionalities - indicated from the defined UCs - to be demonstrated during the first (testing) and the second (operational) round, and the corresponding timeline. Additionally, the involved partners' contribution to the demonstration activities, are given. For each demo site, a separate deployment and demonstration plan and time schedule is presented, based on the local specifications and particularities. Next to the technical aspects, business models, regulatory and social issues are considered while planning the demo activities.

1.2 Structure of the document

This document is structured as follows. Section 1 provides the purpose and scope of the present deliverable, as well as the structure of the content.

Section 2 describes the ecoToolset and the overall timeline until demonstration. This section contains summary information on the individual ecoTool, and their mapping to the four demo sites, providing a revised version of some of the contents of [1]. In addition, a high-level description of the different phases up to and including the demonstration activities themselves are provided.

Section 3 is structured around the four demo sites of the RE-EMPOWERED project: Bornholm (Denmark), Kythnos (Greece), Ghoramara (India) and Keonjhar (India), where the Kythnos site covers two independent test sites: the Kythnos power system and the Gaidouromandra microgrid. For each of these demo sites, separate subsections detail the existing infrastructure; planned upgrades and deployment plans for the ecoTools; demonstration planning to realize the use cases mapped to each demo site; and considerations regarding business models, regulatory and social aspects.

Section 4 summarizes the main conclusions of the deliverable.

2. Description of ecoToolset, Use Cases and Timeline until Demonstration

2.1 Description of ecoToolset

The ecoToolset are a set of solutions for supporting efficient, decarbonized and RES-intensive multi-energy local energy systems. Special focus is given to exploiting synergies among energy vectors, increasing demand flexibility through customer engagement using digitization that will foster an active energy community via sustainable business plans and investments. The solutions of the toolset will be tailored to the specific needs of four pilot cases in the EU and India but will aim at a wide target group for replication and exploitation in both the developed and developing world.

2.1.1. ecoEMS

ecoEMS is an energy management system (EMS) aiming at optimizing the overall performance of isolated and weakly interconnected energy systems by increasing the share of RES. ecoEMS will consider energy storage facilities and will provide advanced on-line security functions, both in preventive and corrective mode. More specifically, ecoEMS will be a modular system comprising load and RES forecast, unit commitment and economic dispatch and on-line security assessment functions. The goal of ecoEMS is the full exploitation of the RES potential (i.e., RES penetration levels above 40%) at reasonable costs in isolated electricity systems.

2.1.2. ecoMicrogrid

ecoMicrogrid is an EMS for microgrids where advanced management algorithms will be deployed to optimize the performance, taking into consideration synergies with different energy vectors like water management and cooling systems. ecoMicrogrid will monitor the state of microgrid components, such as RES production, flexible load consumption, and battery storage charge level, while predicting its short-term development. An optimization procedure will define the required actions like load shedding, diesel generator start-up/shutdown and RES power curtailment according to the desired optimization goals.

2.1.3. ecoPlanning

ecoPlanning is a tool for supporting the decision-making process for the deployment of new electricity generation units (conventional and renewable) in the electrical systems of non-interconnected islands (NIIs) in a mid-term horizon. ecoPlanning will perform the following types of studies: 7-Year energy planning for assessing the deployment plan of new conventional production units; RES hosting capacity for analyzing the hosting capacity of RES in the electric system; and interconnection assessment by performing steady state simulations of the electric system to evaluate the interconnection gains. It will report the operation of the generation units and several results pertaining to the energy production in terms of quantity, fuel consumption and cost, CO_2 emissions, etc.

2.1.4. ecoDR

ecoDR focuses on the development of advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities. In addition to measurement and billing of household energy consumption, it will facilitate remote monitoring and control of non-critical loads based on user preference. This tool will be able to communicate with ecoMicrogrid to access services such as demand-side management and implement scheduling of critical/non-critical loads via load shedding.

2.1.5. ecoPlatform

ecoPlatform is a lightweight, cloud-based platform with the primary objective of providing the RE-EMPOWERED tools with a secure and reliable interface to the deployed distributed energy infrastructure. In addition, ecoPlatform will be capable of managing, processing and handling the heterogeneous data and command stream from the RE-EMPOWERED tools, metering infrastructure, supervisory control and data acquisition (SCADA) systems, microgrid central controllers (MGCCs) and selected controllable assets. ecoPlatform will provide a platform as a service that can integrate all the solutions in one software structure.

2.1.6. ecoMonitor

ecoMonitor focuses on the development of a portable digital control platform equipped with multiple sensors for real time monitoring of ambient air quality parameters (such as CO, NOx, SOx, PM2.5 and PM10 microparticles, etc., as well as ambient temperature and relative humidity). The sensor readings will be transmitted to other ecoTools (such as ecoMicrogrid/ecoPlatform) for further processing and analysis.

2.1.7. ecoCommunity

ecoCommunity is a digital platform aiming to enhance citizen engagement, active participation and technology acceptance in the four demo sites. The main functionalities of ecoCommunity will be the display of dynamic prices for the loads, management of non-critical loads, electronic billing, payment, and a feedback portal. ecoCommunity will contain advanced functionalities and will be tailored to the special requirements of energy-disadvantaged communities.

2.1.8. ecoResilience

ecoResilience focuses on the development of cyclone resilient support structures for both ground-mounted solar photovoltaic (PV) arrays and wind turbines. It aims to optimize the PV configuration to reduce the aerodynamic wind loads through numerical simulations, wind tunnel testing, and field tests. For wind turbines, cyclone resistive hybrid structures will be designed for extreme weather conditions. The small wind turbine will be manufactured locally, with the assistance of local technicians and community members using the available resources of the region, thus allowing for maintenance to be performed quickly with reduced downtime and increased resilience.

2.1.9. ecoConverter

ecoConverter deals with the development of power electronic converters and their control, for DC/AC microgrids. Two power electronic converters, a 30 kW DC/AC inverter and a 50kW DC/DC partial power converter (PPC) for multi-string PV architecture, will be developed. The purpose of these converters is to form a local AC grid providing ancillary services and extracting the maximum power from PV panels under partial shading conditions. The converter will be modular, plug-and-play, reliable and compact with functions like built-in communication, protection, remote control, and display option.

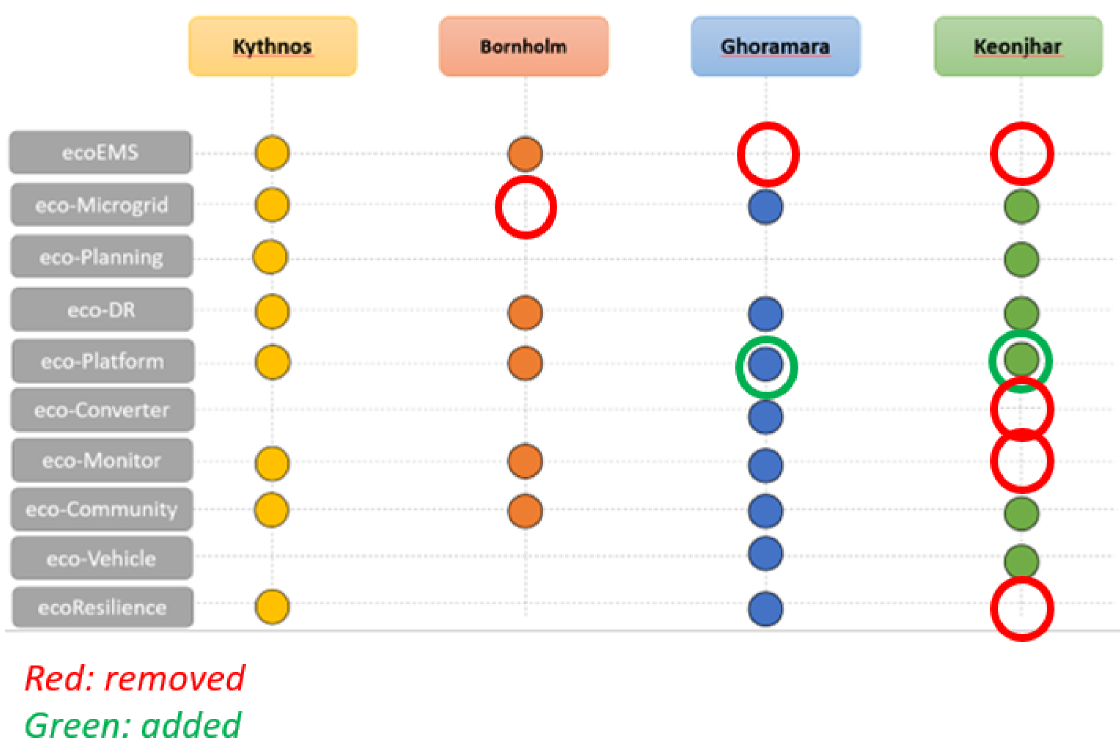
2.1.10. ecoVehicle

ecoVehicle considers the development and deployment of two charging stations, one at Ghoramara with three charging points at 1.5 kW each and the other at Keonjhar with two charging points at 1.5 kW each, to facilitate green transportation. Moreover, four electric three wheelers and an e-Boat will be deployed, which will allow locals to utilize the e-mobility infrastructure and improve local transportation.

2.2 Mapping of ecoTools to demo sites and UCs

[1] focused on the requirements for each demo site, the applicable use cases for each, and KPI definitions. In Table 1, the mapping of ecoTools to the four demo sites is summarized from section 5.3 in that document for convenient reference.

Table 1. Assignment of ecoTools to be demonstrated at each of the four demo sites in RE-EMPOWERED.



In Table 1 the tools to be deployed at each demo site are presented and compared with the initially proposed in the Grant Agreement.

In summary the following changes are noted:
ecoEMS will not be deployed in Ghoramara and Keonjhar, ecoMicrogrid will not be deployed in Bornholm and ecoConverter, ecoMonitor, ecoResilience will not be deployed in Keonjhar.

Instead, ecoPlatform will be deployed in Ghoramara and Keonjhar. These deviations from the Grant Agreement are explained below:

ecoEMS / ecoMicrogrid: These 2 tools were considered as a single entity in Task 4.1 of the Grant Agreement (Proposal). During the detailed scheduling of the tools, it was determined that ecoMicrogrid is suitable for small-scale off-grid systems, while ecoEMS is suitable for larger power systems. Therefore, ecoEMS will be deployed at the larger systems (i.e., Kythnos power system and Bornholm), while eco-Microgrid will be deployed at the smaller systems (i.e., Gaidouromandra microgrid of Kythnos, Ghoramara and Keonjhar)

ecoConverter: The ecoConverter tool was initially planned to be deployed in both Indian demo sites (Ghoramara and Keonjhar). However, after discussion with DST and limited funds availability, the developed tool by IIT KGP and IIT BBS will be deployed only in Ghoramara demo site.

ecoMonitor: The water and air quality of the Keonjhar demo site are well within quality limits. A detailed water quality analysis has been presented to the DST. So, the deployment of the ecoMonitor tool will be meaningless for this demo site.

ecoResilience: Keonjhar demo site is located far away from the seashore and the maximum wind speed recorded during extreme cyclones is around 150 kmph. In this regard, deployment of ecoResilience that aims at designs for wind speeds in the range of 200 kmph will be overrated. The ecoResilience tool has therefore been removed from the Keonjhar demo site.

On the contrary, the need for a better communication and improved interface between ecoMicrogrid and ecoCommunity tools has become essential. Therefore, and in addition to the Grant Agreement obligations, ecoPlatform will be deployed in Ghoramara and Keonjhar.

Moreover, in [1], the draft list of Primary and Secondary UCs that are planned to be tested during the deployment and demonstration phases in each pilot site were defined. The purpose of this deliverable is to provide concrete deployment and demonstration plans for each demo site that will allow the realization and testing of each UC. Section 3 of this document therefore elaborates on the use cases assigned to each demo site and provides detailed planned actions required to implement them.

2.3 High-level description of phases until demonstration

In this section, the several phases and the process that will enable the successful deployment and demonstration of the RE-EMPOWERED ecoToolset are presented. In Figure 1, the planning of the implementation timeline of the high-level phases until demonstration are presented. As it can been same the phases consists of:

- P1. Organization and Preparation
- P2. Control, Operational Functions Definition and Algorithms Designing
- P3. Development of ecoTools and Testing in Laboratory
- P4. Infrastructure Installation (on sites)
- P5. Installation and Deployment of ecoTools
- P6. Demonstration Round 1 (Testing) and 2 (Final Demo)
- P7. Assessment

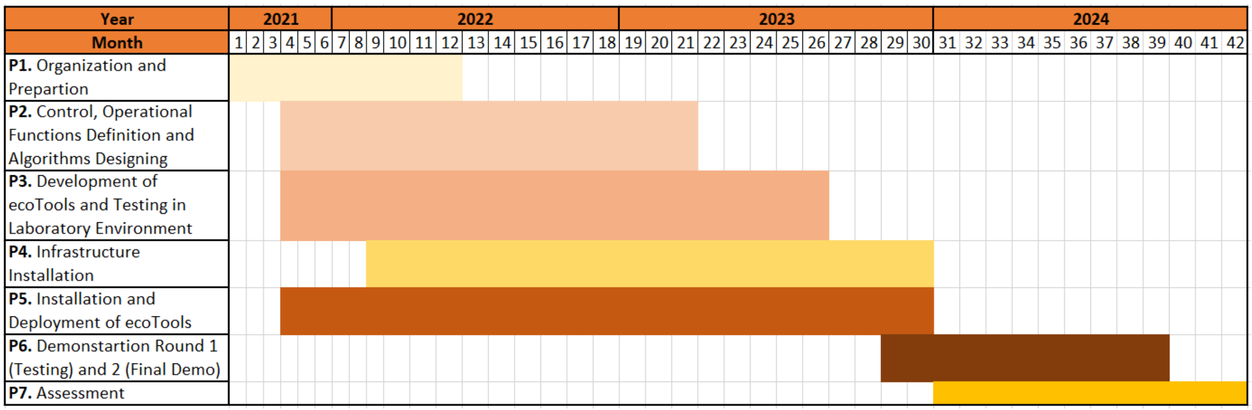


Figure 1. Gantt chart of the phases until demonstration

More information about the various phases is given in the following subsections.

2.3.1. Organization and preparation

The first step for the development of the ecoTools, is associated with the definition of the UCs for the ecoTools, taking into consideration the specific needs of the demo sites, which were identified through a detailed analysis regarding the necessary upgrades for each of them [1]. Next, the technology-agnostic technical architecture is designed for all the ecoTools that communicate, capitalizing on the SGAM methodology to analyze the UCs [2]. On top of that, the functional specifications of each ecoTool are defined. Furthermore, a thorough analysis is carried out for the available important standards and protocols to be utilized to achieve interoperability. Apart from the technical aspects, emphasis is placed on the obstacles to innovation, policy issues, regulatory framework, business models, social and ethics issues. An extensive analysis regarding those aspects applied in EU and India takes place, and the outcomes are utilized to provide insights for the planning of the deployment and demonstration as well as the actual implementation. This preparatory work was carried out in the frame of WP2 and sets the foundations for the next steps providing the skeleton of the ecoTools and setting the intended interoperability between them.

2.3.2. Control, operational functions definition and algorithms designing

Having set the foundations, the next step concerns the technical studies related to the control, operation, and stability of the local energy systems (LESs), as well as the development of the necessary algorithms for the optimal operation of the LESs and the exploitation of the available energy vectors and flexibilities. The technical studies allow better understanding of each demo's technical limitations and pinpoint the necessary action to be taken for the smooth operation of LESs. On the other hand, the algorithms will be incorporated in the developed ecoTools and will constitute the main core of them. This phase is related to the work carried out in the frame of WP3.

2.3.3. Development of ecoTools and testing in laboratory environment

The next important step is the re-design, improvement, and extension of the existing hardware and software solutions for the ecoTools, considering the target TRL for each tool. For that purpose, the previous developed algorithms are further developed and integrated into the ecoTools solutions. Additionally, the necessary communication protocols, and routines are designed and integrated to achieve interoperability and communication of the ecoTools. Finally, prior to field deployment, it is important to test and validate the technologies in a safe and controllable manner, but at the same time, in conditions close to reality. For that purpose, advanced laboratory testing techniques are utilized, like hardware-in-the-loop and real-time simulations, as well as fully hardware testbed setups. After the successfully completion of that stage, and the related work carried out in WP4 and WP5, the actual field deployment will take place.

2.3.4. Infrastructure installation/upgrade (on sites)

In the frame of RE-EMPOWERED, a new microgrid will be built from scratch in Ghoramara Island in India, and a substantial upgrade on the existing infrastructure will take place in Keonjhar in India. Also, smaller scale hardware upgrades will take place in European demo sites, Bornholm and Kythnos island, which will be utilized from the developed ecoTools. It should be noted that Sub task 7.2.1: Preliminary equipment installation for Indian partners (PVs, storage, etc.) and its related Deliverable D7.2 and Milestone MS10 will be delayed after M15 due to tender procedures of the Indian partners. Having the necessary infrastructure at place, the actual deployment can be completed.

2.3.5. Installation and deployment of ecoTools

Apart from the infrastructure installations and upgrades, the necessary hardware and software installations take place for the deployment of the ecoTools. Those can relate to set up of servers, establishment of routines, integration of controllers, communications links, and other relative actions that will allow the implementations and operation of the ecoTools on the demo sites. Having the ecoTools installed in the demo sites, the demonstration of the functionalities and overall project objectives can be achieved.

2.3.6. Demonstration rounds 1 (testing) and 2 (final demo)

Based on the previously defined UCs, the demonstration rounds will take place at the four demo sites. The first round is dedicated to testing purposes, to validate the ecoTools and their functionalities on field. After the testing round, necessary adaptations in the system might be required. Finally, after the incorporation of the corrections and tuning of the system based on the observations from the testing round, the final operational demonstration takes place, in which the complete set of functionalities will be showcased. During the demonstration activities, data will be obtained from the LESs operation, as described in Task 7.4, to be evaluated as part of the assessment stage.

2.3.7. Assessment

After the completion of the deployment and demonstration phases, the assessment of RE-EMPOWERED ecoTools and demos will summarize the impact of the implementation of the new technologies, tools, strategies and business models. Emphasis will be placed on the efficiency, reliability, enhancement, and other operational characteristics of the LESs, as well as on aspects related to business models, strategies, economic considerations, etc. On top of that, the evaluation of the TRL, based on start and end will be done for all the hardware and software tools developed in the frame of RE-EMPOWERED. Finally, social and environmental aspects related to the implementation of the tools will be assessed, like environmental awareness, tackling energy poverty, acceptance of technologies, etc. The aforementioned actions are related to the work carried out in the frame of Task 8.3, Task 8.4 and Task 8.5.

2.4 Ethical considerations

To address the ethical aspect of the deployment and demonstration plan, the four deliverables of the relevant Work Package (WP10: Ethics) can be used. These RE-EMPOWERED deliverables address the topics of:

- The participation of people outside of the project in the research activities [3],
- The protection of personal data [4],
- The involvement of non-European countries [5]
- The creation of a Health and Safety plan that addresses the protection of the environment and the safety of the personnel [6].

An analysis of the relevant European legislation was performed as well as an identification of the relevant Indian legislation. In the following paragraphs an overview of the topics that are included in the WP10 deliverables that can be useful during the deployment and demonstration phase of the project is provided.

Regarding human participation, an information sheet is available that should be distributed to the citizens and a consent form that they should sign. Regarding the protection of personal data, the details of Data Protection Officers are available as well as measures to prevent unauthorized access to the collected data and to safeguard the rights and freedoms of the research participants.

There are also several anonymization techniques provided that can reduce the volume of personal data that need specific handling.

Concerning the involvement of non-European countries, a description of the hardware, software and personal data that are expected to be transferred between European and non-European countries was provided. The overarching goal is to minimize those transfers especially regarding personal data.

Lastly, the Health and Safety plan (drawn according to ISO 45001 by a Greek specialized company) will be the most useful tool during the deployment phase. It describes the roles that need to be assigned in each demo-site, the procedures to be followed in several fields and also template forms that help the responsible person to apply and document the application of the H&S plan.

3. Demo sites

3.1 Bornholm Island

3.1.1. General description – Existing Infrastructure

Bornholm island (in Denmark) has a long history as "test-island" for energy technologies. Bornholm is connected to the mainland (Sweden) electrical grid, but the combined heat and power (CHP) plant in Rønne can run the electrical system in a so-called "island mode" when the sea cable is disconnected. All urban areas are supplied with district heating (DH), and the heat is generated with biomass boilers, using locally produced woodchips and straw as fuel. Specifically, the demo area of RE-EMPOWERED comprises three towns in the eastern part of Bornholm – Østerlars, Østermarie and Gudhjem – that are connected in a district heating network (DHN), with a total of 600 consumers. The main consumption comes from the local swimming pool, church, and households.

Production side

The demo site in Bornholm will include the Østerlars heat plant, which consists of a 4 MW boiler fueled by locally produced straw, four 0.6 MW electric boilers (EBs) for reserve and peak loads, and a 1,500 m^3 hot water storage tank with a capacity of 80 MWh. Those are the heat sources that provide the heat to the local DHN. These units are shown in Figure 2.

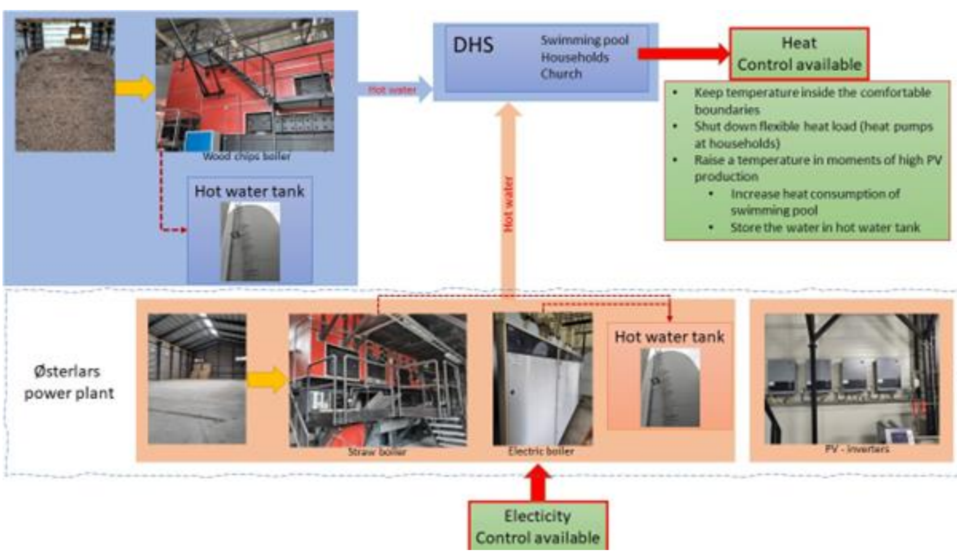


Figure 2. Overview of the heat production and storage units in Østerlars heat plant.

Therefore, the DHN is supplied with hot water by the hot water storage tank, the straw boiler, and the electric boilers. The return water (water flowing back to the source to increase the water temperature) flows back to straw boiler and electric boiler to be heated up. In case of high heat demand or low heat production compared to demand needed, the heat is provided by the hot water tank. On the contrary, in situation of low demand or high production compared to demand needs, the heat is stored in hot water tank.

Finally, the Østerlars heat plant is equipped with 93 kW of rooftop PV, and in Aakirkeby two grid-connected PV plants comprise 2 x 10 MW_{DC} in panel capacity and 2 x 7.5 MW_{AC} in inverter capacity. These two grid-connected PV plants are not owned by Bornholms Varme, but there is established a contact with European Energy, who has the OM contract for the parks, about potential access to high quality production data from the two parks. In addition, Bornholms Varme and its sister companies own six small PV plants between around 15 kW_{AC} and 325 kW_{AC}. These existing units will also participate in the demo to explore sector coupling between PV and DH, the possibility for peak shaving, and production-side flexibility. In addition, new approx. 20 MW PV park in the vicinity of the Østerlars heat plant is being considered, conditional on the business models and results resulting from the RE-EMPOWERED project.

Consumer side

All DH consumers have digital smart meters installed, see Figure 3, that provide continuous monitoring and measurements, enabling detailed analysis of data about consumption, temperatures, and flow in the network. All DH consumers also have hot water storage tanks of at least 100 liters, providing decentralized, flexible storage facilities. In Gudhjem, all consumers have a Danfoss ECL computer installed on the DH units, which control the charging of the hot water tanks and the temperature of the water flowing to the household heating system. This means that direct control of the heat pumps is available in the households.

Smart meters at all consumers.
Data collected and stored daily:
- Energy
- Flow volume
- Temperature in-out

Historical data from Jan. 2019

Figure 3. Digital smart meters are installed at all DH customers at the Bornholm demo site.

Demo goals

The demo will provide means for integrating more electricity from RES, in a community that already has a high penetration of RES. From the heat production side, the electric boilers could provide frequency reserves (mainly downregulation), as well as provide demand side management. This could also be achieved by making the EBs controllable, such that they could be used when there is excess production from PV to avoid imbalances in production and consumption in the power grid. In such situation, the excess power is provided as heat to the DHN, i.e., the temperature of DHN is raised, while kept inside the comfortable and permissible limits. In situation where the DHN has lower consumption of heat, the excess heat is stored in the hot water storage tank. Such a sector coupling, based on forecasts of PV production, would allow for improved utilization of RES at the demo site.

3.1.2. Deployment planning

This section details the upgrades to the existing infrastructure that needs to take place to support the demonstration goals of the Bornholm demo, as well as the individual ecoTools to be deployed to the demo site. Figure 4 provides an overview of the ecoTools and other infrastructure as it relates to the RE-EMPOWERED demonstrations.

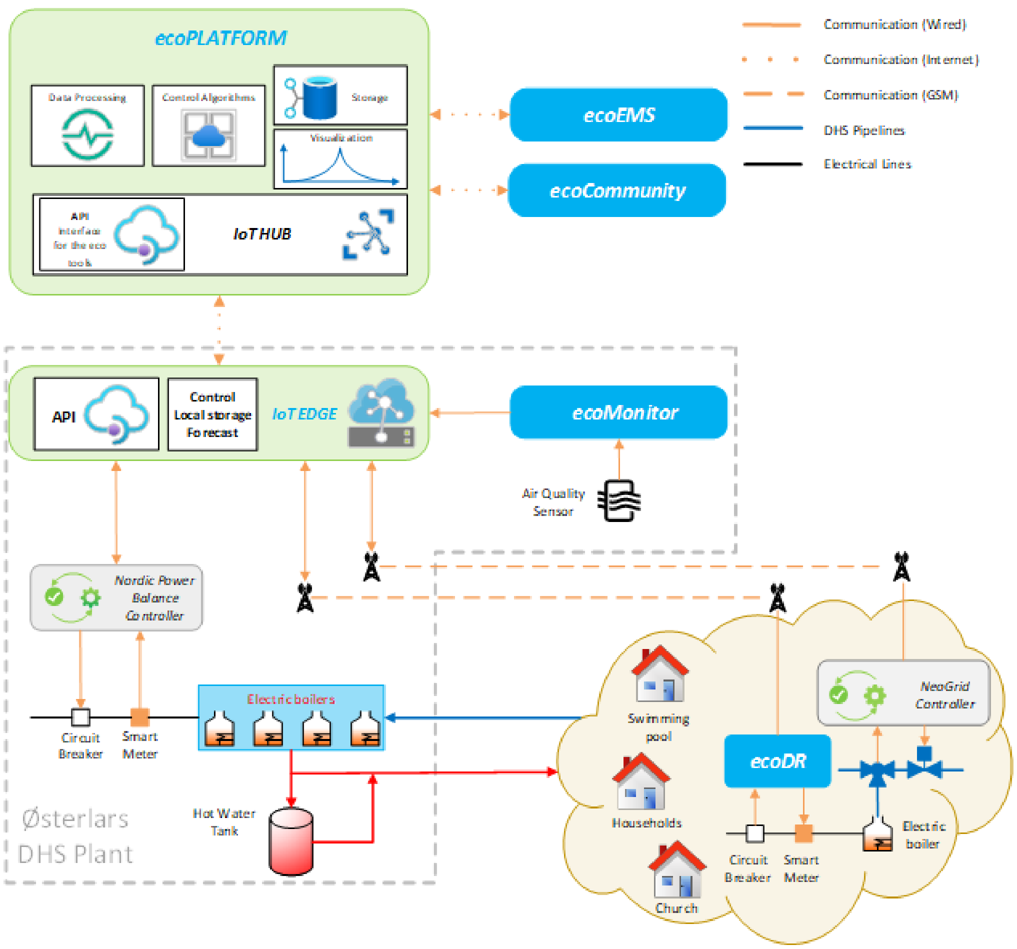


Figure 4. Key components of Bornholm Demo-Site

Upgrade of existing infrastructure

To deliver on the demonstration plans for the Bornholm demo site, the following upgrades of the existing infrastructure are planned:

- **Production side** – Online data collection from heat plant and remote control of electric boilers
    - The EnergiDenmark package installed at the Østerlars heat plant will be replaced by Nordic Power Balance infrastructure which is not in the framework of RE-EMPOWERED
    - Possible installation of new sensors depending on the need which is not in the framework of RE-EMPOWERED
- **Consumer side** – Online data collection from consumers and remote control of DH units
    - Installation of Neogrid internet-of-things (IoT) devices at consumers. The Neogrid equipment comprises a communication box (connected to the Danfoss ECL computer at the consumers), and one or more temperature/humidity sensors.
    - Online data collection from smart meters at the consumer side (swimming pool, church, households)
    - Remote control of Danfoss ECL-computers at the consumption side (swimming pool, church, households)
    - Installation of small-scale electric heater for ecoDR demonstration in the framework of RE-EMPOWERED
- **Interface**
    - Raspberry Pi connection to the signals of Nordic Power Balance and to Neogrid IoT device in the framework of RE-EMPOWERED

	Neogrid IoT Devices	From	To
		M15	M21
System information	**Type:** IoT device **No. of IoT devices:** Approx. 7 **Installed at:** Demo consumers		
Device information	**Manufacturer:** Develco **Model:** SquidLink 2B		
Communication Protocol	Danfoss ECL (110, 210 and 310) via Modbus protocol, M-Bus, wM-bus, Bacnet, MQTT, and Lora		
Measurement Parameters	All smart meter data (flow temperature, return temperature, energy, volume, flow, E8, and E9), ambient temperature, all ECL measurement data, and cold-water volume		
Control Parameters	DH unit set point temperature		
Logging rate	Every minute		

The installation of the Neogrid IoT devices of data collection and control of flexible DH demand requires agreements/contracts with selected consumers, which be secured between M15 and M20. The equipment will be purchased from the vendor between M15 and M16 and installed at the consumers from between M17 and M21.

RE-EMPOWERED ecoTools deployment

This section addresses the ecoTools to be implemented at the Bornholm demo site.

The ecoEMS tool is responsible for optimizing the overall operation to minimize cost. ecoEMS will be linked with the ecoDR to send the ON/OFF signals to an electrical heater. It will be hosted at NTUA premises, and will communicate to the Bornholm demo-site through the ecoPlatform.

	ecoEMS	From	To
		M06	M26
Overall system information	**Function:** Strategy determination, Day ahead scheduling of electric boiler, controllable thermal demand and district heating system to accommodate excess PV production and possible peak shaving **Input Parameters:** Consumptions, Productions, Forecasts, Assets Status, Grid Status, Set points of electric boilers, DHS data, temperature and mass flow limits, Assets datasheet (e.g., maximum and minimum operating limits) **Output Parameters:** Suggested set-points to assets, marginal price, schedule of electric boiler according to the excess PV production and heat demand **Communication protocol:** Ethernet **Measurement parameters:** Active power, electric boiler on/off status, power consumption of EB, water level and temperature of EB, EB power setpoint, hot water tank level		

The ecoDR tool is responsible for controlling non-critical electrical loads (< 3 kW) with the aim of introducing demand response in the electrical grid. In Bornholm demo-site 1 ecoDR unit will be installed for a small electrical load, such as electric heater at a consumer site.

	ecoDR	From	To
		M24	M26
Overall system information	**Function:** Measurement of energy consumption, transmitting time stamped energy data and control of non-critical loads **Input Parameters:** Schedule of electric heater **Output Parameters:** On/off signal **Communication protocol:** GSM, MODBUS **Measurement parameters:** Power consumption		

The ecoPlatform tool is a cloud-based platform for collecting and managing the data from various sources across the Bornholm demo site, as well as for orchestrating the communication and interface between the other ecoTools. Furthermore, it will be used for management of both consumer- and production-side flexibility, by controlling consumer-side demand as well as the operation of the electrical boilers in coordination with forecasted PV production.

	ecoPlatform	From	To
		M15	M28
Overall system information	**Function:** Integration of all eco tools and ensure interoperability, acquire data from various sources and serve as data storage on a cloud platform. **Input Parameters:** EB setpoint, EB status and power consumption, hot water tank temperature and water level, DHS temperature and flow measurement, thermal load measurements, PV power generation, air quality data **Output Parameters:** Make the input parameters available to other tools, visualize some of the data of Bornholm demo site **Communication protocol:** Internet – MQTT or HTTPS **Measurement parameters:** Not installed locally		

The ecoMonitor tool is responsible for measuring the air quality at the Østerlars heat plant to enable correlation with production of the straw boiler, leading to higher emissions of SOx and NOx and vice versa for high PV production and corresponding lower production of straw boiler. It will be hosted at the Østerlars site and communicate with ecoPlatform (through IoT edge device; Raspberry Pi).

	ecoMonitor	From	To
		M15	M28
Overall system information	**Function:** Real time monitoring and analysis of ambient air quality parameters **Input Parameters:** Air quality sensors data **Output Parameters:** Processed sensors data **Communication protocol:** Ethernet **Measurement parameters:** CO, NOx, SOx, PM2.5 and PM10 microparticles, temperature, humidity		

The ecoCommunity tool is responsible for raising citizen engagement and for supporting the community in adopting the ecoTools in service of the project's overall objectives. It will be hosted in the cloud and communicate through ecoPlatform.

	ecoCommunity	From	To
		M15	M28
Overall system information	**Function:** Community engagement through forums, feedback, and problem reporting portals. Community support through training materials and guides. Display the various thermal variables associated with local heating system at the district heating consumers. **Input Parameters:** Thermal Variables **Output Parameters:** Visualization functions of DHN **Communication protocol:** MQTT or HTTPS		

	Measurement parameters: None locally

UCs analysis and planned actions

In the following, the necessary actions for the deployment and demonstration of ecoTools at the Bornholm demo site are presented, based on the defined UCs and the mapping of the UCs for each ecoTool to be tested described in [1] and revised here. Based on this mapping, a list of concrete actions, specific to the demo site, that must be completed to realize each UC is presented.

I. ecoEMS

Item No.	EMS_2UC1.1: Real time monitoring and system data visualization
EMS_1.1.1	Visualize the data produced by the ecoEMS
EMS_1.1.2	Visualize the data produced by other algorithms and SCADA systems

Item No.	EMS_ 2UC1.2: Module manager: intercommunications and data exchange
EMS_1.2.1	Connect with SCADA systems and other algorithms of the ecoTool set through API and receive the data
EMS_1.2.2	Store the data in the ecoEMS integrated database

Item No.	EMS_ 2UC2.1: Mid-term and short-term RES and load forecasting
EMS_2.1.1	Receive the forecasting algorithm from Work Package 3 to forecast the uncertainties

Item No.	EMS_ 2UC2.2: Forecasting model training
EMS_2.2.1	Feedback the forecasting algorithm of the WP3 for retraining and optimization

Item No.	EMS_ 2UC2.3: Unit Commitment and Economic Dispatch algorithms
EMS_2.3.1	Prepare the UC simulation with input of forecasts and thermal generators
EMS_2.3.2	Run the simulation, send the orders and visualize the output
EMS_2.3.3	Run the economic dispatch simulation, update the orders and visualize the output

Item No.	EMS_ 2UC2.4: Multi-energy vector management of operation
EMS_2.4.1	Integrate the temperature discomfort in the Unit Commitment objective function of the ecoEMS
EMS_2.4.2	Integrate all other technical constraints

II. ecoDR

Item No.	DR_2UC1.1: Real time monitoring of energy consumption
DR_1.1.1	Installation of necessary software for the configuration of the metering devices
DR_1.1.2	Configuration of metering devices

DR_1.1.3	Implementation of energy monitoring also having features suitable for communication with ecoEMS
DR_1.1.4	Testing the data acquisition process and assessment

Item No.	DR_2UC2.1: Scheduling of loads
DR_2.1.1	Receiving the load ON/OFF commands from ecoEMS
DR_2.1.2	Turning the switches/relays ON/OFF

III. ecoPlatform

Item No.	PF_2UC1.1: Connect to sensors and acquire data through designated communication network and protocols
PT_1.1.1	Prepare electric boilers for online control
PT_1.1.2	Communication interoperability from different sources such as smart meters to obtain measurements from PV plant, heat plant and electric boiler - Communication and operability of electric boilers and PV from ecoPlatform
PT_1.1.3	Establish communication/access to existing SCADA for data gathering
PT_1.1.4	Online data collection from key-sensors from heat plant and measurements from PV
PT_1.1.5	Data-storage from PV and heat plant in ecoPlatform
PT_1.1.6	Online data collection from smart meters at a few households and larger consumers

Item No.	PF_2UC1.2: Data cleansing to ensure consistency and human machine interface
PT_1.2.1	Ensure consistent data – raw data cleaning and filtering

Item No.	PF_2UC2.1: Facilitate data exchange between dependent tools
PT_2.1.1	Exchange of data between ecoEMS, ecoCommunity and ecoPlatform

Item No.	PF_2UC2.2: Facilitate access to controllable assets for dependent tools
PT_2.2.1	Remote-control capability of Electric boilers, at the Heat plant
PT_2.2.2	Remote control of Danfoss ECL-computers at a few households and larger consumers
PT_2.2.3	Forecasting of PV-production and DH-demand for autonomous controlled PV-balancing by Electric boilers

Item No.	PF_3UC3.1: Route the microgrid data and data from dependent tools to cloud database
PT_3.1.1	Storing the data in the cloud

Item No.	PF_3UC3.2: Facilitate archived data access for dependent tools using API
PT_3.2.1	Provide an API for other tools to access the storage

IV. ecoMonitor

Item No.	MON_2UC1.1: Acquisition and transmission of air quality parameters data
MON_1.1.1	Acquisition of air quality parameters such as CO, NOx, SOx, PM2.5 and PM10 microparticles, temperature, humidity
MON_1.1.2	Real time data transmission to other ecoTools (ecoPlatform)

Item No.	MON_2UC1.2: Data processing and evaluation
MON_1.2.1	Real time monitoring and analysis of air quality parameters

V. ecoCommunity

Item No.	CM_2UC3.1: Feedback and suggestions from users about the tools
CM_3.1.1	Preparation of feedback questionnaire based on the tools installed/ deployed at the demo site.
CM_3.1.2	Implementation and integration of questionnaire and suggestions module in ecoCommunity mobile application.
CM_3.1.3	Testing and deployment of the module.

Item No.	CM_2UC3.2: Reporting of problem
CM_3.2.1	Identifying the various problem categories and preparation of problem reporting form for the demo site.
CM_3.2.2	Implementation and integration of problem reporting module in ecoCommunity mobile application.
CM_3.2.3	Testing and deployment of the module.

Item No.	CM_2UC3.3: Forum to share experiences
CM_3.3.1	Identifying the various forum topic categories relevant to the demo site.
CM_3.3.2	Implementation and integration of forum module in ecoCommunity mobile application.
CM_3.3.3	Testing and deployment of the module

Item No.	CM_2UC4.1: Training material (troubleshooting)
CM_4.1.1	Collecting the various service manuals and training materials associated with the installations from ecoTool leaders
CM_4.1.2	Categorizing the collected service manuals and training materials based on type and application.
CM_4.1.3	Uploading the documents to the common database and integration of the module with ecoCommunity mobile application.

Item No.	CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)
CM_4.2.1	Coordination of the ecoTool leaders for the preparation of necessary multimedia materials for the various ecoTools
CM_4.2.2	Preparation of step-by-step guides for using the various modules of ecoCommunity tool
CM_4.2.3	Collecting and categorizing the various multimedia materials for the demo-site.

CM_4.2.4	Uploading the documents to the cloud database and integration of the module with ecoCommunity mobile application.
CM_4.2.5	Creation of administrative user login for the ecoTool leaders for any future creation or updating of the materials.

Item No.	CM_2UC5.1: Monitoring of heating system at load centers
CM_5.1.1	Implementation and integration of heating system display module in ecoCommunity mobile application.
CM_5.1.2	Identify the local heating system variables measured by the Neogrid IoT Devices.
CM_5.1.3	Establish communication with ecoPlatform for accessing the real-time values of the identified variables from Neogrid IoT Devices.
CM_5.1.4	Testing and deployment of the module.

3.1.3. Demonstration planning

The demonstration planning will be divided in two runs. The first run refers to testing demonstration, i.e., demonstrating the core capabilities of the deployed ecoTools in a limited setting. After the first run, adaptations and adjustments will be performed, leading to the second run, the operational demonstration, i.e., operating the demo site leveraging the benefits of the full functionality offered by the deployed ecoTools.

The first run of the demonstration planning will be divided in two levels. The first level ("Basic functionality") will include the demonstration and validation of the stable and continuous operation of the ecoToolset, the deployment of the software and hardware, as well as the uninterruptable communication of the tools and the components. The second level ("Advanced functionality") will consist of the validation of the advanced functionalities that the ecoTools facilitate. Activities within each run/level need not to be performed in sequence.

First demonstration run (testing demonstration)		From M28	To M32
A	Basic Functionality	From M28	To M30
A1	Electric boiler power consumption monitoring		
A2	Electric boiler setpoint change		
A3	Monitoring and operability of Neogrid controller from ecoPlatform		
A4	Heating load monitoring		
A5	Heating load control		
A6	Solar PV power monitoring		
B	Advanced functionality	From M30	To M33
B1	Forecast of PV production		
B2	Balancing of PV production using EBs based on forecasted PV production		
B3	Economical use of EBs based on forecasts of spot-prices of electricity		
B4	Forecast of heating production from balancing PV production by EBs		
B5	Forecast of DH demand		
B6	Consumer flexibility by decreasing and increasing consumption at certain times		

B7	Real-time air quality monitoring		
Adaptations and adjustments		From M30	To M34
Second demonstration run (operational demonstration)		From M34	To M37
C1	Optimal use of flexibility in the DHN based on selected previous demonstrations		
C2	Online secured access		
C3	Scheduling of flexible loads and Coordination		
C4	Outreach forum of ecoCommunity		
C5	Guidance and training		
C6	Data storage and cloud server		

Involved partners	Contributions
BV and DTU	Bornholm demo-site leader. Leading the implementation of the ecoPlatform tool
ICCS-NTUA	Leading the implementation of the ecoEMS tool
ICL	Leading the implementation of the ecoCommunity tool
CSIR-CMERI	Leading the implementation of the ecoDR and ecoMonitor tools

3.1.4. Business models, regulatory and social considerations related to deployment and demonstration actions

This section addresses business models, regulatory and social considerations related to the Bornholm demo-site and Denmark. Denmark has been very active in the development of renewable energy projects, supporting them with favorable regulation since 1989.

Regulatory background

The first law regarding renewable energy was the 1976 Electricity Supply Act (its last update is the Consolidated Act No. 984 of 12 May 2021). This Act defines the framework for the control of the electricity sector, including the generation, transport, trade and supply of electricity. Only licensed companies are allowed to carry out these activities, using public grids.

Besides, the Minister of Energy is authorized to force electricity supply companies to use some types of energy in the supply mix, or to take energy efficiency measures. This law has been reviewed periodically, to include changes in regulation and technological advances. For instance, in 1989, there were major modifications in the Act, including the obligation for power suppliers to purchase power produced with renewable energy plants and Combined Heat and Power plants. In 1994, there were some amendments regarding environmental protection. Finally, in 1996, the electricity market was liberalized, according to the Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity.

In 1981, the Act on Support for Utilization of Renewable Energy Sources was enacted. It is the most relevant regulation for renewable energy systems in Denmark and offers grants to develop this kind of projects. Despite the long time that has gone by since its first version, this Act is regularly updated, to include changes in technology and European regulation. The last version is the Consolidated Act No. 1791 of September 2021. This document regulates the promotion of renewable energy sources to reduce the energy dependency of Denmark, increase the security of supply and reduce the greenhouse gas emissions. Besides, it includes grants and subsidies for renewable energy projects, which cover a percentage of the approved expenses in the case of solar thermal, biomass, heat pumps and biogas plants.

Incentives

In 1993, for renewable electricity projects, a feed-in tariff, or price supplement, was designed. The act also included measures to promote the manufacturing of wind turbines, which explains why some of the main worldwide leaders in this sector are Danish companies.

To sum up, in Denmark there are different incentives to promote the development of renewable energy projects. They can be divided into price supplements (feed-in-tariffs or premium tariffs) and subsidies to the project construction.

Feed-in tariffs can be divided into four types:

1. Premium on the market electricity price. In some cases, the sum of the premium and the market electricity price is capped and should not be higher than a certain maximum, while for some plants, the bonus to be added to the market electricity price is fixed and there is not a maximum.
2. Fixed settlement price, this is, the project developer receives a fixed electricity price. The difference between the market price and the fixed guaranteed price is then the subsidy it receives.
3. Contract for Difference for tendered offshore wind energy projects. In this case, the amount of the subsidy can be calculated as the difference between the tendered price and the spot market price.
4. Fixed yearly payment, which does not depend on the electricity production.

On the other hand, the subsidies to the project construction are payments for a percentage of the costs, after its justification and approval. These subsidies are applied to technologies such as solar PV, wave power, biogas and biomass. During the last years, feed-in tariffs are being reduced for new projects, as technologies have evolved, and costs have been reduced.

For instance, and because some renewable energy technologies are now totally competitive, since 2020 new solar PV power plants are not offered subsidies, and contracts for difference are used for offshore wind farms.

In 1996, the Electricity Supply Act was updated, to include priority access to the grid, to renewable energy power plants. This update entered into force in 1998.

Denmark has also promoted the installation of solar PV self-consumption projects, especially since the establishment of the net metering for privately owned solar PV systems, which has been in force since 1998. The electricity surpluses of solar PV self-consumption plants are purchased at the same price as the utility sells its electricity. Besides, the electricity surpluses sold are exempted from paying the Public Service Obligation, a surcharge on the electricity tariff, aimed at promoting renewable energy, as well as other taxes and duties, such as VAT.

Energy Agreements

Energy Agreements are agreements about energy policy between the Danish government and other Danish political parties. Their objective has been to reduce the dependence of Denmark on fossil fuels, increasing the objectives of energy efficiency and renewable energy penetration. The first Energy Agreement was signed in 2008 and lasted from 2008 to 2011. In 2012, there was an update, the Energy Agreement 2008-2011. Finally, a new Energy Agreement 2020-2024 was defined in 2018, to update the agreement of 2012. It includes the following objectives:

- To reach 55% of the final energy consumption coming from renewable energy sources by 2030, and 100% by 2050.
- To reach 100% of the electricity consumption coming from renewable energy sources by 2030.
- To ensure that at least 90% of district heating consumption is based on energy sources different from coal, oil or gas by 2030.
- To develop new offshore wind energy farms, with a power capacity of at least 800 MW, to be connected to the grid in 2024-2027, and other two offshore wind farms by 2030.
- To reduce electricity taxes for customers.
- To reduce greenhouse gas emissions by 100% by 2050, becoming carbon neutral.

Finally, in June 2020, the Danish Parliament passed the Climate Act, which has as objective to reduce Denmark's emissions by 70% in 2030, compared to 1990, and reach the climate neutrality in 2050. A rolling five-year target is defined. In 2021, a new emission reduction target of 50-54% by 2025 was included.

Local context at the demo site

According to the current trends and trajectories, Denmark will reach 54% share of renewables by 2030, if no changes in the existing energy policies happens. For this reason, additional policies are needed to reach the 70% of reduction of greenhouse gases emissions, and these policies will focus mostly on the level of penetration of renewable energy.

In the specific case of Bornholm, a group of citizens, supported by the Bornholm municipality, are developing a 100 MW wind turbine offshore, based on local funding. The wind farm is expected to be commissioned by 2025. Besides, new solar PV plants (50 MW) are also planned.

Regarding the used technology of the pilot site, district heating systems have become very common in Denmark: 64.5% of all Danish homes are connected to a district heating system. The use of renewable energy for heating supply has become a major priority in the 1990s, and especially since the Biomass Agreement was passed in the Parliament in June 1993. Before 2018, any decentralized combined heat and power plant received subsidies for generating electricity (feed-in tariffs). However, policies introduced in 2018 limited the subsidies to those plants which generated electricity using renewable energy sources.

Citizens in Bornholm have invested in energy production for the last 30-40 years. At present there are about 1,000 households with approximately 8 MW of rooftop PV panels in total. This high number is due to the PVTP Island project I-III and favorable support mechanisms up to 2015. There are 50 households with their own wind turbines of up to 25 kW. Both PV and wind turbines are grid connected.

The Municipal Energy Plan foresees to increase the renewable energy installed capacity in 50 MW of solar PV, and 100 MW of wind turbines near the shore.

A newer 50 kW PV installation at the public indoor swimming pool in Gudhjem has been raised by crowdfunding among local citizens.

Community engagement

In Bornholm and in the rest of the country, citizens have mentioned that there is some willingness-to-pay (WTP) for electricity coming from renewable energy. As mentioned, the electricity market is totally liberalized, and some electricity suppliers offer their clients electricity with renewable energy origin certificates. In some cases, tariffs in these contracts are higher than electricity provided by large investor-owned companies, but some clients are willing to pay for the difference. Individuals with pro-environmental attitudes and public environmental awareness campaigns can induce individuals to pay an additional price for electricity produced with renewable energy, produced in local energy projects, or by utilities owned by local bodies.

In the EcoGrid projects it is shown that it is possible to engage the citizens and create flexibility in the power grid by controlling household electricity consumption – in this demo, the attempt will be to expand the scope to create flexibility and synergy in both power grid and heat grid and engage citizens and community to participate in the project.

The evolution of the electricity prices in Denmark will be key for the success of the Bornholm district heating plant. One of the objectives of the project is to be able to electrify the generation of heat, and to inject it into heat grids. Currently, heat is primarily produced with biomass. However, the demo site involves exploring the possibility of producing heat using electric boilers. These electric boilers would feed from electricity produced with renewable energy, in those hours when spot market prices and grid fees are lower. This would also allow for increasing the power production with renewable energy, since the excess of production in moments when the demand is lower could be shifted to producing heat.

Regarding the security of supply, in Denmark it is taken for granted. The energy system in Bornholm is generally resilient and reliable, since there exists a sea cable which connects the island to Sweden, increasing the security. However, it is expected that the increasing level of variable renewable energy will increase the volatility of production, leading to potential reliability problems. These problems will be addressed in the Demo about the control and integration of production from solar PV plants.

As for citizen engagement, all the district heating consumers have digital smart meters, which allow them to take detailed information about consumption, temperatures and flow in the network. Consumers also have hot water storage tanks, of at least 100 liters, and in Gudhjem all consumers have a Danfoss ECL computer installed, that controls the charging of the hot water tanks, and the temperature of the income water to the household radiator system.

In the pilot site tests, several consumers will be engaged for the demonstration, and the already installed Danfoss ECL computer will be upgraded with remote controls, to provide access for demand-response, for balancing heat input from PV via electric boilers. Two larger consumers are already recruited: The public indoor swimming pool in Gudhjem and the local schools in Østerlars.

The biggest obstacle in the demo site of Bornholm is the limited capacity of the sea cable which connects Bornholm to the mainland. Since new solar PV and offshore wind energy plants are being developed in the island, in the near future, the cable could have not enough capacity to export electricity from Bornholm in these moments when the wind and solar PV production is higher. For this reason, the demo site involves the design of different ways to use this electricity.

Other risks are the limited participation of the citizens, financial limitations and lack of skills between the professionals of the island.

Business models

In order that the Bornholm pilot site is successful, it is necessary that the price of the heat produced with electric boilers is competitive. Currently, the price of electricity used by electric boilers is the price from the grid. In 2020, the DK2 spot price was lower than 50 DKK/MWh during 861 hours of the year. This leads to an electricity retail price of around 250 DKK/MWh.

In contrast, the cost of the straw needed to produce electricity in the biomass boiler is 200 DKK to produce 1 MWh of electricity. To this cost, it is necessary to add other costs (operation, maintenance, personnel). For this reason, under the current business model, the use of electric boilers cannot compete with the straw boiler.

Some options which can be considered to make electric boilers competitive are:

- Use of the electric boilers to provide system services to the transmission system operator (TSO), receiving payments for it.
- If the new solar PV plants are coupled with direct lines of the district heating system, then TSO and distribution system operator (DSO) fees can be avoided. These fees make electricity from solar PV plants much more expensive and deter the development of electric boilers. By doing so, the district heating can use cheap electricity from the solar PV plants to produce cheap heat, or from the grid when spot prices are low.

- Sector coupling can allow to sell services to the electricity grid (DSO and TSO): Flexibility services (active power services) and reactive power services (from large solar PV inverters).
- Consumers can also participate, with their experiences in the RE-EMPOWERED project, and the Ecogrid projects.

3.2 Kythnos

Kythnos demo site consists of two independent sites. The first site refers to the island's power system (Kythnos power system) and the second site refers to an off-grid system, the Gaidouromandra microgrid. The Gaidouromandra microgrid is not interconnected to the island power system.

The demo sites of Kythnos power system and the microgrid of Gaidouromandra have been described extensively in [1]. In the following, a brief reference is made to the existing infrastructure of the two demo sites.

In Section 2.2, the mapping of ecoTools to each demo site was presented. In Table 2, the distinction between the ecoTools to be installed in Kythnos Power System and Gaidouromandra Microgrid, is shown.

Table 2. Mapping of ecoTools to the two independent Kythnos demo sites.

ecoTool	Gaidouromandra Microgrid	Kythnos Power System
ecoEMS		✓
ecoMicrogrid	✓	
ecoPlanning		✓
ecoDR	✓	
ecoPlatform	✓	
ecoConverter		
ecoMonitor		✓
ecoCommunity	✓	
ecoVehicle		
ecoResilience	✓	

3.2.1. Kythnos Power System

3.2.1.1 General description – Existing Infrastructure

Kythnos is a non-interconnected Island with the following energy mix:

- Peak load: 3.118 MW
- No. of electricity customers (end consumers / producers – LV): 3,353
- Installed capacity of fossil fuel (diesel) Generation: 5.2 MW
    - MWM TBD603V12: 4 x 0.3 MW
    - MITSUBISHI S16R-PTA: 4 x 1 MW
- Installed capacity of renewable energy (RE) Generation units 908.65kW:
    - 3 PV power plants of 1x 98.4 + 1x 69.92 + 1x 69.93 = 238.25kW
    - 2 Roof units of 1x 19.875 + 1x 9.66 = 5.4 kW
    - Wind stations of 5x 33kW + 1x 500 kW = 665 kW

The total yearly local energy production and the total yearly energy consumption of the LES of Kythnos, based on data of the year 2020, are:

Total yearly local energy production	Total yearly energy consumption
10,058.75 MWh (2020)	9,166.75 (MWh) (2020)

Moreover, Kythnos hosts the following other energy related infrastructure:

- Desalination plant of 1x 75 kW
- Number of Electric Vehicles deployed: 3 (7 in total to be deployed by the municipality)
- Number of charging stations installed: 4x22kW + 5 more to be installed (9 in total, double socket, 11kW each)
- Heat Pump in Municipal Building (School)

Heat Pump in Municipal Building (School)

Recently, the heating system in a school in Kythnos was restored, with the installation of a heat pump among other interventions. The said heat pump is of 30 kW power and operates during school days (ca. 2500 h/year).

Electric vehicles (EVs)

There are 7 EVs currently deployed on the island. Also, there are 9 three phase, AC, dual socket, EV chargers installed on the island.

3.2.1.2 Deployment planning

Figure 5 represents the target for Kythnos island after implementation of RE-EMPOWERED project's toolbox, taking also into consideration the actions during national project Kythnos Smart Island (KSI).

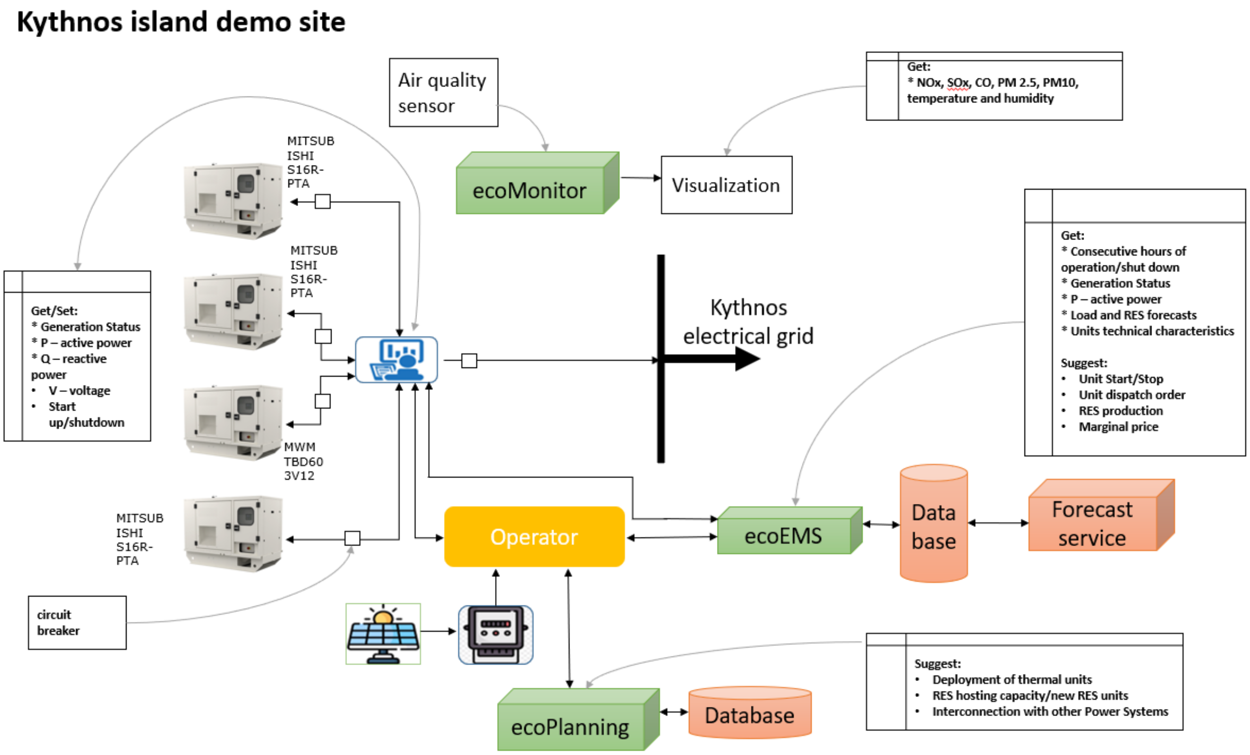


Figure 5. Kythnos power system ecoTools overview.

.Upgrade of existing infrastructure

In Kythnos power system, there is no relevant infrastructure upgrade related to deployment and demonstration activities of RE-EMPOWRED project.

RE-EMPOWERED ecoTools deployment

This section addresses the ecoTools to be implemented in Kythnos power system demo site. The ecoEMS tool is responsible for suggesting the optimized and efficient operation of Kythnos power system, (i.e., optimal dispatch of the generation units of the Kythnos power system). It will consist of 1 hardware component, an industrial PC, which will relate to an executable instance of the tailored software.

	ecoEMS	From	To
		M06	M26
Overall system information	**Function:** Strategy determination **Input Parameters:** Consumptions, Productions, Grid Frequency, Forecasts, Assets Status, Grid Status **Output Parameters:** Suggested set-points to assets, marginal price **Communication protocol:** Ethernet		

	Measurement parameters: Grid Frequency, Active power
Industrial PC	
System information	**Function:** Server **Manufacturer:** // **Model:** // **Communication protocol:** Ethernet **Hardware specifications:** 16GB memory, 5xSATA3 ports or 4xSATA3 + 1xNVMe ports, SSD operating system disk, 4xHDD (1TB each) storage disks, 2xGB Ethernet ports **Software specifications:** Microsoft Windows Server 2019, Microsoft SQL Server 2019, Gurobi solver license

The ecoPlanning tool is responsible for performing simulations that support the decision-making process regarding the deployment of new electricity generation units (conventional and renewable) on the electric systems of NIIs and the interconnection between NIIs.

	ecoPlanning	From	To
		M4	M26
Overall system information	**Function:** Strategy determination **Input Parameters:** RES and load forecast annual timeseries, Assets technical characteristics **Output Parameters:** Set-points to assets, load, annual RES penetration (% of load), maximum instantaneous penetration of Non-Dispatchable RES Units, equivalent full load hours of WPs, diesel consumption, etc. **Communication protocol:** Ethernet **Measurement parameters:** -		
Industrial PC			
System information	**Function:** Server **Manufacturer:** // **Model:** // **Communication protocol:** Ethernet **Hardware specifications:** 16GB memory, 5xSATA3 ports or 4xSATA3 + 1xNVMe ports, SSD operating system disk, 2xHDD (1TB each) storage disks, 2xGB Ethernet ports **Software specifications:** Microsoft Windows Server 2019, Microsoft SQL Server 2019		

The ecoMonitor tool consists of sensors that will be placed at a high school building In Kythnos island, to monitor the air quality.

	ecoMonitor	From	To
		M15	M28
Overall system information	**Function:** Real time monitoring and analysis of ambient air quality parameters **Input Parameters:** Air quality sensors data **Output Parameters:** Processed sensors data **Communication protocol:** Ethernet **Measurement parameters:** CO, NOx, SOx, PM2.5 and PM10 microparticles, temperature, humidity		

UCs analysis and planned actions

In the following, the necessary actions for the installation and testing of ecoTools in Kythnos power system are presented, based on the defined UCs, following the mapping of the UCs for each ecoTool to be tested described in [1]. Based on this mapping, the list of related actions that have to be completed for testing each of the UCs as well as the timeline to be followed, are presented.

I. ecoEMS

Item No.	EMS_2UC1.1: Real time monitoring and system data visualization
EMS_1.1.1	Visualize the data produced by the ecoEMS
EMS_1.1.2	Visualize the data produced by other algorithms and SCADA systems

Item No.	EMS_ 2UC1.2: Module manager: intercommunications and data exchange
EMS_1.2.1	Connect with SCADA systems and other algorithms of the ecoTool set through API and receive the data
EMS_1.2.2	Store the data in the ecoEMS integrated database

Item No.	EMS_ 2UC2.1: Mid-term and short-term RES and load forecasting
EMS_2.1.1	Receive the forecasting algorithm from Work Package 3 to forecast the uncertainties

Item No.	EMS_ 2UC2.2: Forecasting model training
EMS_2.2.1	Feedback the forecasting algorithm of the WP3 for retraining and optimization

Item No.	EMS_ 2UC2.3: Unit Commitment and Economic Dispatch algorithms
EMS_2.3.1	Prepare the UC simulation with input of forecasts and thermal generators
EMS_2.3.2	Run the simulation, send the orders and visualize the output
EMS_2.3.3	Run the economic dispatch simulation, update the orders and visualize the output

II. ecoPlanning

Item No.	PN_1UC1: 7-Year Energy Planning

PN_2UC1.1	Data collection and storage
PN_2UC1.2	Electrical models & demand peak models design, RES & Load estimation
PN_2UC1.3	Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation

Item No.	PN_1UC2: RES Hosting Capacity
PN_2UC2.1	Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds
PN_2UC2.2	Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment.

Item No.	PN_1UC3: Interconnections
PN_2UC3.1	Electrical models, demand peak models & interconnections design, RES & Load estimation
PN_2UC3.2	Hourly Unit Commitment, through optimization algorithm for mid to long term horizon

Item No.	PN_1UC4: Multi-energy vectors
PN_2UC4.1	Energy carriers' identification, data collection and quantification of impact on total load (hourly)
PN_2UC4.2	Electrical models & demand peak design, RES & Load estimation, energy carriers' scenarios integration
PN_2UC4.3	Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers

III. ecoMonitor

Item No.	MON_2UC1.1: Acquisition and transmission of air quality parameters data
MON_1.1.1	Acquisition of air quality parameters such as CO, NOx, SOx, PM2.5 and PM10 microparticles, temperature, humidity
MON_1.1.2	Real time data transmission to other ecoTools

Item No.	MON_2UC1.2: Data processing and evaluation
MON_1.2.1	Real time monitoring and analysis of air quality parameters for further

3.2.1.3 Demonstration planning

The demonstration planning will be divided in two runs. The first run refers to testing demonstration. After the first run, adaptations and adjustments will be performed, leading to the second run, the operational demonstration.

The first run of the demonstration planning will be divided in two levels. The first level will include the demonstration and validation of the stable and continuous operation of the eco Toolsets, later the deployment of the software and hardware, as well as the uninterruptable communication of the tools and the components. The second level will consist of the validation of the advanced functionalities that the RE-EMPOWERED tools facilitate. As ecoEMS, ecoPlanning and ecoMonitor will be deployed and demonstrated in Kythnos power system, the following two tables, accompanied with their own description, concern each ecoTool, respectively. Activities within each run/level need not be performed in sequence.

First demonstration run (testing demonstration)		From M28	To M32
A	Basic Functionality	From M28	To M32
A1	Generation data collection and storage		
A2	Interoperability within ecoTools		
A3	Unit Commitment scenario setup and scenario run		
A4	Energy carriers' identification and quantification at total electricity load		
A5	Power stations and thermal units' identification		
A6	Data collection, inspection and storage		
A7	RES units list identification and data collection		
A8	Electrical models & demand peak models design		
A9	Four types of studies implementation		
A10	Instance deployment		
B	Advanced functionality	From M30	To M33
B1	Continuous online data monitoring		
B2	Automated rolling window Economic Dispatch (every 15 minutes)		
B3	Automated Unit Commitment run on prescheduled time		
B4	Simulation with specific load timeseries is designed and to be implemented		
B5	Updated reports are designed and under implementation		
B6	Real-time air quality monitoring		
Adaptations and adjustments		From M30	To M34
Second demonstration run (operational demonstration)		From M34	To M37
C1	Online secured access		

The basic functionality refers to the basic operation aspects of the grid, the power balance constraint satisfaction, the generation of the thermal units and all the network and technical constraints compliance.

Regarding the communication layer of Kythnos's network components (i.e., generators' production level, load consumption data, observed reserves, marginal cost), the uninterruptable function of the communication systems and the interoperability with other RE-EMPOWERED tools will be verified.

This functionality category also comprises the exact mapping of all the grid components, in order to design and combine two different scenarios: a demand/peak estimation scenario for the desired horizon, and an electrical model scenario which reflects the generation mix that will satisfy the balance constraint, as well as all the technical peculiarities of the system.

Combining other energy vectors such as water treatment through desalination plants or cooling during summertime play critical role in the operation of Kythnos' energy system, so they are addressed in a way to be incorporated in the simulation studies for future growth of the power system, for better management of the energy demand and finally increase the RES capacity. They refer to the pre-process of the infrastructure and finalizes with the first deployment and have test runs in the optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation

Scenario simulation through optimization for 1 year per scenario run.

The advanced functionalities include the principal use cases implemented in Kythnos power system and describe the final status of the ecoEMS to be deployed in Kythnos. Primary goal of the ecoEMS is to continuously monitor the production of each generation unit and the load consumption, as well as the frequency to observe the power quality of the grid. Furthermore, the ecoEMS targets in running automatically and provide at specific predefined time the suggested scheduling of the generation units.

Following the first demonstration run of both tools, a period of 2 months will be dedicated in adaptations and adjustments, based on the feedback of the first run, while the second run of operational demonstration targets at reinsuring the stability of the ecoTool.

The responsibilities of each partner involved in Kythnos island demo site is presented in the following table.

Involved partners	Contributions
ICCS-NTUA	Kythnos demo-site leader. Leading the implementation of ecoEMS and ecoPlanning tools.
DAFNI	Responsible for community engagement and facilitating the communication with local citizens.
CSIR-CMERI	Leading the ecoMonitor activities
PROTASIS	Contributing to the deployment of ecoTools in Kythnos power system

3.2.1.4 Business models, regulatory and social considerations related to deployment and demonstration actions

As in other countries, the energy policies of Greece are aimed at ensuring the security of supply, with a constant and predictable supply, at economic prices, and reducing the greenhouse gas emissions.

In Greece, the first law related to renewable energies was Law 1559/85: Regulation of alternative forms of energy and specific issues of power production. This law allowed third parties to produce a certain amount of electricity from renewable energy sources, although the production was limited to the producer's needs. Any surplus could only be sold to the Public Power Corporation (the public utility in charge of the electricity supply in Greece), and not to third parties. The total capacity of grid-connected renewable energy plants for self-consumption was limited to three times the total installed capacity of equipment for wind, solar and hydro power, and twice the installed capacity for geothermal energy, and the same capacity for cogeneration.

Additionally, Law 1416/84 allowed local governments to produce electricity from renewable energy sources to sell it to the Public Power Corporation.

Law 2689/87, issued in 1987 included criteria for the selection of the sites to develop wind energy, within the boundaries of inhabited areas, uninhabited, rural and industrial areas.

In that year, the Centre for Renewable Energy Sources was created, following the Article 25 of Law 1514/1985 on the Promotion of scientific and technology research. The main objective of this Centre is the promotion of renewable applications and energy efficiency. It also carries out research on the physical, technical and economic potential of these technologies, and certifies them.

The Law 1892/1990 on Economic Development had as objective to modernize, develop and regulate investments for renewable energy production and electricity generation in Greece. It included the creation of subsidies between 40% and 55% of the investment in renewable energy projects, and tax exemptions of 100%. As a result of this law, twelve wind parks with a total power capacity of 90 MW were developed with a funding rate of 40%. Besides, low interest rate loans were offered for solar PV systems.

In 1994, the Second Community Support Framework was launched. It was a subsidy program, which lasted since 1994 to 1999, and offered grants around €92 million to 77 renewable energy investment projects. The grants were around 43% of the total investment cost of projects. The program was very successful to stimulate renewable energy development, especially during the period 1997-2000.

As part of the Second Community Support Framework, the Operational Programme for Energy offered capital cost grants for 125 renewable energy projects (130 MW of wind energy, 72 MW of small hydro, 46 MWh of biomass district heating, 42 MW of CHP of biomass, 5 MWh of other biomass projects, 42 solar central active systems, 8 projects for solar PV systems and 5 projects for passive solar systems). Besides, around 300 projects related to energy efficiency and replacement of fossil fuels and electricity for natural gas in the industry and tertiary sector were approved between 1994 and 2006. The total budget of the Operational Programme for Energy was 340 million € for the period 1994-1999 and 505 million € for the period 2000-2006. Capital grants depended on the technology, being up to 50% for solar PV projects, 30% for onshore wind farms and 40% for small hydro, biomass, geothermal and passive solar. Tax exemptions and reduced interest rate loans were also offered.

The first systematic regulation regarding renewable energies in Greece was Law 2244/94. This law offers incentives to encourage investments in renewable electricity generation. The Public

Power Corporation continued being the only electricity buyer and retailer. Production by self-consumers and independent producers was liberalized up to 50 MW. Self-consumers are also allowed to counterbalance 80% of the electricity produced using renewables with electricity consumption from the grid.

Law 2364/95 created the Board for Energy Planning and Control. Besides, households are offered tax exemptions to buy renewable energy equipment: 75% of the cost of the facility can be deducted from taxable income.

The abovementioned Law 1892/90 on Economic Development was superseded by Law 2601/98 on Economic Development. It continues offering subsidies for renewable energy projects which produce electricity. Depending on the location of the project, subsidies on the investment range from 15% to 40%. Besides, loans at reduced interest rates and tax credits were also offered. Up to 2001, 38 projects had been approved.

Law 2773/99, approved in February 1999 deals with the liberalization of the Greek electricity market. It also offers to renewable energy projects priority access to network dispatching, limited to projects with an installed capacity under 50 MW (10 MW for hydropower). The Transmission System Operator and the Public Power Corporation are obliged to offer connection to new renewable energy generators. Ten-year renewable contracts between independent producers and the System Operator were also signed. The price paid by the Public Power Corporation is composed of an energy and a capacity charge, except for non-interconnected islands, where only the energy charge is paid. This law also included a 2% tax on electricity production from renewables at the local level.

Law 2601/98 on Economic Development was replaced with the New Development Law 3299/2004. This law increases the subsidies to the investment to 20%-40% (depending on the part of the country where the project is carried out, since the country is divided into three zones). The grant can be increased by 10% for medium-scale companies and up to 20% for small ones. Alternatively, a tax exemption of 100% for the cost of the installation was offered.

Law 3468/2006 on Generation of Electricity using Renewable Energy Sources and High-Efficiency Cogeneration of Electricity and Heat and Miscellaneous Provisions was issued in October 2006. It transposed Directive 2001/77/EC of the European Parliament and of the Council of September 27th, 2001, on the promotion of electricity produced from renewable energy sources in the internal electricity market. It is focused on the promotion of wind energy, solar energy, wave energy, tidal energy, biomass, gases coming from landfills and biological treatment plants, biogases, geothermal energy and hydro power plants. The law regulates the authorization of new renewable energy power plants, priority access to the grid for these plants (independently of the installed capacity, except for hydroelectric plants, for which the capacity is limited to 15 MW).

Another important article of Law 3468/2006 is Article 13 Billing of electricity produced by RES plants or through high-efficiency co-generation and in hybrid stations. It defines fixed feed-in tariffs for renewable power plants with a capacity up to 35 MW.

Besides, a photovoltaic development program had to be prepared by the Regulatory Authority for Energy.

In June 2009, Law 3468/2006 was complemented with a new feed-in tariff for small rooftop solar PV systems, up to 10 kWp, for residential users and small companies. This feed-in tariff amounted to €0.55/kWh, guaranteed for 25 years.

Law 3851/2010 Accelerating the development of Renewable Energy Sources to deal with climate change and other regulations addressing issues under the Authority of the Ministry of Environment, Energy and Climate change included ambitious renewable energy targets, which are defined as follows:

1. The share of renewable energy will be 20% of the gross final energy consumption by 2020.
2. The share of renewable electric energy will be 40% of the gross electrical energy consumption by 2020.
3. The share of renewable energy in heating and cooling will be at least 20% of the final energy consumption for heating and cooling by 2020.
4. The share of renewable electric energy in transport will be at least 10% of the gross electricity consumption in transport by 2020.

Besides, a Special Renewable Energy Investment Service was created to act as an interface between public institutions and investors, and to assess the main challenges to renewable energy deployment and manage the support of funding allocation process.

A share of the taxes on renewable energy projects paid by producers to regional and local authorities is allocated to local households, as credits for the electricity bill to share the benefits of living near renewable energy generation plants. Moreover, the licensing process for renewable energy power plants was made easier, and the whole licensing process should have a duration under 30 months. The grid priority access for renewable energy projects disappears, instead, they are given access on a first-come first served procedure until the network is saturated. The grid utility has 4 months to provide access to the grid since it is demanded.

Feed-in tariffs were also defined in Law 3851/2010, including its reduction and review every year.

In 2010, the National Renewable Energy Action Plan was launched. This plan included the path to achieve the 2020 renewable energy targets (as defined in Law 3851/2010), by means of feed-in tariffs, use of solar water heaters in public administration buildings, energy efficiency measures and tax reductions for these projects.

In 2014, a net metering system for autonomous producers was introduced in Greece. This net metering process is described in FEK B' 3583/2014. Besides, "virtual net metering" was introduced in 2016, amending Law 3468/2006. According to it, city and regional councils, schools, universities, farmers and farming associations are allowed to develop solar PV and wind energy projects located at a considerable distance from the place of the actual power consumption.

As described before, since 2006, feed-in tariffs were the main instrument, along with subsidies and tax rebates, to promote renewable energy projects. In August 2016, Law 4414/2016 (amended by Law 4513/2018) changed this mechanism to a feed-in premium. This involves that, instead of receiving a fixed price for the electricity, producers receive an additional remuneration to the price of the electricity in the markets. Therefore, producers have to participate in the wholesale electricity markets, either directly, or through renewable energy aggregators, and to take some balancing responsibilities. Wind farms up to 3 MW and other renewable energy power plants up to 500 kW continue receiving feed-in tariffs.

Feed-in premiums are awarded to renewable and CHP plants through technology-specific auctions. Auctions have been called with a specific capacity for each technology since 2017.

Law 4513/2018 introduced the concept of energy communities in Greece as a step towards energy democracy. The law aims to enable local actors (citizens, municipalities, local businesses, universities etc.) to get actively involved in the clean energy transition with some special provisions for islands.

The targets of renewable energy penetration defined in the National Renewable Energy Action Plan and Law 3851/2010, dating back to 2010, were reviewed and updated in the National Energy and Climate Plan, from 2020. These objectives are as follows:

1. The share of renewable energy will be at least 35% of the final energy consumption by 2030.
2. The share of renewable electric energy will be at least 60% of the gross final electricity consumption by 2030.
3. The share of renewable energy in heating and cooling needs to exceed 40% of the final energy consumption for heating and cooling by 2030.
4. The share of renewable energy in transport sector should exceed 14% of the gross energy consumption in transport by 2030.
5. Reduction of greenhouse gas emissions by 40% in 2030 compared to 1990, or 55% compared to 2005 levels.

To reach these objectives, competitive tenders will be called periodically for commercially mature renewable energy technologies. Besides, these technologies are obligated to participate in the market. Specific renewable energy projects can be supported with grants, especially high domestic added value pilot projects. Finally, licensing procedures should be simplified and optimized.

In particular, Law 4685/2020 includes the producer's certificate issued by the Regulatory Authority for Energy, trying to simplify the process of obtaining the licensing for power plants.

In Kythnos, there is not specific regulation apart from the general Greek regulation described before.

Although Kythnos has a large renewable energy potential, as a not-interconnected island, the integration of these power plants is limited due to the seasonality of demand, the absence of storage, and technical restrictions due to the variability of wind and solar PV. In Kythnos, the share of solar PV energy is 4% of local energy production. No more solar PV plants are currently allowed to be developed right now.

As for prices, in Kythnos the electricity price is the same as that for continental inhabitants, although the generation cost is considerably higher.

The electricity market in Greece is liberalized. However, in Kythnos, the electricity price is partially subsidized, to ensure that all Greek consumers pay the same. The electricity tariff for consumers depends on the supplier, the level of contract, and the contract chosen.

In Kythnos, there are issues regarding the reliability of supply since there are some blackouts. The reason for this is mainly the sharp increase of demand in summer, due to the touristic activity. This demand is mainly covered with natural gas turbines which can be moved from one island to another.

One of the objectives of the pilot sites is to try to improve the system average interruption frequency index (SAIFI) and the system average interruption duration index (SAIDI), as well as the protection of the grid against extreme weather conditions.

Regarding social considerations, citizens-led energy initiatives have not been developed in the Kythnos island. This would be possible under Law 4513/2018, on energy communities. The pilot site is already being supported by important stakeholders, such as the Municipality of Kythnos and commercial associations.

One of the objectives of the RE-EMPOWERED projects is, indeed, the development of energy communities in the island, involving local authorities, local citizens, and businesses to maximize the local benefit, and to accelerate the clean energy transition of Kythnos, being socially inclusive.

Regarding obstacles, in Kythnos there exists a lack of specialized professionals in the island. Besides, it is feared that local community will have a reduced participation in decision-making processes.

Threats for the development of the pilot site include the high transportation cost, and installation cost, and the lack of economies of scale in the project. The regulatory framework for the demand side is not appropriate. Finally, the installed equipment can be affected by high salinity and humidity. There are also some clean energy transition issues for local communities (e.g., gas stations).

3.2.2. Gaidouromandra Microgrid

3.2.2.1 General description – Existing Infrastructure

Gaidouromandra is a small territory at the southeast of Kythnos as shown in Figure 6. Gaidouromandra operates first microgrid in Europe, installed in 2001 in order to electrify 14 vacation houses. The deployment of the microgrid system is a result of several European projects.

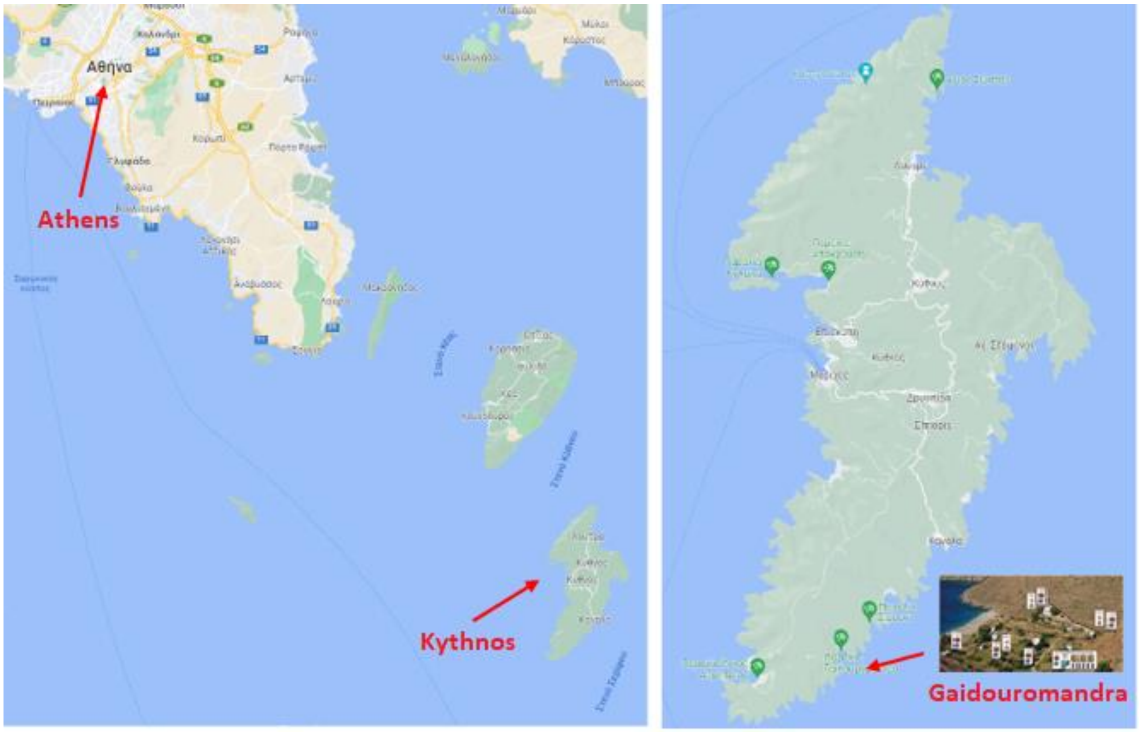


Figure 6. Kythnos and Gaidouromandra.

The microgrid operates autonomously and provides electric power to 14 vacation houses, from several distributed energy resources (DER), consisting of PVs (rooftop and ground mounted), a battery energy storage system (BESS) and a diesel generator (as a back-up source). 3-phase low voltage overhead AC power lines (operating at 230 V) are used to connect the various buidings of the microgrid, as well as a communication cable (RS 485) running parallel to power lines. The low voltage system is formed by the battery inverters. Some of the houses in Gaidouromandra are equipped with a water pump, which is responsible for replenishing a water tank and in this way supplying water to the household. In addition, the residents use the water for some small-scale agricultural activities and gardening. The two energy carriers can be combined and co-optimized for the efficient operation of the local energy system.

Generation & Storage

The “center” of the microgrid is the “System House”, a building constructed to house the BESS, the diesel generator, the grid forming inverters and all the computer and communication equipment used to monitor the grid. The rooftop of the system house is used for the installation of PVs. The microgrid structure is shown in Figure 7.

Grid components	
PV installations	System House: 1.920kWp (2X16 Solarex MSX60) connected to 3 inverters (3X SMA SB 1100)

	H4: 1.920kWp (2X16 Solarex MSX60) connected to 2 inverters (2X SMA SB 1100)
	H5: 1.200kWp (2X10 Solarex MSX60) connected to 1 inverter (SMA SB 1100)
	H7: 2.025kWp (9 Suntech STP225-20/WD) connected to 1 inverter (SMA SB 1700)
	H8: 1.920kWp (2X18 Solarex MSX60) connected to 1 inverter (SMA SB 2500)
	H10: 2.160kWp (2X18 Solarex MSX60) connected to 1 inverter (SMA SB 2500)
Battery system	OPzV (VRLA GEL) battery bank with nominal capacity 11900Ah/48V, connected through 3 single phase battery inverters (SMA SI5048)
Diesel generators	22 kVA generator: PETROGEN P22E, with STAMFORD generator and PERKINS 404A-22G engine

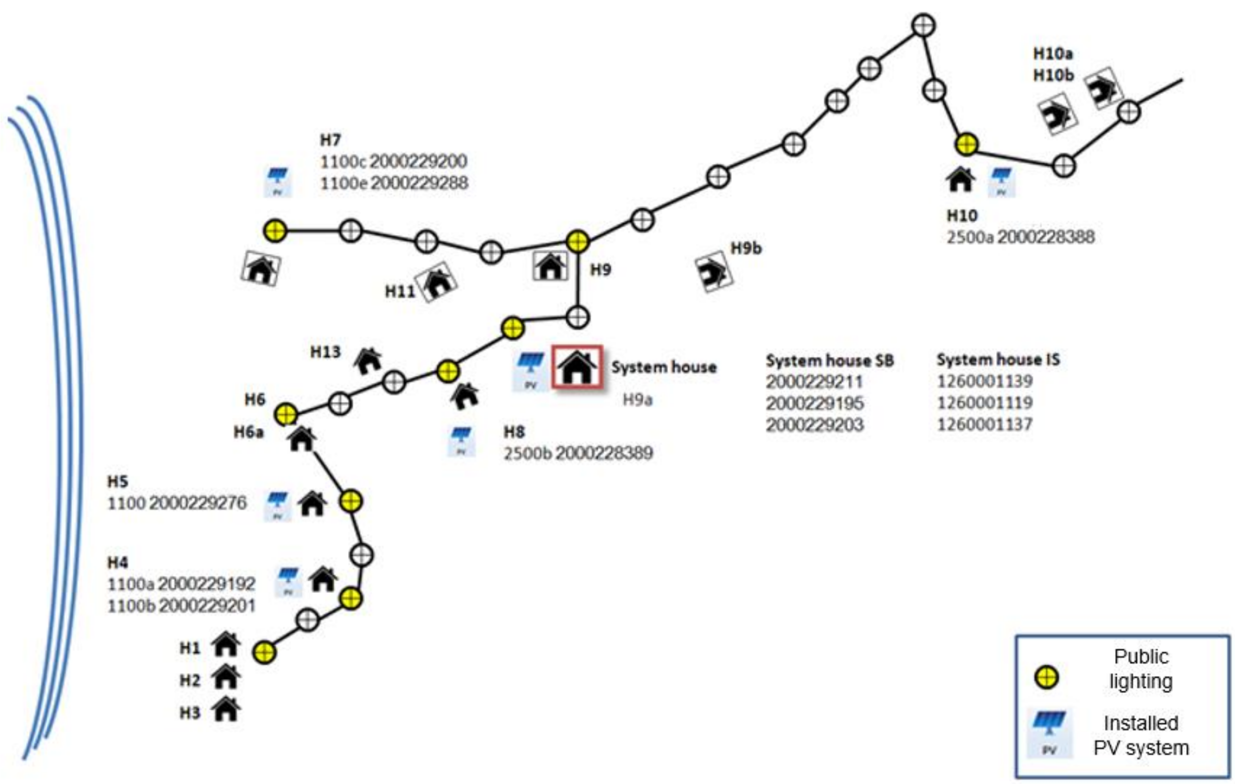


Figure 7. Microgrid structure.

The BESS is installed in the system house. The principal goal of the BESS is to maintain the continuous power supply mainly without the diesel generator participation in the system.

One of the vacation Houses (H7) has additionally installed a Flexmax charger from OutBack, for coupling batteries and PVs in a common DC bus, while it performs the maximum power point tracking algorithm of PVs. Moreover, a Xtender (XTM 3500-24) inverter from Ateca, is used to either connect the BES/PV system to the existing AC microgrid or to form the voltage waveform if an outage in the main microgrid supply occurs. The total storage capacity is 24V/460Ah.

Communication & Control

The main communication physical infrastructure of the microgrid are RS-485 cables.

The monitoring equipment of the microgrid initially consisted of 3 subsystems as described below.

Monitoring equipment	
Energy counters	Single-phase enegy counters at every house, PV plant, public lighting and 3-phase multifunctional meters at BESS and generators. The collected metering data are transferred via LON-bus (Local Operating Network) to system house PC equipped with LON interface to collect and store the metering data.
SMA WEBBOX	WEBBOX monitoring, connected with the inverters and logging parameters of PVs and BESS, as well as some meteorological data
Power quality analyzer	HAAG monitoring for power quality measurements at system house. Values measured: AC voltages & AC currents

The current structure of the microgrid, including power & communication cables is presented in Figure 8.

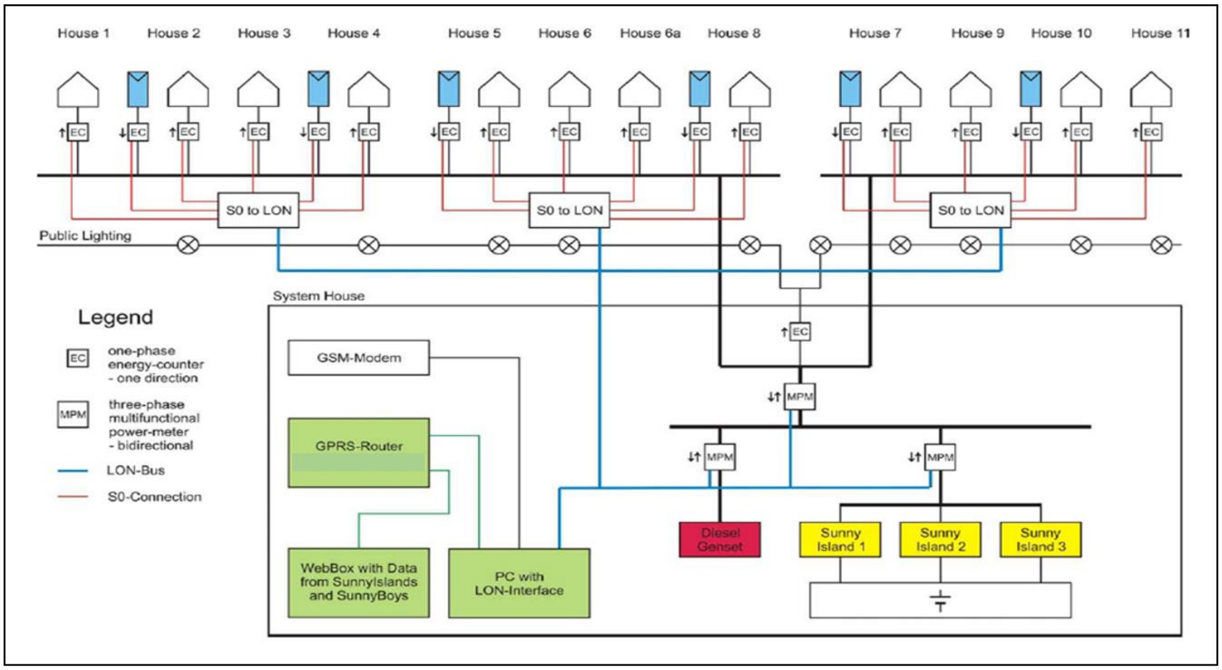


Figure 8. Microgrid's current structure.

The energy counters system, as well as the power quality analyzer, have been developed in the context of a pilot project and are currently out of order.

Additionally, intelligent load controllers (ILC) and a MGCCs had been installed in Gaidouromandra but are not currently in operation. ILCs control noncritical loads (ex. water pumps) using decentralized technologies, like Multi-Agent Systems, featuring Wi-Fi interface to connect to the MGCC, that is responsible for monitoring the operation of the microgrid. The ILCs exchange messages via Wi-Fi to negotiate the level of consumption according to the batteries' state of charge (SOC) and solar production, without receiving set-points form MGCC. This is one of the first applications of decentralized apply negotiation messages to adjust the coordination of the ILCs. MGCC gathers data for consumption and production from ILCs, PV and battery inverters, to achieve restoration of voltage & frequency mitigations, control the noncritical loads and start the diesel generator, if necessary.

3.2.2.2 Deployment planning

Figure 9 represents the target for Gaidouromandra's microgrid in Kythnos island after implementation of RE-EMPOWERED project's toolbox, taking also into consideration the actions during national project KSI.

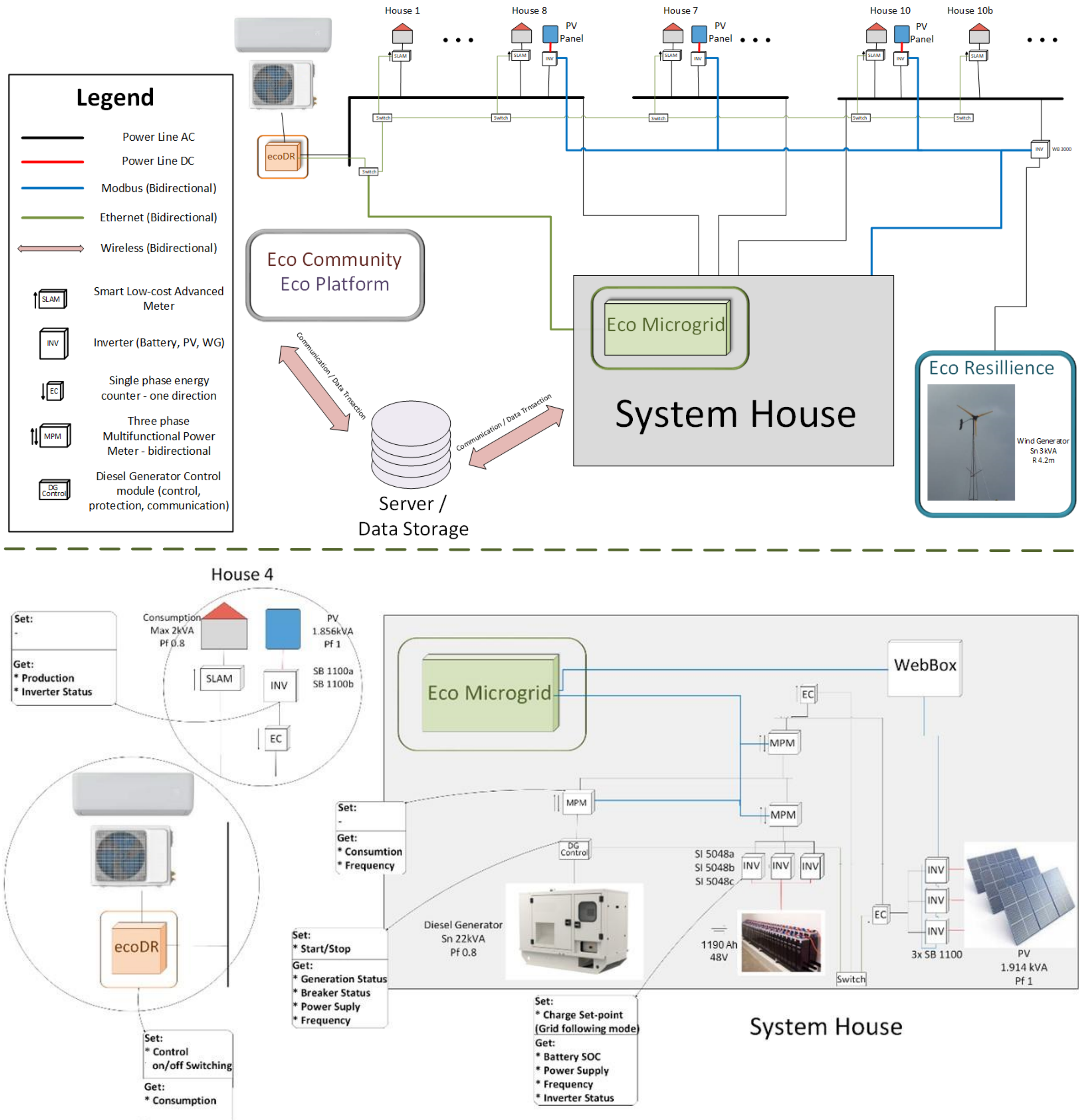


Figure 9. Target for Gaidouromandra Microgrid: a) Microgrid overview b) Crucial microgrid components.

Upgrade of existing infrastructure

Several upgrades of the Microgrid will take place in the context of the national KSI project which is on-going. They include the renewal of some of the previously described equipment. Below are the information sheets for the equipment to be installed, regarding assets renewal and communication network upgrades which are planned under the KSI project.

	New PV System	
System information	**PV at house**	**Nominal Power**
	System House	~6kW
	House 10	~6kW
	House 8	~4kW
	Total	**16 kW**
PV panels information	**Manufacturer(s):** SUNTECH **Model(s):** STP225-20/Wd 225 Wp	
Inverter(s) type	**Manufacturer:** SMA **Model(s) / Number:** SB 5.0 , SB 3.0 **Nominal Power:**	
Communication Protocol	Ethernet, RS485, Modbus RTU, Modbus TCP/IP	
Measurement Parameters	Active power, Apparent power, Reactive power, Energy, Current, Voltage, frequency, Power Factor, DC Voltage, DC Current, DC Power, Modbus RS-485, Ethernet	
Control Parameters	Max production setpoint	

	New Battery System (installed July 2022)
System information	**Storage Energy:** 96 kWh **Number of cells/ system Voltage:** 48 cells / 48V **Type of Technology:** Valve Regulated Tubular Plate GEL Batteries
Battery information	**Manufacturer:** SunLight **Model:** RES SOPzV 1190Ah (C120)
Inverter(s) type	**Manufacturer:** SMA **Model:** SI 5048 **Number of Inverters:** 3
Communication Protocol	Ethernet, RS485, Modbus RTU
Measurement Parameters	Active power output, Reactive power output, Voltage, AC Current, DC Current, SOC, Battery Temperature
Control Parameters	Battery Inverter operation mode (forming, following), Charge and Discharge set-point, Generator start/stop
Logging rate	1 min

The upgrade of communication network facilities is a necessary work for Gaidouromandra pilot site. Ethernet network must be added, in order to ensure a more reliable communication infrastructure for all new equipment.

	Ethernet network
System information	**Meters:** 3.5 km **Cable Type:** Cat 7, S/FTP

	Digital relays
System information	**Type:** Feeder protection relays **No. of digital relays:** 3 **Installed at:** System house
Relays information	**Manufacturer:** SEL **Model:** SEL-751
Communication Protocol	SEL, EtherNet/IP, firmware-based IEEE 1588 PTP, Modbus TCP/IP, Modbus RTU, DNP3, FTP, IRIG-B, Telnet, SNTP, IEC 61850 Edition 2, IEC 60870-5-103, the Parallel Redundancy Protocol (PRP) for dual-Ethernet models, Mirrored Bits communications, and IEEE C37.118-2005 (synchrophasors).
Measurement Parameters	Instantaneous, Light, Analog Inputs, Energy, Math Variables, RMS, Remote Analogs, Thermal, Demand and Peak Demand, Synchrophasors, Max/Min, HIF (High-Impedance Fault)
Control Parameters	Protection Control functionalities, Monitoring

	Energy meters & load controllers (SLAMs)
System information	**Type:** Smart meters **Installed at:** houses
Energy meters information	**Model:** SM10 **Manufacturer:** Grupo Etra
Communication Protocol	Modbus RTU, Modbus TCP/IP, MQTT
Measurement Parameters	Active power output, Reactive power output
Control Parameters	Under Frequency Load Shedding, Remote Control
Logging rate	1 min

In order to optimize the Microgrid operation, to deploy protection schemes, recordings from the RES, BESS and loads and remote monitoring of the Microgrid, will be used. Protection, measurement and logging services will be handled by three 3x feeder relays that perform many functionalities. Such as protection against short circuits, load shedding to avoid overloads and extensive discharge of the batteries, with under frequency functionalities or communication-based schemes.

An MGCC will control these units in order to perform those functionalities. In Gaidouromandra, the ecoMicrogrid tool will have the role of the MGCC. Furthermore, in an islanded microgrid, like Gaidouromandra, that might have no residents at certain periods throughout the year, it is important to have a remote monitoring system that allows the microgrid operator to identify any possible problems, from malfunctions of specific equipment (e.g., PV inverter) to a microgrid outage.

Also, Energy meters & load controllers (SLAM) will be installed at each house. SLAM's functionality has been extended with additional services, such as:

- Under-frequency load shedding functionality.
- Remote control of the internal switch for harmonized operation with the MGCC

RE-EMPOWERED ecoTools deployment

This section addresses the ecoTools to be implemented in Gaidouromandra site.

ecoDR is a tool that offers monitoring, load shedding based on flexible loads and implements demand response techniques. It will control a flexible load, most likely an air conditioning system located at the System House, where the battery system is installed.

	ecoDR	From	To
		M24	M28
Overall system information	**Function:** Measurement of energy consumption, transmitting time stamped energy data and control of non-critical loads **Input Parameters:** Control commands **Output Parameters:** On/off signal **Communication protocol:** MODBUS, Ethernet, DLMS, MQTT **Measurement parameters:** Power consumption		
Air Conditioning System			
System information	**Manufacturer:** TBD **Model:** TBD **Nominal Power:** ~ 2.5 kW **Starting method / starting current:** **Usage frequency (per day, week):** 8-10 h/day **Energy consumption estimated (per day, week):**		
Communication Protocol	//		
Measurement Parameters	//		
Control Parameters	Power State (ON, OFF), Temperature (Power)		
Logging rate	//		

ecoMicrogrid tool is responsible for the optimized and efficient operation of Gaidouromandra microgrid, (e.g. optimal dispatch of the resources of the microgrid). It will be placed inside the system house. ecoMicrogrid will consist of hardware components, suitable software etc. A possible implementation of ecoMicrogrid, subject to change based on the Task 4.1 work, is presented below.

<table>
<tr><th rowspan="2"></th><th rowspan="2">ecoMicrogrid</th><th>From</th><th>To</th></tr>
<tr><th>M15</th><th>M28</th></tr>
<tr><td>Overall system information</td><td colspan="3">Function: Strategy determination
Input Parameters: Consumptions, Productions, Grid Frequency, Forecasts, Assets Status, Grid state, etc.
Output Parameters: Set-points to assets, grid’s elements etc.
Communication protocol: Modbus, Ethernet, MQTT
Measurement parameters: Voltage, grid Frequency, Current, Active power, Reactive Power</td></tr>
<tr><td colspan="4">Industrial PC</td></tr>
<tr><td>System information</td><td colspan="3">Function: Server
Manufacturer: //
Model: //
Communication protocol: Ethernet
Hardware specifications: ≥32GB memory, ≥5xSATA3 ports or 4xSATA3 + 1xNVMe ports, SSD operating system disk, 4xHDD (1TB each) storage disks, 2xGB Ethernet ports
Software specifications: Microsoft Windows Server 2019, Microsoft SQL Server 2019</td></tr>
<tr><td colspan="4">Real-Time Automation Controller</td></tr>
<tr><td>System information</td><td colspan="3">Function: Real-Time Control and Logic Processing
Manufacturer: SEL
Model: SEL-3505
Communication protocol: HTTPS, SSL/TLS, SSH, DNP3 Serial, DNP3 LAN/WAN, Modbus RTU, Modbus TCP, SEL ASCII, SEL Fast Messaging, LG 8979, IEEE C37.118, CP2179, SNMP, SES-92, CDC Type II, Courier, IEC 60870-5-103, EtherNet/IP Explicit Message Client, DNP3 Serial, DNP3 LAN/WAN, Modbus RTU, Modbus TCP, SEL Fast Messaging, LG 8979, SES 92, IEC 61850 MMS, IEC 60870-5-101/104, IEEE C37.118, FTP, SFTP, CDC Type II, EtherNet/IP Implicit Message Adapter, IEEE-61850 GOOSE, SEL MIRRORED BITS Communications, Network Global Variables (NGVL), Parallel Redundancy Protocol.</td></tr>
</table>

ecoResilience tool concerns the locally manufactured residential wind turbine. The goal is to increase the power capacity of the wind turbines, while also considering extreme weather conditions, e.g., storms and wind fires. In Gaidouromantra microgrid the wind turbine part will be deployed (on a regular mounting structure), while in Ghoramara island in India the full functionality of ecoResilience (i.e. wind turbine and resilient mounting structure) will be deployed.

	ecoResilience (W/T system)	From	To
		M12	M18
Overall system information	**Function:** Resilient diversification of energy mix **Input Parameters:** Wind speed and W/T system rated power **Output Parameters:** Wind energy production **Communication protocol:** Ethernet **Measurement parameters:** Real power, Apparent power, Reactive power, Energy, Current, Voltage, Grid frequency, Power Factor		
Wind Turbine			
System information	**Function:** Power generation **Manufacturer:** Locally manufactured at NTUA **Description of the construction:** 4.34m rotor diameter, Horizontal axis three blade wooden rotor, Constant pitch angle, Passive gravity furling tail system **Type:** Variable speed machine, Coreless axial flux permanent magnet generator, Double rotor single stator configuration **Nominal Power:** 3kW @ 11m/s		
Inverter(s) type			
System information	**Manufacturer:** Magnetek/PowerOne/ABB **Model:** Aurora PVI-3.6-OUTD-W		
Communication Protocol	Ethernet		
Measurement Parameters	Real power, Apparent power, Reactive power, Energy, Current, Voltage, Grid frequency, Power Factor		
Control Parameters	Active power limitation as function of grid frequency		
Logging rate	1 min		
Protection			
System information	**Function:** Overvoltage Protection and Dump Load info **Type:** PVI-7200-Wind interface, 5kW, 69Ω		

ecoPlatform tool will be a cloud-based platform collecting and managing the data from Gaidouromandra site.

	ecoPlatform	From	To
		M15	M28
Overall system information	**Function:** Integration of eco tools and ensure interoperability, acquire data from various sources and serve as data storage on a cloud platform		

	Input Parameters: air quality data, consumption and production, of assets on Gaidouromandra demo site, forecasts of load and renewable generation **Output Parameters:** Make the input parameters available to other tools, visualize some of the data of Gaidouromandra demo site **Communication protocol:** Internet – MQTT or HTTPS **Measurement parameters:** Not installed locally

ecoCommunity tool will be a digital platform for raising citizen engagement.

	ecoCommunity	From	To
		M15	M28
Overall system information	**Function:** Display energy consumption and dynamic energy prices to the consumers. Generate consumer bills, and bill payment portal. Scheduling and coordination of flexible non-critical loads and shared loads Community engagement through forums, feedback, and problem reporting portals. Community support through training materials and guides. **Input Parameters:** Energy price, Energy consumption, Available booking time slots **Output Parameters:** Booked Time Slots, visualization of various functions **Communication protocol:** Internet, API **Measurement parameters:** None locally		

UCs analysis and planned actions

In the following, the necessary actions for the installation and testing of ecoTools in Gaidouromandra Microgrid are presented, based on the defined UCs. In [1], the mapping of the UCs for each ecoTool to be tested has been performed. Based on this mapping, the list of related actions that have to be completed for testing each of the UCs as well as the timeline to be followed, are presented.

I. ecoMicrogrid

Item No.	MG_2UC1.1: Real time microgrid monitoring and data acquisition
MG_1.1.1	Installation of necessary software for the configuration of the metering devices
MG_1.1.2	Configuration of metering devices
MG_1.1.3	Interoperability between metering devices and ecoDR, Data Concentrator/Microgrid Operator
MG_1.1.4	Testing the operation of the monitoring system and assessment

Item No.	MG_2UC1.2: RES production estimation
MG_1.2.1	Parametrization of the RES production estimation algorithm
MG_1.2.2	Gathering historical weather data
MG_1.2.3	Testing the forecast data and assessment

Item No.	MG_2UC1.3: Data concentration, storage, and management
MG_1.3.1	Configuration of monitoring devices to log the measured data
MG_1.3.2	Setup of the industrial PC responsible for the data storage
MG_1.3.3	Establishment of communication between monitoring devices, PV inverters and Data Concentrator/Microgrid Operator
MG_1.3.4	Establishment of communication/data transaction between server and Data Concentrator/Microgrid Operator
MG_1.3.5	Testing and assessment of data concentration, storage, and management

Item No.	MG_2UC2.1: Effective communication with controllable assets
MG_2.1.1	Design of the communication scheme, according to recommended protocols
MG_2.1.2	Establish interoperability between devices and Microgrid Operator
MG_2.1.3	Test the effective delivery of commands to controllable assets and assessment

Item No.	MG_2UC2.3: Multi-energy vector microgrid management of operation
MG_2.3.1	Determination of the energy vectors
MG_2.3.2	Determination of the operational, security and availability constraints
MG_2.3.3	Design of the management algorithm for the most efficient and economic operation
MG_2.3.4	Test the operation of the management system and assessment

II. ecoDR

Item No.	DR_2UC1.1: Real time monitoring of energy consumption
DR_1.1.1	Installation of necessary software for the configuration of the metering devices
DR_1.1.2	Configuration of metering devices
DR_1.1.3	Implementation of energy monitoring also having features suitable for communication with ecoMicrogrid
DR_1.1.4	Testing the data acquisition process and assessment

Item No.	DR_2UC1.2: Dynamic pricing-based energy cost computation
DR_1.2.1	Timestamping the energy consumption data
DR_1.2.2	Transmitting the time stamped data to ecoMicrogrid

Item No.	DR_2UC2.1: Scheduling of loads
DR_2.1.1	Receiving the ON/OFF command table from ecoMicrogrid
DR_2.1.2	Turning the switches/relays ON/OFF

III. ecoPlatform

Item No.	PF_2UC2.1: Facilitate data exchange between dependent tools
PT_2.1.1	Communication interoperability from different sources such as smart meters or ecoMicrogrid/ecoEMS to obtain measurements from RES and demand
PT_2.1.2	Establishing communication
PT_2.1.3	Online data collection
PT_2.1.4	Data storage
PT_2.1.5	Ensure consistent data – raw data cleaning and filtering
PT_2.1.6	Exchange of data between different tools

Item No.	PF_2UC3.1: Route the microgrid data and data from dependent tools to cloud database
PT_3.1.1	Storing the data in the cloud

Item No.	PF_2UC3.2: Facilitate archived data access for dependent tools using API
PT_3.2.1	Provide an API for other tools to access the storage

IV. ecoCommunity

Item No.	CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile
CM_1.1.1	Implementation and integration of energy pricing display module in ecoCommunity mobile application.
CM_1.1.2	Identify the range of energy prices associated with the tri-color coded representation.
CM_1.1.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the real-time/ forecasted energy pricing data.
CM_1.1.4	Testing and deployment of the module.

Item No.	CM_2UC1.2: Billing and payments
CM_1.2.1	Develop various consumer categories and their associated energy plans for the calculation of bills.
CM_1.2.2	Implementation and integration of billing module in ecoCommunity tool to generate and bills for each billing cycle.
CM_1.2.3	Implementation and integration of bill history module with ecoCommunity mobile application to display the bills for previous billing cycle.
CM_1.2.4	Implementation and linking of consumer user accounts with various ecoDR devices.
CM_1.2.5	Establish communication with ecoPlatform and ecoDR for sharing energy consumption data of the consumers to generate bills.
CM_1.2.6	Implementation and integration of payment gateway for the payment of bills using various payment options.
CM_1.2.7	Testing and deployment of the module.

Item No.	CM_2UC1.3: Data security and privacy

CM_1.3.1	List out the personal and sensitive information required for creating consumer user profile.
CM_1.3.2	Create a minimal data model based on IEC-62746-10-1 for the personal and sensitive information of the users.
CM_1.3.3	Implement the minimal data model on the secure cloud database of the ecoCommunity tool

Item No.	CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads
CM_2.1.1	Identify and categorize the various non-critical/flexible loads at demo site.
CM_2.1.2	Implementation and integration of slot booking module with ecoCommunity mobile application to book time slots for the flexible loads.
CM_2.1.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the available time periods for connecting the flexible loads.
CM_2.1.4	Testing and deployment of the module.

Item No.	CM_2UC2.2: Coordination of communal/shared loads
CM_2.2.1	Identify the various communal/shared loads at demo site.
CM_2.2.2	Implementation and integration of load booking module with ecoCommunity mobile application to book shared load.
CM_2.2.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the available time periods for connecting the shared loads and sending the estimated loading pattern based on booking
CM_2.2.4	Testing and deployment of the module.

Item No.	CM_2UC3.1: Feedback and suggestions from users about the tools
CM_3.1.1	Preparation of feedback questionnaire based on the tools installed/ deployed at the demo site.
CM_3.1.2	Implementation and integration of questionnaire and suggestions module in ecoCommunity mobile application.
CM_3.1.3	Testing and deployment of the module.

Item No.	CM_2UC3.2: Reporting of problem
CM_3.2.1	Identifying the various problem categories and preparation of problem reporting form for the demo site.
CM_3.2.2	Implementation and integration of problem reporting module in ecoCommunity mobile application.
CM_3.2.3	Testing and deployment of the module.

Item No.	CM_2UC3.3: Forum to share experiences
CM_3.3.1	Identifying the various forum topic categories relevant to the demo site.
CM_3.3.2	Implementation and integration of forum module in ecoCommunity mobile application.
CM_3.3.3	Testing and deployment of the module

Item No.	CM_2UC4.1: Training material (troubleshooting)
CM_4.1.1	Collecting the various service manuals and training materials associated with the installations from ecoTool leaders
CM_4.1.2	Categorizing the collected service manuals and training materials based on type and application.
CM_4.1.3	Uploading the documents to the common database and integration of the module with ecoCommunity mobile application.

Item No.	CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)
CM_4.2.1	Coordination of the ecoTool leaders for the preparation of necessary multimedia materials for the various ecoTools
CM_4.2.2	Preparation of step-by-step guides for using the various modules of ecoCommunity tool
CM_4.2.3	Collecting and categorizing the various multimedia materials for the demo-site.
CM_4.2.4	Uploading the documents to the cloud database and integration of the module with ecoCommunity mobile application.
CM_4.2.5	Creation of administrative user login for the ecoTool leaders for any future creation or updating of the materials.

V. ecoResilience

Item No.	RS_1UC3: WT Local Manufacturing and Testing
RS_3.1.1	Study for the connection of Wind Turbine on the existing Gaidouromandra's grid.
RS_3.1.2	Wind Turbine tower installation works.
RS_3.1.3	Wind Generator and blades manufacturing.
RS_3.1.4	W/G permanent placement at Gaidouromandra as well as inverter and cables (power & communication) installation.
RS_3.1.5	Establish interoperability between W/T (inverter) and ecoMicrogrid.

3.2.2.3 Demonstration planning

The demonstration planning will be divided in two runs. The first run refers to testing demonstration. After the first run, adaptations and adjustments will be performed, leading to the second run, the operational demonstration.

The first run of the demonstration planning will be divided in two levels. The first level will include the demonstration and validation of the stable and continuous operation of the microgrid, later the deployment of the software and hardware, as well as the uninterruptable communication of the tools and the components. The second level will consist of the validation of the advanced functionalities that the RE-EMPOWERED tools facilitate, such as the optimization of the microgrid operation, the demand response activation, the flexible loads participation. Activities within each run/level need not be performed in sequence.

First demonstration run (testing demonstration)		From M28	To M32
A	Basic Functionality	From M28	To M32
A1	Continuous supply to all end customers (security of supply)		
A2	Frequency / Voltage stability		
A3	Battery System charge / discharge		
A4	Start / supply / stop of the diesel generator		
A5	Active/reactive power control of PV generators		
A6	Uninterruptable operation of the communication systems		
A7	Connection / disconnection of loads		
A8	Consumption data collection and storage		
B	Advanced functionality	From M30	To M33
B1	Microgrid optimal management of operation		
B2	Increased energy monitoring at demand side		
B3	Platform as a service for dependent tools integration		
B4	Data storage and cloud server		
B5	Interoperability between Wind Turbine (inverter) and ecoMicrogrid		
Adaptations and adjustments		From M30	To M34
Second demonstration run (operational demonstration)		From M34	To M37
C1	ecoMicrogrid operation & communication		
C2	ecoDR energy monitoring, control & communication		
C3	ecoPlatform operation & communication		
C4	ecoResilience operation & communication		
C5	Dynamic pricing of electricity		
C6	Scheduling and Coordination		
C7	Outreach forum of ecoCommunity		
C8	Guidance and Training		

The basic functionality refers to the basic operation aspects of the grid. Crucial factors to be checked will be the continuous supply to all end customers (or at least achieve supply time higher than prior to the tools implementations) and the frequency / voltage stability (between the limits set by the standards). Vital for the long-term stable operation of the microgrid is the state of the Battery System. Therefore, the SOC of the system will be monitored to verify that it remains between the desirable limits and therefore avoiding fast degradation. The continuous supply to the end customers, as well the battery system lifetime, depends to a large extent on the efficient start / supply / stop of the diesel generator. Therefore, the appropriate operation of the diesel generator will be examined. In addition, the microgrid management requires the controllability of loads. Flexible loads can be controlled to meet specific goals, while non-critical and critical loads can be disconnected in case of emergency with different priority. Thus, load controllability has to be examined.

Regarding the communication layer of the microgrid, the uninterruptable function of the communication systems and the RE-EMPOWERED tools will be verified, along with the efficient consumption data collection and storage.

The advanced functionality, as described in the aforementioned table, includes the principal use cases implemented in Gaidouromandra microgrid. Primary goal of the advanced functionalities is the real-time monitoring of the microgrid. The main aspects to be tested will be the data acquisition of the various components of the microgrid by ecoMicrogrid, the effective communication with the controllable assets and the delivery of the appropriate signals, for the increased energy monitoring at the demand side. The optimal management of the microgrid is strictly linked to the battery system stable operation and control. The control of the battery system will be performed by under frequency load functionality and over frequency PV shedding.

The active participation of prosumers is important for the optimal operation of a microgrid. To achieve higher engagement, suitable events will be organized to inform and familiarize the locals with the use of the new tools and the Outreach forum use and materials.

The end of the first demonstration run will be followed by 1-2 months period of adaptations and adjustments, based on the notices and data collected during the first run of inspection.

Subsequently, the second run of operational demonstration will be carried out, ensuring the proper and stable operation of the microgrid, as well as the optimal function of the ecoToolset.

The responsibilities of each partner involved in Gaidouromandra demo site is presented in the following table.

Involved partners	Contributions
ICCS-NTUA	Kythnos demo-site leader. Leading the implementation of ecoMicrogrid and the Wind Turbine deployment/demonstration under ecoResilience.
PROTASIS	Leading the provision and setting up of the necessary hardware for the ecoMicrogrid tool and communication with ecoDR and other infrastructure
DAFNI	Responsible for community engagement and facilitating the communication with local citizens. Facilitating the implementation of the ecoCommunity tool.
ICL	Leading the implementation of the ecoCommunity tool
DTU	Leading the implementation of the ecoPlatform tool
CSIR-CMERI	Leading the ecoDR activities

3.2.2.4 Business models, regulatory and social considerations related to deployment and demonstration actions

The regulation for renewable energies in the Gaidouromandra demo site is the same which applies to Greece and has been described in high detail in the Kythnos power system description.

In Gaidouromandra, the electricity cost is limited, and covers the maintenance cost, other costs and the purchase of fuel. In turn, the tariff does not include the power fixed term.

As in the case of the Kythnos demo site, there are some issues related to security of supply. Some blackouts and voltage drops can happen, even more in Gaidouromandra. It has to be considered that in summer, due to the high number of tourists who visit the demo site, there is a sharp increase in demand. These problems will be solved as soon as a new generator replaces the existing one. The installation of the new battery system is expected to improve the reliability of the microgrid.

In general, consumers are not happy with the electricity prices, since they are going up, in all Greece.

The biggest problem in the operation of the Gaidouromandra microgrid is the overload of batteries, since the maximum demand of many houses appear at the same time. For this reason, users have been accustomed to a grid-oriented energy culture, instead of a culture of autonomous energy supply. One of the objectives of the demo site is to adapt technical and behavioral demand response techniques to the microgrid, to manage energy efficiently. A Microgrid Management System will be also developed for optimal microgrid operation.

If the weaknesses of the Gaidouromandra pilot site are analyzed, it is necessary to note the possibility of component failure, the lack of appropriate maintenance, possible dissatisfaction of the customer, the lack of an appropriate business model, lack of citizen engagement and lack of backup generation.

There are threats related to environmental licensing complexity concerns due to the proximity of the shoreline, land and infrastructure ownership issues, and site-specific resource utilization concerns.

3.3 Ghoramara

Ghoramara Island is located between 21° 53′ 56″ N to 21° 55′ 37″ N latitude and 88° 06′ 59″ E to 88° 08′ 35″ E longitude within the Hugli estuary of western part of Indian Sundarbans. The major occupation of local people is agriculture, fishing and prawn seed collection. It has approximately 1200 families and it has faced many severe cyclones in the last few years.

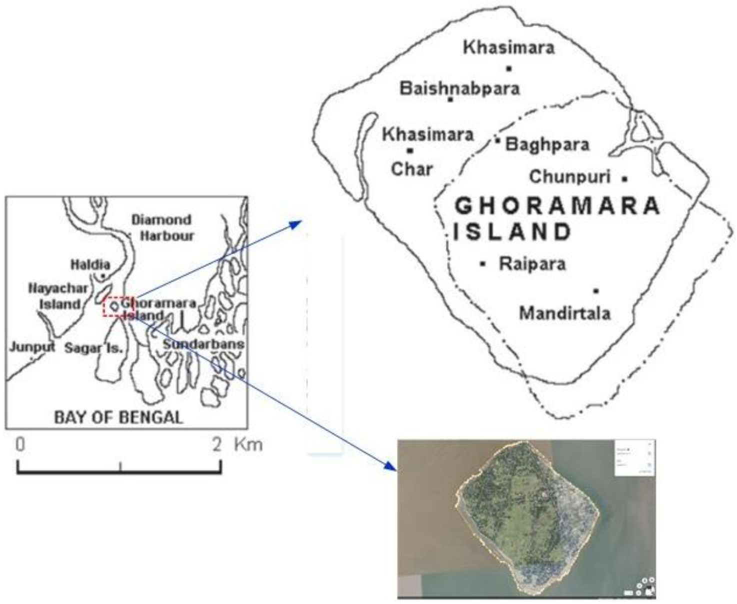


Figure 10. Map and location of Ghoramara island.

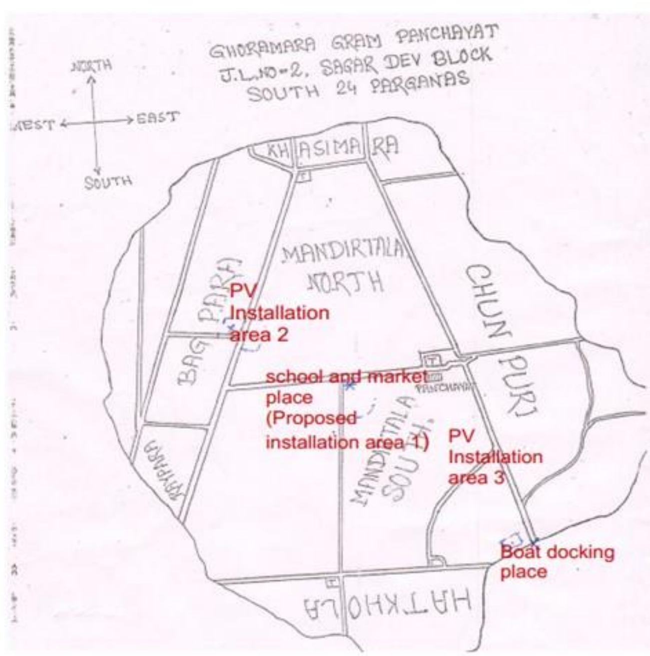


Figure 11. Villages of Ghoramara island.

Ghoramara Island is located approx. 92 km south of Kolkata, in the Sundarban of the Bay of Bengal. A google image of the island is shown in Figure 10. The island comprises five different villages as shown in Figure 11. The nearest mainland is Kakdwip which is approximately 5 km away and takes around 1 hour through diesel operated boats.

This island is roughly five square kilometers in area with a population of 3,000 residents (1100 houses) as of 2016. Out of the whole population, 50% belongs to SC category, and 20-30% belongs to minority group.

Details of beneficiaries including the local agencies / authorities

- Around 3000 residents are staying there over 1100 houses.
- Two primary schools, one higher secondary school (420 students), and a primary health care center are available in the island.
- A few shops (around 30 numbers) are located at the central area of the island near to the schools.
- The administration of the entire island is controlled by an elected Gram-panchayat system

The mapping of ecoTools Ghoramara Island is shown in Table 3.

Table 3. Mapping of tools to Ghoramara demo site.

ecoTool	Ghoramara
ecoEMS	
ecoMicrogrid	✓
ecoPlanning	
ecoDR	✓
ecoPlatform	✓
ecoConverter	✓
ecoMonitor	✓
ecoCommunity	✓
ecoVehicle	✓
ecoResilience	✓

3.3.1. General description – Existing Infrastructure

The existing vectors are as described below.

- Utility grid is not available in the island.
- A 3kW wind turbine was installed near Ghoramara school, but the system was damaged during cyclone AMFAN which makes it inoperative. The wind turbine is shown in Figure 12.

Figure 12. Photographic view of an existing (damaged) wind turbine (3 kW) in Ghoramara island.

- A few discrete solar panels are found on the roof-top of individual houses and shops which are mostly used for mobile charging and glowing of LED lamp (one/two in numbers using home lighting solution). The roof-top-solar-panels are shown in Figure 13.

Figure 13. House with roof-top solar panel (a) shops (b) individual houses.

- Around 100 streetlights with solar panels, as shown in Figure 14, are also found which are now inoperative.

Figure 14. Streetlight at Ghoramara island.

The capacity of the existing energy vectors

The capacity of the existing energy vectors at Ghoramara island is mentioned in Table 4.

Table 4: Overview of existing energy vectors on Ghoramara island.

Energy vectors	Type of installation	Capacity
Solar	• A few panels are mounted on the roof-top of some individual houses to provide power to one/two LED lamp and mobile charging. In some cases, the battery is damaged and replacement is not yet done. • Around 100 solar-powered streetlights were installed all over the island, but most of them are presently not operational due to the non-maintenance of battery units.	Power rating is corresponding to one PV module. Note that PV module is mounted in only a few houses.
Wind*1	A 3 kW wind turbine is mounted at the vicinity of school which is not operational after the cyclonic storm "AMPHAN".	3 kWp

*1: The average wind speed on the island is 4.6 – 5.6 m/s which has the capability to generate 6800-7200 kWh wind energy per year from a 5kW wind turbine (i.e. 19-20 kWh per day).

The following infrastructure is available at Ghoramara island.

- One high school and two primary schools are available where around 420 students are studying.
- One health care center is also present in the island to provide initial medical facility to the residents.
- The main source of income is agriculture (mainly betel leaves, and rice) in which 85-90% of peoples is involved, and the remaining people is dependent on fishing.
- Two rice-cum-hauler meals are present in the island which are run by diesel engine.

Four e-rickshaws are presently running in the island to meet the requirements of residents. The charging is done through a diesel generator which is neither economical nor an environment friendly approach.

3.3.2. Deployment planning

Figure 15 provides an overview of the ecoTools and other infrastructure as it relates to the RE-EMPOWERED demonstrations on Ghoramara.

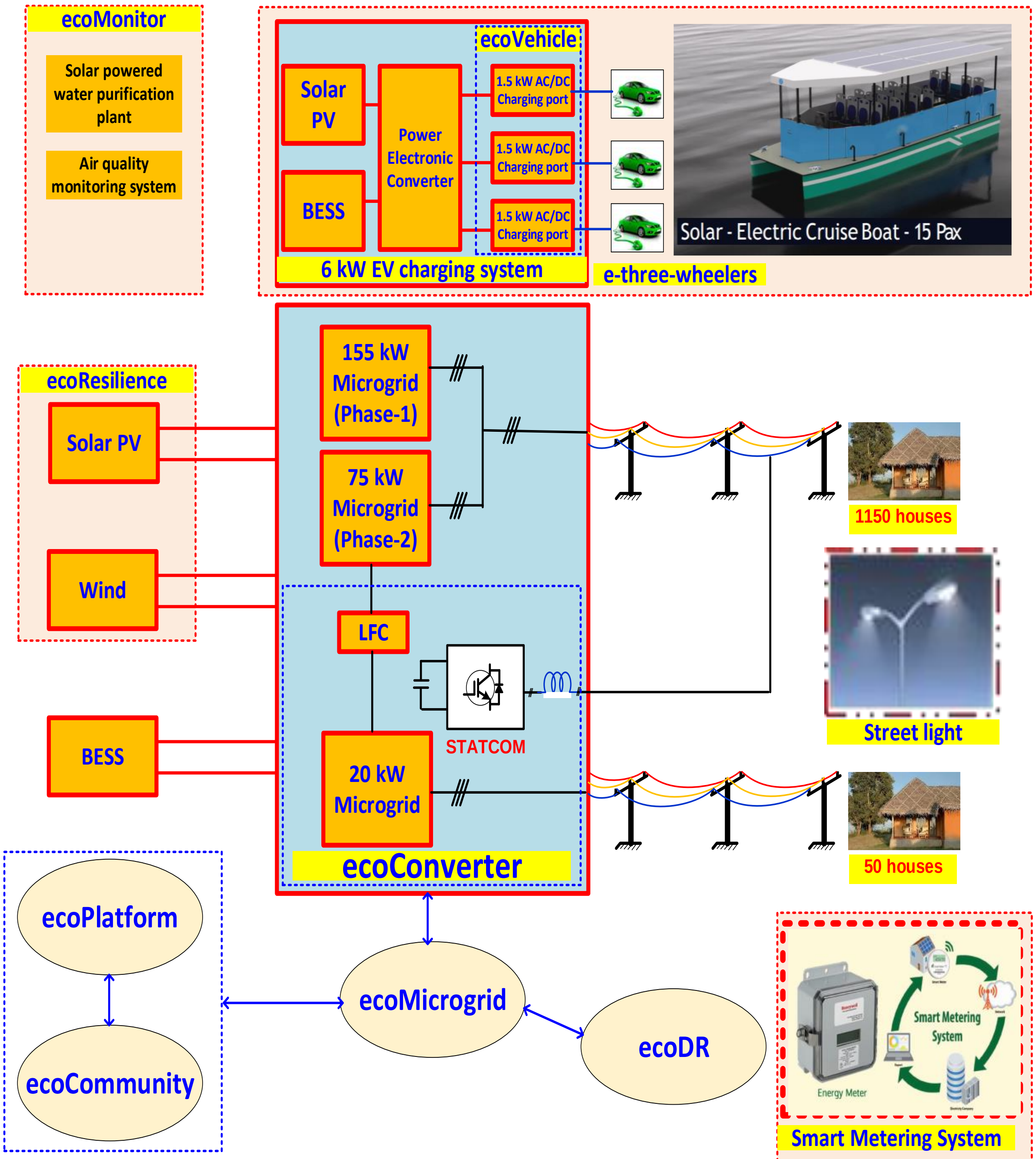


Figure 15. Overview of ecoTools on Ghoramara.

Upgrade of existing infrastructure

The following energy sources will be added in Ghoramara island to provide electricity to 1100 houses of the island along with school, shops and health center as given in Table 5.

Table 5. Proposed additional energy sources in Ghoramara.

Proposed energy sources	Proposed capacity
PV	240 kWp
Wind Turbine	10 kWp

In addition, Table 6 provides the planned upgrade of the existing infrastructure.

Table 6. Upgrade of the existing infrastructure in Ghoramara

Sl. No.	Proposed hardware facilities	Capacity of the proposed hardware facilities	ecoTool related	Description	Deployment month
1.	AC microgrid # 1 (Phase-1)	155 kW capacity (150 kW PV + 5 kW Wind, 700 kWh BESS)	ecoConverter	155kW microgrid will be installed by commercially available vendors.	M24
1a.	AC microgrid # 1 (Phase-2)	75 kW capacity (70 kW PV + 5 kW Wind, 500 kWh BESS)	ecoConverter	75kW microgrid will be installed by commercially available vendors.	M28
2.	AC microgrid # 2	20 kW capacity (17.5 kW PV + 2.5 kW Wind, 100 kWh BESS)	ecoConverter	This 20kW microgrid will be developed using RE-EMPOWERED developed technologies. The features of this microgrid are as follows : Partial Power Converters (PPC) for higher capture of solar energy, (ii) SiC based dc-dc converters for BESS and wind power integration, (iii) modular configuration, (iv) in-built communication, (v) Advanced EMS	M30
3.	Load Flow Controller	5 kW capacity to transfer 20 kW power between microgrid # 1 and Microgrid # 2.	ecoConverter	Lower rating of the converter compared to power transfer between the microgrids.	M24
4.	A Power Conditioner	20 kW capacity – will be connected at PCC of AC microgrid # 2	ecoConverter	(i) A multilevel converter topology is used which is modular, and hence, can be upgraded to higher power level with less complexity, (ii) Loss of the converter is lower than the conventional one	M24

5.	PPC	Two 10 kW PPC will be connected to Microgrid # 2 to take care of partial shading.	ecoConverter	PPC for higher capture of solar energy, (ii) SiC based dc-dc converters for BESS and wind power integration, (iii) modular configuration, (iv) in-built communication, (v) Advanced Energy Management System (EMS)	M24
6.	An SiC based dc-dc converter	One 10 kW dc-dc converter will be used to integrate BESS with the 20 kW microgrid system.	ecoConverter	One 10 kW dc-dc converter will be used to integrate BESS with the 20 kW microgrid system.	M24
7.	FPGA based digital control platform	The FPGA board using Spartan-6 IC (or higher version) will be customized according to the requirements of RE-EMPOWERED project. It would have adequate ADC, DAC, digital I/Os, and other features.	ecoConverter	The board will be customized according to the requirements of RE-EMPOWERED project. It would have adequate ADC, DAC, digital I/Os and other features.	M24
8.	Electric three wheelers	Quantity – 02 Motor type – BLDC Motor rating – 2 kW base power, 4 kW peak power Battery: 48V, 100 AH Li-Ion battery	ecoVehicle	The three wheelers will be customized according to the requirement of the demo site.	M15
9.	Dimmable street light with common features	Quantity – 80 (60 Non-Dimmable+20 Dimmable)	Not applicable	Common features: (i) Automatic ON/OFF based on ambient light conditions - No human intervention, (ii) Sensing the presence of pedestrians/vehicles using motion sensors and accordingly increases the	M15

				brightness of the LED , (iii) Reaches to predefined dim state (50% or 25%) when no-body in the vicinity around light pole Special features: (i) Semi-integrated configuration with retrofitting possibility in existing LED street lights (ii) Configurable brightness of individual light (10-100%) (iii) Higher energy savings employing time specific dim state – 30% up to 10 PM and thereafter 10% (iv) Pet tolerance capability (iv) Low False Alarm Rate	
10.	Dimmable street light with advanced features	Quantity – 5	Not applicable		M30
11.	Conventional smart meters	Quantity – 50	ecoDR	Common features: (i) Automatic ON/OFF based on ambient light conditions - No human intervention, (ii) Sensing the presence of pedestrians/vehicles using motion sensors and accordingly increases the brightness of the LED , (iii) Reaches to predefined dim state (50% or 25%) when no-body in the vicinity around light pole Special features: (i) Semi-integrated configuration with retrofitting possibility in existing LED street lights (ii) Configurable brightness of individual light (10-100%) (iii) Higher energy savings employing time specific dim state – 30% up to 10 PM and thereafter 10% (iv) Pet	M21

				tolerance capability (iv) Low False Alarm Rate	
12.	Smart meters with advanced features	Quantity – 5	ecoDR		M24
13.	Auto disconnection arrangement under overloading condition (Load limiter)	Quantity – 1100	ecoDR	(i) Power limiting option for each house (ii) Energy limiting option for each house (iii) Auto-disconnection and auto-reconnection (iv) Display (v) Tariff calculation and automatic billing arrangement.	M27
14.	Cyclone resilient structure	i.Cyclone resilient structure for 20 kW PV Cyclone resilient structure for 5 kW wind turbine	ecoResilience	Existing practice: (i) To withstand high wind and cyclonic loads, usual practice is to employ heavy support structure and foundation, which are usually overdesigned and therefore costly. RE-EMPOWERED Developed technology: (i) Optimized PV panel configuration with air gap between panels to reduce the aerodynamics wind loads, (ii) Passive aerodynamic control surfaces with flexible support structure of the PV arrays to minimize the wind loads, which helps in a significant reduction in the cost of support systems	M30
15.	e-boat	Electric boat to carry 15 passengers	ecoVehicle	Navalt (Navgati) has the capability to make this boat. This will be deployed in Ghoramara island and will be operated through forming a co-operative systems (to make system self-sustainable).	M24
16.	Charging station with local PV and	uG capacity – 11 kW No. of ports: 3 ports, each of	ecoVehicle	(i) SOC estimation, (ii) up to 3.0C/10 charging algorithm for CC/CV Normal charging, (iii) Temperature regulated fast	M9 (C) M24 (A)

	BESS (11 kW capacity)	3.3 kW ac with 230 V rating Advanced charger - 1 no.		charging (iv) exploring the options of V2G and G2V	
17.	Wind turbines (will be purchased from the market)	5 kW, 2 Nos.	ecoResilience	Commercially available 5kW wind turbine will be deployed in Ghoramara island.	M21
18.	Wind turbine	2.5 kW, 1 No.	ecoResilience	The parts of the wind turbines will be supplied by NTUA which will be assembled at CMERI and will be finally deployed to Ghoramara island.	M21
19.	Power electronic interface for wind turbine	Two 5kW each WTs will be connected to the microgrid inverter through the interface arrangement.	ecoConverter	An SiC based high-gain Power Electronic Interface will be developed for the integration of 5kW wind turbine with the microgrid inverter.	M24
20.	Remote monitoring system	Transmitter and receiver system for remote data access between demo site and IITD/IIT KGP.	ecoMonitor		M24

RE-EMPOWERED ecoTools deployment

The testing of ecoTools will take place in AC microgrid #2 which has 20 kW capacity. AC microgrid # 1 (Phase-1) and (Phase-2) will be deployed by a vendor.

	ecoCommunity	From	To
		M15	M28

Overall system information	**Function:** Display energy consumption and dynamic energy prices to the consumers. Coordination of the usage of shared communal loads. Community engagement through forums, feedback, and problem reporting portals. Community support through training materials and guides. **Input Parameters:** Energy price, Energy consumption, Available booking time slots **Output Parameters:** Booked Time Slots, visualization of various functions **Communication protocol:** Internet, API **Measurement parameters:** None locally

	ecoMicrogrid	From	To
		M15	M28
Overall system information	**Function:** Strategy determination **Input Parameters:** Consumptions, Productions, Grid Frequency, Forecasts, Assets Status, Grid state **Output Parameters:** Set-points to assets, grid's elements etc. **Communication protocol:** Modbus, Ethernet **Measurement parameters:** Voltage, grid Frequency, Current, Active power, Reactive Power		

	ecoDR	From	To
		M24	M28
Overall system information	**Function:** Measurement of energy consumption, transmitting time stamped energy data and control of non-critical loads **Input Parameters:** Control commands **Output Parameters:** On/off signal **Communication protocol:** MODBUS, Ethernet, DLMS, MQTT **Measurement parameters:** Power consumption		

ecoPlatform tool will be a cloud-based platform collecting and managing the data from Ghoramara demo site.

	ecoPlatform	From	To
		M15	M28
Overall system information	**Function:** Integration of eco tools and ensure interoperability, acquire data from various sources and serve as data storage on a cloud platform **Input Parameters:** air quality data, consumption and production, of assets on Ghoramara demo site, forecasts of load and renewable generation		

	Output Parameters: Make the input parameters available to other tools, visualize some of the data of Ghoramara demo site **Communication protocol:** Internet – MQTT or HTTPS **Measurement parameters:** Not installed locally

	ecoMonitor	From	To
		M15	M28
Overall system information	**Function:** Real time monitoring and analysis of ambient air quality parameters Deployment of water purification plant Surveillance and monitoring of drinking water quality parameters at periodic interval in offline mode **Input Parameters:** Air quality sensors data **Output Parameters:** Processed sensors data **Communication protocol:** Ethernet **Measurement parameters:** CO, NOx, SOx, PM2.5 and PM10 microparticles, temperature, humidity		

	ecoResilience	From	To
		M18	M30
Overall system information	**Function:** To have resilient support structures for solar photovoltaic and wind turbines systems to withstand severe cyclonic wind loads. These structures will be fabricated and tested with equivalent loads before being deployed at the demo site. In addition a small wind turbine will be constructed and installed in Ghoramara. **Input Parameters:** NA **Output Parameters:** NA **Communication protocol:** NA **Measurement parameters:** NA		

	ecoConverter	From	To
		M9	M30
Overall system information	**Function:** Development of 230 kW local energy system by commercially available vendors. It will provide electricity to 1050 houses. Development of a 20 kW local energy system using RE-EMPOWERED developed technologies. All the eco-tools will be tested on this system. The 20 kW local energy system will be comprised of Partial Power Converters (PPC), plug-and-play type inverters, advanced EMS, grid		

	forming control strategy, communication, display, and other advanced features. It will provide electricity to 50 houses. A Load Flow Controller (LFC) will be provided for interconnection of the local energy systems. A multilevel STATCOM will be installed to improve power quality of the islanded system **Input Parameters:** 240 kW PV, 10 kW wind, 1300 kW-h BESS **Output Parameters:** 225 kW (10% loss is considered), 400V L-L rms, 50 Hz three-phase AC **Communication protocol:** CAN or RS232 or Ethernet **Measurement parameters:** Voltage, currents, frequency, power, power quality indices

	ecoVehicle	From	To
		M6	M26
Overall system information	**Function:** Facilitate green transportation at the demo site. To cater the charging facility for EVs. **Input Parameters:** 230V, 50Hz. (On Board charger) **Output Parameters:** 1.5kW at 48V, 30A (0.3C Charging Rate) **Communication protocol:** CAN, Internet **Measurement parameters:** SOC, Temperature of batteries.		

UCs analysis and planned actions

I. ecoMicrogrid

Item No.	MG_2UC1.1: Real time microgrid monitoring and data acquisition
MG_1.1.1	Installation of necessary software/hardware of the metering devices
MG_1.1.2	Configuration of metering devices and eco-Microgrid tool
MG_1.1.3	Interoperability between metering devices and ecoDR, Data Concentrator/Microgrid Operator
MG_1.1.4	Testing the operation of the monitoring system and assessment

Item No.	MG_2UC1.3: Data concentration, storage and management
MG_1.3.1	Configuration of monitoring devices to log the measured data
MG_1.3.2	Establishment of communication between monitoring devices, PV inverters and Data Concentrator/Microgrid Operator
MG_1.3.3	Testing and assessment of data concentration, storage, and management

Item No.	MG_2UC2.1: Effective communication with controllable assets
MG_2.1.1	Define the communication scheme, according to recommended/supported protocols

MG_2.1.2	Evaluate interoperability between metering devices and ecoMicrogrid Data Concentrator
MG_2.1.3	Test the effective delivery of commands from ecoMicrogrid Data Concentrator to controllable assets and assessment

Item No.	MG_2UC2.2: Multi objective microgrid management - Optimization of Energy Production, Storage and Purchase
MG_2.2.1	Determine the objectives of the optimization algorithm (flexible loads, cost minimization, RES utilization, batteries management, etc.)
MG_2.2.2	Determination of the operational, security and availability constraints
MG_2.2.3	Setup of the hardware equipment of ecoMicrogrid and deploy the optimization module
MG_2.2.4	Testing and assessing the operation of the management system

Item No.	MG_2UC2.3: Multi-energy vector microgrid management of operation
MG_2.3.1	Determination of the energy vectors
MG_2.3.2	Determination of the operational, security and availability constraints
MG_2.3.3	Design of the management algorithm for the most efficient and economic operation
MG_2.3.4	Test the operation of the management system and assessment

II. ecoDR

Item No.	DR_2UC1.1: Real time monitoring of energy consumption
DR_1.1.1	Implementation of energy monitoring also having features suitable for communication with ecoMicrogrid.
DR_1.1.2	Testing the data acquisition process and assessment

Item No.	DR_2UC1.2: Dynamic pricing-based energy cost computation
DR_1.2.1	Timestamping the energy consumption data
DR_1.2.2	Transmitting the time stamped data to ecoMicrogrid

Item No.	DR_2UC2.1: Scheduling of loads
DR_2.1.1	Receiving the load ON/OFF commands from ecoMicrogrid
DR_2.1.2	Turning the switches/relays ON/OFF

Item No.	DR_2UC2.2: Programmable Load shedding controller
DR_2.2.1	Receiving the max permissible value of load, duration and max permissible value of energy from ecoMicrogrid
DR_2.2.2	Setting up the flag to reset the load and energy to default values after the expiry of duration

III. ecoMonitor

Item No.	MON_2UC1.1: Acquisition and transmission of air quality parameters data

MON_1.1.1	Acquisition of air quality parameters such as CO, NOx, SOx, PM2.5 and PM10 microparticles, temperature, humidity
MON_1.1.2	Real time data transmission to other ecoTools

Item No.	MON_2UC1.2: Acquisition and Monitoring of water quality
MON_1.2.1	Collection of water samples from the field at periodic interval
MON_1.2.2	Analysis of water quality parameters in laboratory environment
MON_1.2.3	Real time monitoring and analysis of air quality parameters

IV. ecoCommunity

Item No.	CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile
CM_1.1.1	Implementation and integration of energy pricing display module in ecoCommunity mobile application.
CM_1.1.2	Identify the range of energy prices associated with the tri-color coded representation.
CM_1.1.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the real-time/ forecasted energy pricing data.
CM_1.1.4	Testing and deployment of the module.

Item No.	CM_2UC1.2: Billing and payments
CM_1.2.1	Develop various consumer categories and their associated energy plans for the calculation of bills.
CM_1.2.2	Implementation and integration of billing module in ecoCommunity tool to generate bills for each billing cycle.
CM_1.2.3	Implementation and integration of bill history module with ecoCommunity mobile application to display the bills for previous billing cycle.
CM_1.2.4	Implementation and linking of consumer user accounts with various ecoDR devices and community managers with consumers
CM_1.2.5	Establish communication with ecoPlatform and ecoDR for sharing energy consumption data of the consumers to generate bills.
CM_1.2.6	Implementation and integration of payment gateway for the payment of bills using various payment options.
CM_1.2.7	Testing and deployment of the module.

Item No.	CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads
CM_2.1.1	Identify and categorize the various non-critical/flexible loads at demo site.
CM_2.1.2	Implementation and integration of slot booking module with ecoCommunity mobile application to book time slots for the flexible loads.
CM_2.1.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the available time periods for connecting the flexible loads.
CM_2.1.4	Testing and deployment of the module.

Item No.	CM_2UC2.2: Coordination of communal/shared loads
CM_2.2.1	Identify the various communal/shared loads at demo site.

CM_2.2.2	Implementation and integration of load booking module with ecoCommunity mobile application to book shared loads.
CM_2.2.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the available time periods for connecting the shared loads.
CM_2.2.4	Testing and deployment of the module.

Item No.	CM_2UC3.1: Feedback and suggestions from users about the tools
CM_3.1.1	Preparation of feedback questionnaire based on the tools installed/ deployed at the demo site.
CM_3.1.2	Implementation and integration of questionnaire and suggestions module in ecoCommunity mobile application.
CM_3.1.2	Testing and deployment of the module.

Item No.	CM_2UC3.2: Reporting of problem
CM_3.2.1	Identifying the various problem categories and preparation of problem reporting form for the demo site.
CM_3.2.2	Implementation and integration of problem reporting module in ecoCommunity mobile application.
CM_3.2.2	Testing and deployment of the module.

Item No.	CM_2UC3.3: Forum to share experiences
CM_3.3.1	Identifying the various forum topic categories relevant to the demo site.
CM_3.3.2	Implementation and integration of forum module in ecoCommunity mobile application.
CM_3.3.3	Testing and deployment of the module

Item No.	CM_2UC4.1: Training material (troubleshooting)
CM_4.1.1	Collecting the various service manuals and training materials associated with the installations from ecoTool leaders
CM_4.1.2	Categorizing the collected service manuals and training materials based on type and application.
CM_4.1.3	Uploading the documents to the common database and integration of the module with ecoCommunity mobile application.

Item No.	CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)
CM_4.2.1	Intimation to ecoTool leaders for the preparation of necessary multimedia materials for the various ecoTools
CM_4.2.2	Preparation of step-by-step guides for using the various modules of ecoCommunity tool
CM_4.2.3	Collecting and categorizing the various multimedia materials for the demo-site.
CM_4.2.4	Uploading the documents to the cloud database and integration of the module with ecoCommunity mobile application.
CM_4.2.5	Creation of administrative user login for the ecoTool leaders for any future creation or updating of the materials.

V. ecoResilience

Item No.	RS_2UC1.1: Optimal selection of parameters
RS_1.1.1	The preliminary design of support structure for solar photovoltaic system is performed through analytical methods based on the data available in the literature. The aerodynamic components of required shape and size were added based on the expected wind load and the designed speed to operate the panel structure passively.
RS_1.1.2	Next, the model is made using CAD software for structural analysis. The preliminary required shape and size of the components were finalized through analytical method based on the expected wind load.
RS_1.1.3	Next, detailed structural analysis of solar PV support structure is performed using ANSYS software considering wind loads and moments.

Item No.	RS_2UC1.2: Computational fluid dynamics and structural analysis of support structures
RS_1.2.1	Computational fluid dynamics studies were performed at different wind velocities (30, 45, and 60 m/s) in both upstream and downstream direction to calculate the aerodynamics loads for conventional and proposed design of the solar photovoltaic support structure.
RS_1.2.2	The calculated aerodynamic loads and moments were applied on the different components of the solar PV system and the structural analysis was performed with the calculated forces and moments.
RS_1.2.3	Few modifications were made on base structure attached with foundation which takes the dead and aerodynamics loads based on the fluid structure interaction study.

Item No.	RS_2UC1.3: Experimental validation of the designed structure through wind tunnel testing
RS_1.3.1	A prototype of the designed solar PV support structure is made based on the simulated results. Two numbers of solar PV panels having 1m × 2m size is attached with the support structure.
RS_1.3.2	Loads were applied on the panels and the designed prototype performs its functions properly. However, few modifications were performed on the support frame to increase the rigidity of the panels with support structures based on the expert's opinion.
RS_1.3.3	A scale-down model of the whole PV support structure is made using 3D printing with PV panels to perform wind tunnel testing. It will be performed in due course of time.

Item No.	RS_2UC1.4: Design of resilient foundation for solar photovoltaic system
RS_1.4.1	The foundation depth and width for the solar PV support structure were chosen based on the wind loads experienced during cyclone taking care of the soil bearing capacity.
RS_1.4.2	A foundation with a prototype of the solar PV support structure is made in the laboratory and tested for its stability by applying loads on the main frame.
RS_1.4.3	The designed foundation will be made in the domo site in due course of time.

Item No.	RS_2UC2.1: Preliminary design of a tower truss structure and its optimization

RS_2.1.1	The preliminary design of wind turbine support structure is performed mainly considering the demo site constrain in deployment and maintenance. A hybrid structure having truss and monopole is proposed. It is designed using CAD software based on the structural characteristics of truss elements and pipes.
RS_2.1.2	Detailed structural analysis of wind turbine support structure is performed using ANSYS software considering wind loads from the head wind.
RS_2.1.3	Mechanism to move the monopole structure up and down during maintenance is added with the hybrid structure in the preliminary design.

Item No.	RS_2UC2.2: Design of a resilient mechanism to reduce wind loads on blades and its optimization
RS_2.2.1	The hybrid structure is designed taking into the wind loads acting on the turbine blades. However, the blades from the wind turbine will be removed by lowering the mono pole tower using the designed mechanism.
RS_2.2.2	A simple mechanism with a chain hoist is designed for moving the monopole structure up and down during severe weather condition.
RS_2.2.3	Structural analysis of the designed wind turbine support structure is performed to optimize the size of the individual elements in the truss and monopole tower. Few modifications in the thickness of the elements were performed based on the maximum wind load on wind turbine blades.

Item No.	RS_2UC2.3: Laboratory and field testing of the mechanism
RS_2.3.1	Laboratory testing of the solar PV support structure is under progress along with wind tunnel model testing.
RS_2.3.2	The support structure for wind turbine is at its final design stage as many iterations were made to optimize the weight of the tower and installation of wind generator on top of monopole structure.
RS_2.3.3	The support structure will be fabricated for laboratory testing. The procurement of commercial wind turbine is under progress. A field testing will be performed at CMERI before deploying the wind turbine at demo site.

Item No.	RS_2UC2.4: Resilient foundation for wind turbine tower structure
RS_2.4.1	The foundation depth and width for the wind turbine support structure were chosen based on the wind loads experienced during cyclone taking care of the soil bearing capacity.
RS_2.4.2	A foundation with a prototype of the wind turbine support structure will be made in CSIR-CMERI and tested for its stability by applying loads on the main frame.
RS_2.4.3	Analytical calculations were performed for wind turbine foundation having four legs based on the expected moments from wind turbine. These foundations will be made in the domo site in due course of time.

Item No.	RS_2UC3.1: Small Wind Turbine Manufacturing and installation
RS_3.1.1	The small wind turbine will be manufactured at CMERI premises, under the guidance of ICCS-NTUA
RS_3.1.2	The wind turbine will be mounted on the resilient foundation in Ghoramara.

VI. ecoConverter

Item No.	C_UC1.1: Development and control of power electronic converters
C_1.1.1	Literature survey and selection of topologies for the converters
C_1.1.2	Development of simulation models
C_1.1.3	Development of control techniques and their validation through simulation for islanded microgrid application
C_1.1.4	Development of hardware prototypes
C_1.1.5	Development of an FPGA based real-time platform

Item No.	C_UC1.2: Testing and on-filed demonstration of the power electronic converters satisfying various standards
C_1.2.1	Testing of the converters at laboratory environment satisfying various standards
C_1.2.2	Formulation of various test cases and dynamic performance study
C_1.2.3	On-field demonstration

Item No.	C_UC1.3: Exchange, replicability and scalability in EU and India
C_1.3.1	Industry involvement for scalability and replicability
C_1.3.2	MoU with the 3rd party and associated technology transfer

VII. ecoPlatform

Item No.	PF_2UC2.1: Facilitate data exchange between dependent tools
PT_2.1.1	Communication interoperability from different sources such as smart meters or ecoMicrogrid/ecoEMS to obtain measurements from RES and demand
PT_2.1.2	Establishing communication
PT_2.1.3	Online data collection
PT_2.1.4	Data storage
PT_2.1.5	Ensure consistent data – raw data cleaning and filtering
PT_2.1.6	Exchange of data between different tools

Item No.	PF_2UC3.1: Route the microgrid data and data from dependent tools to cloud database
PT_3.1.1	Storing the data in the cloud

Item No.	PF_2UC3.2: Facilitate archived data access for dependent tools using API
PT_3.2.1	Provide an API for other tools to access the storage

VIII. ecoVehicle

Item No.	VH_2UC1.1: Effective control strategies for dc-bus voltage regulation
VH_1.1.1	Identifying various control mechanisms
VH_1.1.2	Implementation of modified current control for bus voltage regulation

VH_1.1.3	Hardware validation of identified control mechanism.

Item No.	VH_2UC1.2: State of charge and temperature estimation
VH_1.2.1	Survey on Various methods of SOC estimation and Temperature.
VH_1.2.2	Implementation of SOC and Temperature estimation on developing Charger
VH_1.2.3	Proper charging control by ensuring above parameters in limit.

Item No.	VH_2UC1.3: Temperature regulated charging strategies
VH_1.3.1	Battery health can be ensured by temperature regulations by means of various strategies.
VH_1.3.2	Implementing of Charging strategy by control parameters like SOC, Voltage, Current, Temperature.

Item No.	VH_2UC2.2: Customization of the vehicle to the demo site requirements
VH_2.2.1	Customization in electric three wheelers with foldable seating arrangement such as to accommodate only passengers with full capacity or passengers with partial loads

Item No.	VH_2UC3.1: PV Integration with e-Boat
VH_3.1.1	Integration of solar energy with the propulsion system of battery-operated electric boat

3.3.3. Demonstration planning

The demonstration planning will be divided in two runs. The first run refers to testing demonstration, i.e., demonstrating the core capabilities of the deployed ecoTools in a limited setting. After the first run, adaptations and adjustments will be performed, leading to the second run, the operational demonstration, i.e., operating the demo site leveraging the benefits of the full functionality offered by the deployed ecoTools.

The first run of the demonstration planning will be divided in two levels. The first level ("Basic functionality”) will include the demonstration and validation of the stable and continuous operation of the ecoToolset, the deployment of the software and hardware, as well as the uninterruptable communication of the tools and the components. The second level (“Advanced functionality”) will consist of the validation of the advanced functionalities that the ecoTools facilitate. Activities within each run/level need not be performed in sequence.

First demonstration run (testing demonstration)		From M28	To M32
A	Basic Functionality	From M28	To M32
A1	The local energy system is running properly and continuous power supply is ensured to all the houses.		
A2	SCADA or equivalent communication system is working properly. All the electrical parameters are visible on the display unit of the control room. The command can be		

	changed by the users and the operation of the microgrid should be changed accordingly.		
A3	The overload arrangement is working properly and auto-disconnection and auto-reconnection is taken place depending on the loading condition to each house.		
A4	Frequency / Voltage stability is ensured at the far-end of the distribution system.		
A5	Battery System charge / discharge is working properly.		
A6	Remote data exchange is happening properly.		
A7	50 smart meters have been deployed and they are working satisfactorily.		
A8	80 street lights have been deployed and they are working satisfactorily.		
A9	Two numbers of e-three-wheelers have been deployed and they are working satisfactorily.		
A10	One number of e-boat has been deployed and it is working satisfactorily.		
A11	6 kW EV charging station has been deployed and it is working satisfactorily.		
A12	Remote monitoring system has been deployed and it is working satisfactorily.		
B	Advanced functionality	From M30	To M33
B1	20 kW microgrid with RE-EMPOWERED developed technologies will be deployed to the island. The performance of the microgrid will be tested.		
B2	All the ecoTools, e.g. ecoMicrogrid, ecoDR, ecoPlatform, ecoMonitor, ecoConverter, ecoResilience will be validated using the 20 kW microgrid system.		
B3	Five advanced dimmable street light will be deployed to Ghoramara island and the advanced features will be tested.		
B4	Five advanced smart meters will be deployed to Ghoramara island and the advanced features will be tested.		
B5	A temperature controlled charger will be deployed to the island.		
B6	A remote monitoring system will be installed for data exchange with the cloud.		
B7	Wind resilient structure for 20 kW PV and 2.5 kW wind turbine will be deployed to the island.		
B8	The communication system and interoperability among the microgrids and with the smart meters will be checked.		
B9	Implementation of tariff collection mechanism and online payment system		
B10	Realization of ecoMonitor tool for Ghoramara island		
Adaptations and adjustments		From M30	To M34
Second demonstration run (operational demonstration)		From M34	To M37
C1	ecoMicrogrid operation & communication		
C2	ecoDR operation & communication		
C3	ecoConverter operation		
C4	ecoVehicle Operation		
C5	Wind resilient structure under ecoResilience tool		
C6	Training will be given to the local people of the island for maintaining of the local energy system		
C7	A local cooperative system will be developed for the maintenance and sustainability of the local energy system		
C8	Guidance and Training		

C9	A suitable business model will be implemented for the sustainability of the local energy system
C10	Performance of the entire local energy system will be analyzed again and interoperability will be investigated further. Study under fault and recovery strategy will be verified (ecoDR and ecoEMS).

Involved partners	Contributions
IIT KGP	The leader of Ghoramara Demo Site. IITKGP is leading the WP 7 (Deployment and demonstration) and also take part in developing tools like ecoConverter, development of Business models, impact assessment and replication strategies.
CSIR-CMERI	Leading the implementation of the ecoDR, ecoVehicle, ecoResilience, ecoMonitor in the island.
VNIT	Leading the implementation of the ecoVehicle tool (Charging Infrastructure) in the island for charging e-three wheelers and e-boat
IISc	IISc will develop an auto disconnection/reconnection arrangement to limit power and energy to each house of the island (ecoDR). It will also setup an algorithm for tariff collection and online payment system.
LCI	LCI will develop an FPGA based digital control platform for the implementation of control logic for converter/inverter system (ecoConverter)
IITD	IITD is responsible for the installation of remote monitoring system in the island (ecoCommunity).
ICCS-NTUA	Leading the implementation of the ecoMicrogrid and the Wind Turbine deployment/demonstration under ecoResilience.
ICL	Leading the implementation of the ecoCommunity tool
DTU	Leading the implementation of the ecoPlatform
PROTASIS	Facilitating in providing and setting up the necessary hardware for the ecoMicrogrid tool

3.3.4. Business models, regulatory and social considerations related to deployment and demonstration actions

Ghoramara island has no grid connectivity, and the only mode of transportation is ferry, which highly constraints the mobility creating logistic issues. It is also characterized by severe weather conditions posing a threat to the proposed 250 kW (230 kW with conventional technology + 20 kW with RE-EMPOWERED technology) micro grid local system and the assets. Access to clean electricity will significantly enhance the welfare and quality of life of the people however, the impoverished population requires handholding for income generating avenues through the acquired electricity. It will provide clean energy for limited residential use and commercial purposes. Technical feasibility is critical for economic and financial viability of the project. Hence, with the help of indigenous technical solutions (ecoTools) demonstrating novel state-of-the-art features will resolve specific issues and enhanced efficiency with better management of the micro grid:

- use of smart devices and solutions for automation and remote monitoring of the system
- to improve voltage profile and other power quality issues of the micro grid
- innovative algorithms and control simulations and various components for power flow management
- integration of multiple renewable energy vectors with fewer elements, higher efficiency at low cost
- ecoVehicle demonstration to facilitate transportation at low running cost
- a novel privacy pricing algorithm is developed to determine the price of privacy of consumers' smart meter energy data for usability
- developing a cyclone resilient support structure for micro grid system due to severe cyclonic storms phenomenon for reliable power generation and asset protection
- dimmable LED street lighting system with advanced motion sensors offers on demand dynamic lighting for energy savings and reduction of light pollution

Low-cost hardware is often installed to keep tariffs affordable, but the combination of less efficient hardware, deficient technical training, lack of spare and replacement parts, and late payments often contributes to reducing the life span of systems. The proposed business plan will be geared to accommodate real time challenges toward long term sustainability. For instance, the load shedding controller feature enables operator (energy supplier) to create a local load shedding once the energy consumption/load connection goes beyond the threshold value. This important feature may also be used by the committee members to address the free rider problem and reduce risk of defaulter. Further, the ICT based remote monitoring system may create a system of checks and balances to service provider to exercise some control to resolve social conflict, if any. Moreover, such novel multiple technology expertise with demonstrated competencies motivates the consumers to pay guaranteed or shared savings fees to ESCOs. Many a times actual saving is much lower than forecasted which can be checked by the consumers via developed software with consumer interface to choose from the energy scenarios based on dynamic pricing. Further, the plug-n-play modular devices not only develops operational simplicity but also allows quick fault detection and maintainability.

With the given hardware and software proprietary technology, it becomes pertinent to evaluate the economic viability form business perspective. It can be elaborated in two ways, first the ownership business model for the micro grid and secondly the business and commercial potential that it can create among the communities of Ghoramara with a clear sustainable socioeconomic impact in long run. This section will describe both the aspects of business modelling for the energy community

The value proposition is clear i.e., installation of a unique reliable and efficient 'product' solar and wind micro grid for the community comprising 1100 households which is grid-less with no access to electricity bridging the accessibility gap for the vulnerable residents. It will provide six to eight hours of clean energy at affordable price to households, businesses, and community institutions like school, relief centre, etc. The customers served are the residents with access to lightning, mobile charging at household level while shops, enterprises, etc. at commercial level. It incorporates an inclusive approach with the local manpower engagement, creating a support and maintenance network, local skill building (trainings) and local capacity building (groups, networks, and entrepreneurs).

The project aims to build entrepreneurship within the community and network with other enterprises and industry outside the island for effective monetary growth and rotation. Well planned and executed strategies will lead to pro-business environment for emerging new businesses like rice hullers; additional fishing due to electric boats; extended operation hours to shops. It may multiply the revenue streams by diversifying into monetary generation from charging stations, logistics and transportation to and from to nearby islands and mainland, ecotourism, poultry farming.

A user-friendly ecosystem for electricity generation and transmission, which could be operated directly by the village community will be created. This will help the locals to gain necessary skills to operate their own electricity generation, transmission, and maintenance of plant. It is realised that there is a need for local interface to ensure last mile connectivity as it facilitates to generate awareness, to build trust and transparency. Therefore, training and skilling becomes an integral activity to be engaged as technical support, customer service agents, local entrepreneurs, across the value-chain. Novel financing options model will be tested for offering end to end energy solutions by enabling door-step financing and door-step servicing with integration of microfinancing elements for providing customised solution. Such model will become a de-facto guideline for project developers and energy service providers in rural areas characterizing high scalability and replicability potential. Therefore, business model will be tested and benchmarked over time leading to standardisation of processes and protocols. Since, ESCOs have used varying methods of repayment and financing including vendor financing, direct ownership, energy service contracts, power purchase agreements, debt financing, and other alternative energy financiers, the business model will explore in-depth to incorporate all-inclusive elements factoring to implementation of best business practices.

A commonly applied business model is the user cooperative, which involves the establishment of a non-profit community organization owned and managed by its members. It acts as an ESCO, providing services under a fee-for-service system. The user cooperative owns and maintains the system, and users pay a fee for electricity consumed, including the power used to charge batteries. Community members, needs to be involved early in the planning process. Experience has shown that when there is no personal sense of ownership, projects are not sustainable. Because of range of stakeholders involved and services provided, business models suitable for decentralized applications differ greatly. Application of business models to renewable energy projects depends highly on the roles of the five primary project stakeholders: financier, owner, operator, maintenance entity and consumer. The business environment for decentralized rural electrification projects is different as the operating environment is often not defined, therefore local conditions will be considered during business modelling of Ghoramara Island. Business model for hybrid micro grid projects can provide internal rate of return to investors from the consumers having per capita income above poverty line. Hence, for Ghoramara community, income generating activities are most critical which are enabled by access to reliable clean electricity. The most appropriate business model will therefore depend on the state of the infrastructure, the local energy resource, and the geographic setup of the remote rural area.

3.4 Keonjhar

The demo site of Keonjhar has an existing microgrid of 22 kWp, which primarily supplying consumers during nighttime with limited capacity. As a part of the RE-EMPOWERED project, the existing microgrid will be upgraded to another 50 kWp to support the commercial applications in the demo site. The details of the microgrid of Keonjhar have been described extensively in [1]. In the following, a brief reference is made to the existing infrastructure. In Table 7, the distinction between the ecoTools to be installed in Keonjhar Microgrid is presented.

Table 7. Mapping of tools to Keonjhar demo site.

ecoTool	Keonjhar Microgrid
ecoEMS	
ecoMicrogrid	✓
ecoPlanning	✓
ecoDR	✓
ecoPlatform	✓
ecoConverter	
ecoMonitor	
ecoCommunity	✓
ecoVehicle	✓
ecoResilience	

3.4.1. General description – Existing Infrastructure

Kanheigola, Nola and Ranipada are small Villages/hamlets in Harichadanpur-Tehsil reserve forest in Keonjhar District of Odisha State, India. It is located 54 KM towards South from District headquarters Keonjhar and 180 KM from state capital Bhubaneswar. At present these villages are not connected to the main utility grid. A total of 77 kWp (Kanheigola- 30 kWp, Nola -25kWp and Ranipada- 22 kWp) Solar PV installations are supplying to approximately 1000 villagers, living in 306 households. These solar PV installations are completely isolated and commissioned by the Odisha Renewable Energy Development Agency in 2017-2018. The proposed site is ideal for the test bed and demonstration site case as it already has some basic renewable energy presence, which can be upgraded with various available energy vectors and improve the living standards of the community.

Apart from the above the following general infrastructure is available in the demo site

- One high school and one primary school are available run by Tribal/Social Welfare Department.
- One sub center of primary health care center is also present in these villages to provide initial medical facility to the residents.
- The main source of income is agriculture (mainly rice) in which 80-90% peoples are involved. The water from the downstream is the major source for cultivation.
- Three rice-cum-hauler meals are present which are run by diesel engine (consuming 6-7 liters of diesel per day per machine)

Every house in these villages is provided with 100 W for meeting the basic facilities like 2 tube lights and fan only during nighttime (6 PM to 10 PM)

Demo Goals:

1. Develop and demonstrate various energy vectors integration, by means of high energy efficient converters and its control.
2. Implement a livelihood program to complement its off-grid systems in selected remote villages, aiming to create support ecosystems to promote income-generating energy uses in agriculture and small businesses.
3. Increase of population awareness and customer engagement, such that rural to urban migration can be minimized.

3.4.2. Deployment planning

Figure 16 provides an overview of the ecoTools and other infrastructure as it relates to the RE-EMPOWERED demonstrations on Keonjhar.

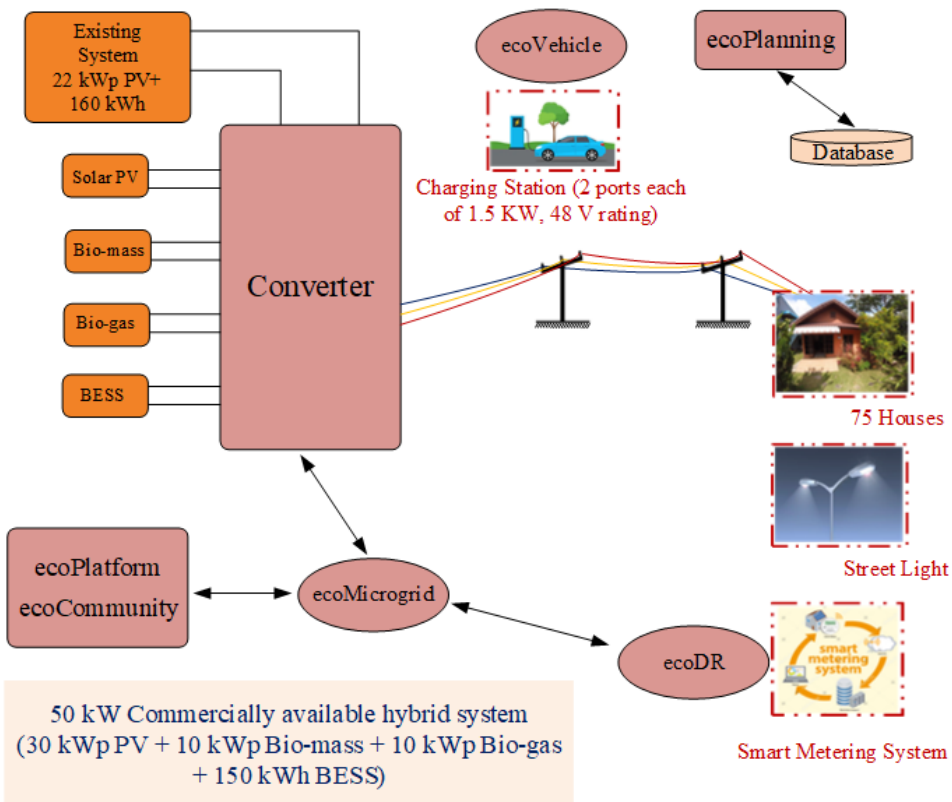


Figure 16. Key components and tools at Keonjhar demo site

Upgrade of existing infrastructure

The planned upgrade of the existing infrastructure is shown in Table 8.

Table 8. Planned upgrades to the Keonjhar energy infrastructure.

Sl. No.	Proposed hardware facilities	Capacity of the proposed hardware facilities	ecoTool related	Description	From	To
1.	A 50 kW microgrid system	30 kWp PV + 10 kW Biomass + 10 kW Biogas	Commercial Instillation. ecoMicrogrid will be tested	(i) DC bus control and (ii) Advanced Energy Management System (EMS)	M18	M26
2.	Electrical Vehicles	2 Nos	Commercial three-wheeler will be deployed. Charging infrastructure developed under ecoVehicle will be tested.	The Three wheelers will be designed to the requirement of the demo site	M18	M21
3.	Smart Meters, with Fuse and MCCB/MCB	20 nos	ecoDR	(i) Inbuilt programmable load limiter, (ii) Load-shedding controller, (iii) Integrated communication module, (iv) Remote firmware upgrades facility (v) Management of Non-critical loads	M24	M28
4.	Solar Dimmable Lights	20 nos	CMERI developed dimmable lights will be installed	(i) Semi-integrated configuration with retrofitting possibility in existing LED street lights (ii) Configurable brightness of individual light (10-100%) (iii) Higher energy savings employing time specific dim state – 30% up to 10 PM and thereafter 10% (iv) Pet tolerance capability (iv) Low False Alarm Rate	M21	M27

5.	Charging Facility, 2 Ports	1.5 kW, 48V	ecoVehicle	(i) SOC estimation, (ii) up to 3.0C/10 charging, algorithm for CC/CV Normal charging, (iii) Temperature regulated fast charging	M18	M26
6.	IoT based remote measuring system	1 nos	Not applicable	Not applicable	M24	M28

RE-EMPOWERED ecoTools deployment

	ecoCommunity	From	To
		M15	M28
Overall system information	**Function:** Display energy consumption and dynamic energy prices to the consumers. Generate consumer bills, and bill payment portal. Coordination of the usage of shared communal loads. Community engagement through forums, feedback, and problem reporting portals. Community support through training materials and guides. **Input Parameters:** Energy price, Energy consumption, Available booking time slots **Output Parameters:** Booked Time Slots, visualization of various functions **Communication protocol:** Internet, API **Measurement parameters:** None done locally		

	ecoMicrogrid	From	To
		M15	M28
Overall system information	**Function:** Strategy determination **Input Parameters:** Consumptions, Productions, Grid Frequency, Forecasts, Assets Status, Grid state **Output Parameters:** Set-points to assets, grid's elements etc. **Communication protocol:** Modbus, Ethernet **Measurement parameters:** Voltage, grid Frequency, Current, Active power, Reactive Power		

ecoPlatform tool will be a cloud-based platform collecting and managing the data from Keonjhar demo site.

	ecoPlatform	From	To
		M15	M28
Overall system information	**Function:** Integration of eco tools and ensure interoperability, acquire data from various sources and serve as data storage on a cloud platform **Input Parameters:** consumption and production, of assets on Keonjhar demo site, forecasts of load and renewable generation **Output Parameters:** Make the input parameters available to other tools, visualize some of the data of Keonjhar demo site **Communication protocol:** Internet – MQTT or HTTPS **Measurement parameters:** Not installed locally		

ecoPlanning tool is responsible for performing simulations that support the decision-making process regarding the deployment of new electricity generation units (conventional and renewable) on the electric systems of NIIs and the interconnection between NIIs.

It will consist of 1 hardware component, an industrial PC, which will relate to an instance of the tailored software.

	ecoPlanning	From	To
		M4	M28
Overall system information	**Function:** Strategy determination **Input Parameters:** RES and load forecast annual timeseries, Assets technical characteristics **Output Parameters:** Set-points to assets, load, annual RES penetration (% of load), maximum instantaneous penetration of Non-Dispatchable RES Units, equivalent full load hours of WPs, diesel consumption, etc. **Communication protocol:** Ethernet **Measurement parameters:** -		
Industrial PC			
System information	**Function:** Server **Manufacturer:** // **Model:** // **Communication protocol:** Ethernet **Hardware specifications:** 16GB memory, 5xSATA3 ports or 4xSATA3 + 1xNVMe ports, SSD operating system disk, 2xHDD (1TB each) storage disks, 2xGB Ethernet ports **Software specifications:** Microsoft Windows Server 2019, Microsoft SQL Server 2019		

	ecoDR	From	To

		M24	M28
Overall system information	**Function:** Measurement of energy consumption, transmitting time stamped energy data and control of non-critical loads **Input Parameters:** Control commands **Output Parameters:** On/off signal **Communication protocol:** MODBUS, Ethernet, DLMS, MQTT **Measurement parameters:** Power consumption		

	ecoVehicle	From	To
		M6	M26
Overall system information	**Function:** Providing green transportation. To cater the charging facility for EVs. **Input Parameters:** On board charger (230V, 50Hz) **Output Parameters:** 1.5kW, 48V at 30A (0.3C rate) **Communication protocol:** CAN , Internet **Measurement parameters:** SOC and Temperature of Battery		

UCs analysis and planned actions

I. ecoMicrogrid

Item No.	MG_2UC1.1: Real time microgrid monitoring and data acquisition
MG_1.1.1	Installation of necessary software/hardware of the metering devices
MG_1.1.2	Configuration of metering devices and ecoMicrogrid tool
MG_1.1.3	Interoperability between metering devices and ecoDR, Data Concentrator/Microgrid Operator
MG_1.1.4	Testing the operation of the monitoring system and assessment

Item No.	MG_2UC1.3: Data concentration, storage and management
MG_1.3.1	Configuration to log the measured data
MG_1.3.2	Establishment of communication between PV inverters and Data Concentrator/Microgrid Operator
MG_1.3.3	Testing and assessment of data concentration, storage, and management

Item No.	MG_2UC2.1: Effective communication with controllable assets
MG_2.1.1	Define the communication scheme, according to recommended/supported protocols
MG_2.1.2	Evaluate interoperability between metering equipment and ecoMicrogrid Data Concentrator
MG_2.1.3	Test the effective delivery of commands from ecoMicrogrid Data Concentrator to controllable assets and assessment

Item No.	MG_2UC2.2: Multi objective microgrid management - Optimization of Energy Production, Storage and Purchase
MG_2.2.1	Determine the objectives of the optimization algorithm (flexible loads, cost minimization, RES utilization, batteries management, etc.)
MG_2.2.2	Determination of the operational, security and availability constraints
MG_2.2.3	Setup of the hardware equipment of eco-Microgrid and deploy the optimization module
MG_2.2.4	Testing and assessing the operation of the management system

Item No.	MG_2UC2.3: Multi-energy vector microgrid management of operation
MG_2.3.1	Determination of the energy vectors
MG_2.3.2	Determination of the operational, security and availability constraints
MG_2.3.3	Design of the management algorithm for the most efficient and economic operation
MG_2.3.4	Test the operation of the management system and assessment

II. ecoPlanning

Item No.	PN_1UC1: 7-Year Energy Planning
PN_2UC1.1	Data collection and storage
PN_2UC1.2	Electrical models & demand peak models design, RES & Load estimation
PN_2UC1.3	Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation

Item No.	PN_1UC2: RES Hosting Capacity
PN_2UC2.1	Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds
PN_2UC2.2	Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment.

Item No.	PN_1UC3: Interconnections
PN_2UC3.1	Electrical models, demand peak models & interconnections design, RES & Load estimation
PN_2UC3.2	Hourly Unit Commitment, through optimization algorithm for mid to long term horizon

Item No.	PN_1UC4: Multi-energy vectors
PN_2UC4.1	Energy carriers' identification, data collection and quantification of impact on total load (hourly)
PN_2UC4.2	Electrical models & demand peak design, RES & Load estimation, energy carriers' scenarios integration
PN_2UC4.3	Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers

III. ecoPlatform

Item No.	PF_2UC2.1: Facilitate data exchange between dependent tools
PT_2.1.1	Communication interoperability from different sources such as smart meters or ecoMicrogrid/ecoEMS to obtain measurements from RES and demand
PT_2.1.2	Establishing communication
PT_2.1.3	Online data collection
PT_2.1.4	Data storage
PT_2.1.5	Ensure consistent data – raw data cleaning and filtering
PT_2.1.6	Exchange of data between different tools

Item No.	PF_2UC3.1: Route the microgrid data and data from dependent tools to cloud database
PT_3.1.1	Storing the data in the cloud

Item No.	PF_2UC3.2: Facilitate archived data access for dependent tools using API
PT_3.2.1	Provide an API for other tools to access the storage

IV. ecoDR

Item No.	DR_2UC1.1: Real time monitoring of energy consumption
DR_1.1.1	Implementation of energy monitoring also having features suitable for communication with ecoMicrogrid
DR_1.1.2	Testing the data acquisition process and assessment

Item No.	DR_2UC1.2: Dynamic pricing-based energy cost computation
DR_1.2.1	Timestamping the energy consumption data
DR_1.2.2	Transmitting the time stamped data to ecoMicrogrid

Item No.	DR_2UC2.1: Scheduling of loads
DR_2.1.1	Receiving the load ON/OFF commands from ecoMicrogrid
DR_2.1.2	Turning the switches/relays ON/OFF

Item No.	DR_2UC2.2: Programmable Load shedding controller
DR_2.2.1	Receiving the max permissible value of load, duration and max permissible value of energy from ecoMicrogrid
DR_2.2.2	Setting up the flag to reset the load and energy to default values after the expiry of duration

V. ecoCommunity

Item No.	CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile
CM_1.1.1	Implementation and integration of energy pricing display module in ecoCommunity mobile application.
CM_1.1.2	Identify the range of energy prices associated with the tri-color coded representation.

CM_1.1.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the real-time/ forecasted energy pricing data.
CM_1.1.4	Testing and deployment of the module.

Item No.	CM_2UC1.2: Billing and payments
CM_1.2.1	Develop various consumer categories and their associated energy plans for the calculation of bills.
CM_1.2.2	Implementation and integration of billing module in ecoCommunity tool to generate bills for each billing cycle.
CM_1.2.3	Implementation and integration of bill history module with ecoCommunity mobile application to display the bills for previous billing cycle.
CM_1.2.4	Implementation and linking of consumer user accounts with various ecoDR devices and community managers with consumers
CM_1.2.5	Establish communication with ecoPlatform and ecoDR for sharing energy consumption data of the consumers to generate bills.
CM_1.2.6	Implementation and integration of payment gateway for the payment of bills using various payment options.
CM_1.2.7	Testing and deployment of the module.

Item No.	CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads
CM_2.1.1	Identify and categorize the various non-critical/flexible loads at demo site.
CM_2.1.2	Implementation and integration of slot booking module with ecoCommunity mobile application to book time slots for the flexible loads.
CM_2.1.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the available time periods for connecting the flexible loads.
CM_2.1.4	Testing and deployment of the module.

Item No.	CM_2UC2.2: Coordination of communal/shared loads
CM_2.2.1	Identify the various communal/shared loads at demo site.
CM_2.2.2	Implementation and integration of load booking module with ecoCommunity mobile application to book shared loads.
CM_2.2.3	Establish communication with ecoPlatform and ecoMicrogrid for accessing the available time periods for connecting the shared loads.
CM_2.2.4	Testing and deployment of the module.

Item No.	CM_2UC3.1: Feedback and suggestions from users about the tools
CM_3.1.1	Preparation of feedback questionnaire based on the tools installed/ deployed at the demo site.
CM_3.1.2	Implementation and integration of questionnaire and suggestions module in ecoCommunity mobile application.
CM_3.1.2	Testing and deployment of the module.

Item No.	CM_2UC3.2: Reporting of problem
CM_3.2.1	Identifying the various problem categories and preparation of problem reporting form for the demo site.

CM_3.2.2	Implementation and integration of problem reporting module in ecoCommunity mobile application.
CM_3.2.2	Testing and deployment of the module.

Item No.	CM_2UC3.3: Forum to share experiences
CM_3.3.1	Identifying the various forum topic categories relevant to the demo site.
CM_3.3.2	Implementation and integration of forum module in ecoCommunity mobile application.
CM_3.3.3	Testing and deployment of the module

Item No.	CM_2UC4.1: Training material (troubleshooting)
CM_4.1.1	Collecting the various service manuals and training materials associated with the installations from ecoTool leaders
CM_4.1.2	Categorizing the collected service manuals and training materials based on type and application.
CM_4.1.3	Uploading the documents to the common database and integration of the module with ecoCommunity mobile application.

Item No.	CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)
CM_4.2.1	Coordination of the ecoTool leaders for the preparation of necessary multimedia materials for the various ecoTools
CM_4.2.2	Preparation of step-by-step guides for using the various modules of ecoCommunity tool
CM_4.2.3	Collecting and categorizing the various multimedia materials for the demo-site.
CM_4.2.4	Uploading the documents to the cloud database and integration of the module with ecoCommunity mobile application.
CM_4.2.5	Creation of administrative user login for the ecoTool leaders for any future creation or updating of the materials.

VI. ecoVehicle

Item No.	VH_2UC1.1: Effective control strategies for dc-bus voltage regulation
VH_1.1.1	Identifying various control mechanisms
VH_1.1.2	Implementation of modified current control for bus voltage regulation
VH_1.1.3	Hardware validation of identified control mechanism.

Item No.	VH_2UC1.2: State of charge and temperature estimation
VH_1.2.1	Survey on Various methods of SOC estimation and Temperature.
VH_1.2.2	Implementation of SOC and Temperature estimation on developing Charger
VH_1.2.3	Proper charging control by ensuring above parameters in limit.

Item No.	VH_2UC1.3: Temperature regulated charging strategies
VH_1.3.1	Battery health can be ensured by temperature regulations by means of various strategies.

VH_1.3.2	Implementing of Charging strategy by control parameters like SOC, Voltage, Current, Temperature.

Item No.	VH_2UC2.2: Customization of the vehicle to the demo site requirements
VH_2.2.1	Customization in electric three wheelers with foldable seating arrangement such as to accommodate only passengers with full capacity or passengers with partial loads

3.4.3. Demonstration planning

The demonstration planning will be divided in two runs. The first run refers to deployment of the proposed 50 kWp Microgrid setup and testing demonstration. After the first run, adaptations and adjustments will be performed, leading to the second run, the operational demonstration.

The first run of the demonstration planning will be divided in two levels. The first level will include the deployment, demonstration and validation of the stable and continuous operation of the microgrid, later the deployment of the software and hardware, as well as the uninterruptable communication of the tools and the components. The existing facility integration to the proposed microgrid will be tested with different options in the first run. The second level will consist of the validation of the advanced functionalities that the RE-EMPOWERED tools facilitate, such as the optimization of the microgrid operation and control. The detailed plan is given in the table below. Activities within each run/level need not be performed in sequence.

First demonstration run (testing demonstration)		From M28	To M32
A	Basic Functionality	From M28	To M32
A1	Continuous supply to all end customers (security of supply)		
A2	Frequency / Voltage stability		
A3	Battery System charge / discharge		
A4	Start / supply / stop of the various energy vector such as Biomass, Biogas and existing system		
A5	Uninterruptable function of the communication systems		
A6	Consumption data collection and storage		
B	Advanced functionality	From M30	To M33
B1	Microgrid optimal management of operation		
B2	Installation of smart meters and Increased energy monitoring at demand side		
B3	Platform as a service for dependent tools integration		
B4	Data storage and cloud server		
B5	Charing infrastructure testing for three wheelers		
Adaptations and adjustments		From M30	To M34
Second demonstration run (operational demonstration)		From	To

		M34	M37
C1	ecoMicrogrid operation & communication		
C2	ecoDR operation & communication		
C3	ecoPlatform operation & communication		
C4	ecoVehicle Operation		
C5	Scheduling and Coordination		
C6	Outreach forum of ecoCommunity		
C7	Guidance and Training		

Involved partners	Contributions
IIT BBS	Keonjhar Demo Site Leader. Leading the WP 4 (Innovation in infrastructure development) and also take part in developing tools like ecoConverter, ecoVehicle ecoEMS/Microgrid.
CSIR-CMERI	Leading the implementation of the ecoDR and ecoVehicle deployment.
VNIT Nagpur	Leading the implementation of the ecoVehicle (Charging Infrastructure)
IIT KGP	Development of Business models, impact assessment and replication strategies.
ICL	Leading the implementation of the ecoCommunity tool
ICCS-NTUA	Leading the implementation of the ecoMicrogrid, ecoPlanning
DTU	Leading of the implementation of ecoPlatform
PROTASIS	Providing and setting up the necessary hardware for the ecoMicrogrid tool

3.4.4. Business models, regulatory and social considerations related to deployment and demonstration actions

Business Model

In the Keonjhar District of Odisha – three villages viz., Kanheigola, Nola and Ranipada – are supplied with clean energy of 77 kWp isolated solar micro grid to approximately 1000 people. The project proposes to upgrade this existing infrastructure through indigenously developed technology by deploying secondary 50kW micro grid comprising various renewable energy vectors with a mix of PV, Biomass and Biogas, a unique local energy solution. Each house in these villages is provided with 100 W for residential requirements i.e. basic lightning facilities during evening hours.

- It will be equipped with advanced energy management system and integration.
- Commercial three-wheeler will be tested and deployed with charging infrastructure, especially designed to fulfil the local needs of the community
- Smart meters with load limiter and load management
- IoT based remote measuring system
- Solar dimmable streetlights with configurable brightness, energy saving ensuring public safety

State-of-the-art hardware and software solutions will be tested not only for technical upscaling but also for economic viability having higher efficiency coupled with low cost. This will enhance access to clean energy mostly for commercial activities by replacing fossil fuel and build new income streams in the involved community. Novel product features enables the users and operators for responsible energy consumption as well as production conditions. Seamless integration and interoperability allows low outages while providing cumulative saving, optimal usage with high satisfaction rate. This will make RE microgrid community systems attractive and feasible to serve low-income tier customers and will encourage rational fiscal and promotional incentives facilitating private investment on account of increasing market characterized with sufficient internal rate of returns.

The proposed business model will establish sustainability by addressing current challenges with a scope to configure and deliver measurable impact towards livelihood creation, entrepreneurship development, social upliftment, reduce migration, better health and education, etc. To enable such deep impact, it is imperative that the proposed technical solutions are demonstrated successfully with continuous operation and maintenance support. This will be achieved by capacity building of the local community members by imparting technical knowledge, training and skilling. Possible scenarios for dynamic pricing may be estimated from advanced forecasting algorithms to offer affordable tariffs from consumption patterns. IoT remote monitoring will further equip the service providers to exercise some control and data management.

Regulatory

Odisha has undertaken necessary policy formulation and implementation over past few years to propel growth of various RE vectors. Odisha Electricity Regulatory Commission has issued (Procurement of Energy from Renewable Sources and its Compliance) Regulations 2015 for purchase of electricity, making it mandatory for obligated entities to source certain percentage of their power purchase form RE sources. According to the National Tariff Policy 2016, the RPO to reach 8% solar by 2022. In order to achieve targeted capacity in State, solar capacity will be added mainly through four means:

1. Land based solar projects: IDCO has identified patches of land under its Land Bank Scheme to set up solar plants and projects. The project developer may utilize energy generated for self-consumption or selling power within / outside State.

2. Utilizing water bodies: Areas under lakes, reservoirs, canals and ponds can be considered for solar projects development by mounting solar PV panels or floating technologies. GRIDCO in co-ordination with concerned departments notify tenders for power procurement through competitive bidding.
3. Consumer side of meter: Decentralized mode for promoting small scale solar PV projects on consumer side of meter. Investors/ consumers develop rooftop PV by connecting to the grid at either 33 kV/11 kV or 440/ 220 V phase depending on the system size. Odisha Renewable Energy Development Agency shall be nodal agency for projects below 1 MW capacity and higher than that will be implemented by Green Energy Development Corporation of Orissa Ltd. Net metering facility to be extended to all project developers and follow guidelines.
4. Solar parks: It has dedicated zones for development of solar power generation projects, solar manufacturing projects and R&D.

Odisha Renewable Energy Development Agency undertakes commercial feasibility of Biomass Power Projects with resource assessment and supply chain mechanism to identify biomass catchments in different parts of State. Government of Odisha will make land available to project developer according to IPR-2015. Waste and fallow lands may be allocated for plantations to meet up to 20% of annual biomass fuel requirement. State Government to develop Odisha Renewable Energy Development Fund for accelerated development of RE in State. According to Orissa Draft Renewable Energy Policy 2015-22, targets under policy are 2300 MW solar and 180 MW biomass. Various incentives under Odisha Industrial Policy, 2007 provided, for power being sold to off-grid areas, an additional subsidy of INR 0.50/kWh will be provided for first three years of operation. Also, an incentive of INR 0.50 per unit to be provided on gross generation from systems installed by residential consumers. Further, exemption from electricity duty and cess for a period of 10 years from the date of commissioning will be given with waiver of some test charges.

Odisha Electricity Regulatory Commission amended Net Metering / Bi-directional Metering and their connectivity with respect to Rooftop Solar PV Projects. As, several issues such as group net metering, virtual net metering etc. have been raised by various stakeholders so Ministry of New and Renewable Energy requested States to issue guidelines. In addition, Ministry of Power, has made amendment to the Electricity (Rights of Consumers) Rules, 2020 and has capped the maximum Net Metering capacity of a Prosumer up to 500 kW or up to the sanctioned load, whichever is lower. After considering the notification of Ministry of Power and advisory of Ministry of New and Renewable Energy, as well as suggestions from various stakeholders, the Commission hereby made amendments to Net Metering/ Bi-Directional Metering/ Gross Metering/ Group Net Metering/ Virtual Net Metering and their connectivity with respect to Solar PV Projects 2016 (as amended up to 05.05.2022). Virtual Net Metering Framework shall be applicable for consumers under “Domestic” and “Specified Public Purpose” category as per Odisha Electricity Regulatory Commission Distribution (Conditions of Supply) Code, 2019 and also for the offices of Government/ local authorities. The capacity of the Renewable Energy System under Group Net Metering or Virtual Net Metering framework to be installed by any Renewable Energy Generator shall not be less than 5 kW and more than 500 kW.

4. Conclusions

This deliverable describes the deployment and demonstration plans for each of the four demo sites of the RE-EMPOWERED project: Bornholm (Denmark), Kythnos (Greece), Ghoramara (India) and Keonjhar (India).It should be noted that theKythnos demo-site covers two independent test sites: the Kythnos power system and the Gaidouromandra microgrid.

The existing infrastructure at each demo site has been described, as well as the plans for upgrades to this infrastructure, both directly within the framework of RE-EMPOWERED as well as separate upgrades that directly impact and benefit the project's demonstration activities.

Summaries of each ecoTool, developed through RE-EMPOWERED, have been provided in relation to each demo-site. These summaries cover each ecoTool's function, input and output parameters, communications protocol, and measurement parameters, as they relate to the individual demo sites. For each tool, primary and secondary use cases were defined in (RE-EMPOWERED, D2.1, 2021) and mapped to the individual demo sites to which they were applicable. This deliverable provides detailed planned actions for the deployment and implementation of the ecoTools appropriate to each demo site to realize each of the identified use cases.

Demonstration plans have been presented for each demo site, categorized into two main runs: a first demonstration run focused on testing demonstrations, after which adaptations and adjustments may be implemented; followed by a second demonstration run focused on final, operational demonstrations. Business models, regulatory and social considerations have been included in each of the four demonstration plans.

This deliverable thus provides a detailed and concrete deployment and demonstration plan for the activities in Tasks 7.2–7.4. In doing so, this deliverable is an important step towards the overall objectives for RE-EMPOWERED.

5. References

[1] RE-EMPOWERED, D2.1, "Deliverable 2.1: Report on requirements for each demo, use cases and KPIs definition," 2021.

[2] RE-EMPOWERED, D2.3, "Deliverable 2.3: Report on the technical architecture and specifications," 2022.

[3] RE-EMPOWERED, D10.1, "Deliverable 10.1: H-Requirement No.1," 2022.

[4] RE-EMPOWERED, D10.2, "Deliverable 10.2: POPD-Requirement No.2," 2022.

[5] RE-EMPOWERED, D10.3, "Deliverable 10.3: NEC-Requirement No. 3," 2022.

[6] RE-EMPOWERED, D10.4, "Deliverable 10.4: EPQ-Requirement No.4," 2022.