RE-EMPOWERED

Renewable Energy EMPOWERing European & InDian Communities

Deliverable 7.3 / 7.2b: Report on deployment of RE-EMPOWERED solutions

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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 filings, 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)
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Executive Summary

The overarching goal of RE-EMPOWERED is to develop a set of solutions (ecoToolset) namely ecoEMS, ecoMicrogrid, ecoPlanning, ecoDR, ecoPlatform, ecoConverter, ecoMonitor, ecoCommunity, ecoVehicle and ecoResilience for efficient, de-carbonized and RES-intensive multi-energy local energy systems. This deliverable reports on the deployment phase of the ecoToolset in the four demo sites laying the foundation for the demonstration phase.

For each demo, a brief introduction with general description and background details is provided, along with an overview of the deployed solutions. For each ecoTool, a description is given that outlines the goal of deploying the particular ecoTool, highlighting its purpose and necessity for the specific demo site and generally for the project, but also providing insights on its technical diversification for the specific site implementation. Moreover, a discussion takes place about the specific challenges faced during deployment phase, reporting the procedure followed and the solutions applied to overcome the various difficulties encountered. In addition, the deployment timeline for each tool is presented along with photographs of the deployment activities, proving its status, and a time-plan for the future steps. Furthermore, a summary of the completed works and main achievements for each demo-site with respect to ecoTools' deployment as well as the contribution of the partners to achieve this outcome are presented.

Throughout the deployment phase of RE-EMPOWERED solutions, numerous challenges were encountered, which were overcome by the joint efforts of the European and Indian partners.

Keywords:

Local Energy Systems, Deployment, Bornholm, Kythnos, Ghoramara, Keonjhar, ecoTools, ecoEMS, ecoMicrogrid, ecoResilience, ecoDR, ecoMonitor, ecoConverter, ecoCommunity, ecoPlanning, ecoVehicle, ecoPlatform.

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Acronyms

Acronym	Description
AMI	Advanced Metering Infrastructure
API	Application Programming Interface
APK	Android Application Package
BESS	Battery Energy Storage System
BLDC	Brush Less Direct Current
CHP	Combined Heat and Power
DER	Distributed Energy Resources
DH	District Heating
DHN	District Heating Network
DSM	Demand Side Management
DSO	Distribution System Operator
EB	Electric Boiler
EMS	Energy Management System
ESB	Enterprise Service Bus
EV	Electric Vehicle
GDPR	General Data Protection Regulation
HVAC	Heating Ventilation and Air Conditioning
ILC	Intelligent Load Controllers
IoT	Internet of Things
KSI	Kythnos Smart Island
LCD	Liquid Crystal Display
LES	Local Energy System
LMSWT	Locally Manufactured Small Wind Turbine
MGCC	Microgrid Central Controller
MPPT	Maximum Power Point Tracking
MQTT	Message Queuing Telemetry Transport
NIIPS	Non-Interconnected Power Systems
OREDA	Odisha Renewable Energy Development Agency
PLC	Programmable Logic Controller
PPC	Partial Power Converter
PSO	Particle Swarm Optimization
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Source
SCADA-HMI	Supervisory Control and Data Acquisition – Human Machine Interface
SLAM	Smart Low-cost Advanced Meter
SOC	State of Charge
SWT	Small Wind Turbine
TSO	Transmission System Operator
UC	Use Case
UI	User Interface
VPN	Virtual Private Network
VRLA	Valve Regulated Lead Acid
WTP	Willingness to Pay

1 Introduction

1.1 Purpose and Scope of the document

The RE-EMPOWERED project aims to provide local communities with tools for economic and social development through sustainable energy systems. To achieve these goals, the project has delivered a suite of “ecoTools,” deployed them at four demo sites across the EU and India, and is currently demonstrating their value in energy systems at different scales and levels of maturity. The solutions of the toolset are tailored to the specific needs of the four pilot cases in India and EU but they are designed for a wide range of microgrids to foster the replication and exploitation in both the developed and developing world. In particular, the Indian demo-site Ghoramara Island in West Bengal has explored the use of the ecoToolset in a newly-built 100%-RES standalone system aiming at improved energy access for sustainable community development, while Keonjhar in Orissa, India examined the upgrade of the existing rural microgrid towards higher energy availability and affordability. In EU, Bornholm demo-site focused on unlocking the demand flexibility for higher RES utilization in grid-connected islands and Kythnos has increased whole system efficiency and digitization. Kythnos demo also includes the Gaidouromantra microgrid, a small 100% RES system, which has been upgraded using the ecoToolset. The four demo sites have different starting points in terms of infrastructure, size, technologies, socioeconomic boundaries, and actors, while they operate under different regulatory regimes.

Deliverable D7.3 / D7.2(b) reports on the deployment phase of RE-EMPOWERED solutions in the four demo sites laying the foundation for the demonstration phase that is ongoing. In each demo site, different types of RE-EMPOWERED developed ecoTools have been installed, based on the particularities of each case. The scope of this document is to present the latest updates on the deployment phase of each tool in the respective demo sites, describing in detail what was implemented in each case with reference to details on the procedure followed and the steps taken to overcome the various challenges encountered. The status of the activities is explained, along with deployment timelines and selected photographs of the installations. Moreover, future timeline and main achievements for each demo-site with respect to ecoTools’ deployment/demonstration are presented and the involved partners’ contribution to the deployment activities is explained. A summary of the mapping between the demos and tools is shown in Figure 1 (adjusted from D7.1 [1]).

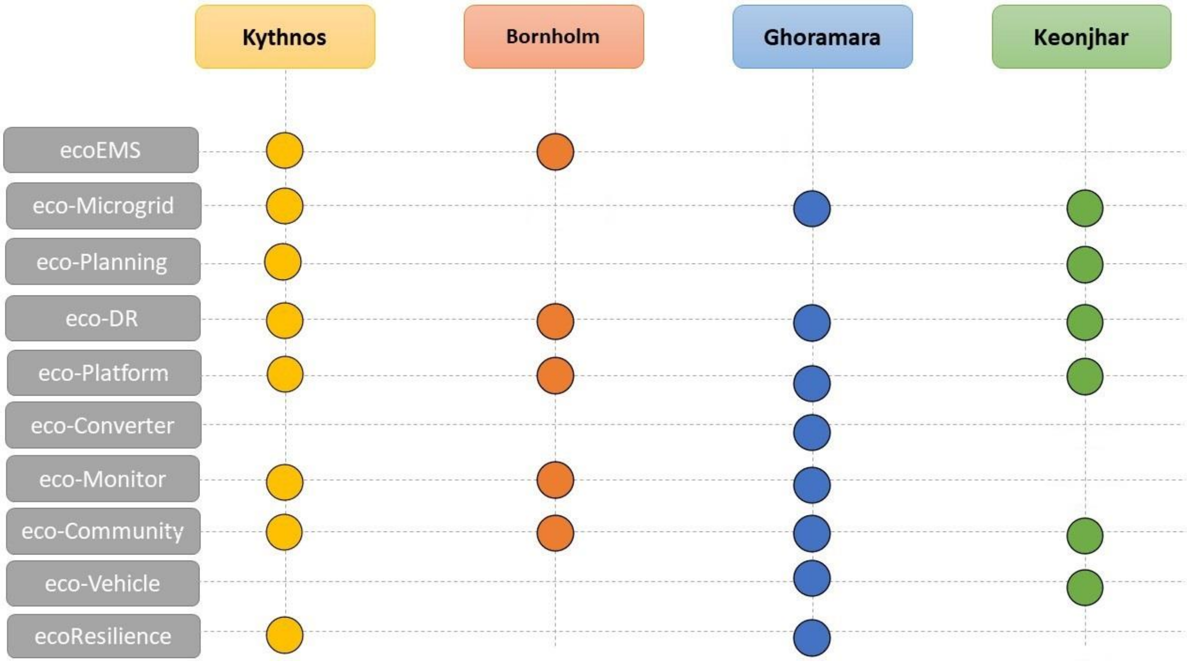


Figure 1: ecoTools to be demonstrated at each of the four demo sites in RE-EMPOWERED.

1.2 Structure of the document

This document is structured as follows:

Section 2 describes the ecoTools deployment at Ghoramara Island, West Bengal in India and the details of each ecoTool that has been installed are provided: ecoMicrogrid, ecoConverter, ecoVehicle, ecoDR, ecoMonitor, ecoResilience, ecoCommunity, ecoPlatform. The challenges faced during the deployment are also mentioned.

Section 3 describes the ecoTools deployment at Keonjhar, Orissa in India and the details of each ecoTool that has been installed are provided: ecoMicrogrid, ecoVehicle, ecoDR, ecoPlanning, ecoPlatform and ecoCommunity. The challenges faced during the deployment are also mentioned.

Section 4 describes the ecoTools deployment at Kythnos demo site, Greece and the details of each ecoTool that has been installed are provided: ecoEMS, ecoMicrogrid, ecoDR, ecoPlanning, ecoPlatform, ecoMonitor, ecoResilience and ecoCommunity. The challenges faced during the deployment are are also mentioned.

Section 5 describes the ecoTools deployment at Bornholm Island, Denmark and the details of each ecoTool that has been installed are provided: ecoEMS, ecoDR, ecoPlatform, ecoMonitor and ecoCommunity. The challenges faced during the deployment are also mentioned.

Section 6 details the development of some additional ecoMicrogrid functionalities that occurred following the completion of tasks T3.1 and T4.1. It provides a brief overview of the State of Charge (SOC) algorithm implemented to address the absence of data regarding the SOC of the battery systems at the Indian demo sites which is critical for the effective operation of the ecoMicrogrid tool.

Section 7 concludes the document.

2 Ghoramara Island

2.1 Introduction

Ghoramara Island is located approx. 92 kilometers south of Kolkata, in the Sundarbans of the Bay of Bengal. The nearest mainland is Kakdwip which is approximately 5 km away and takes around 1 hour to reach with 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% belong to the SC category, and 20-30% belong to the minority group.

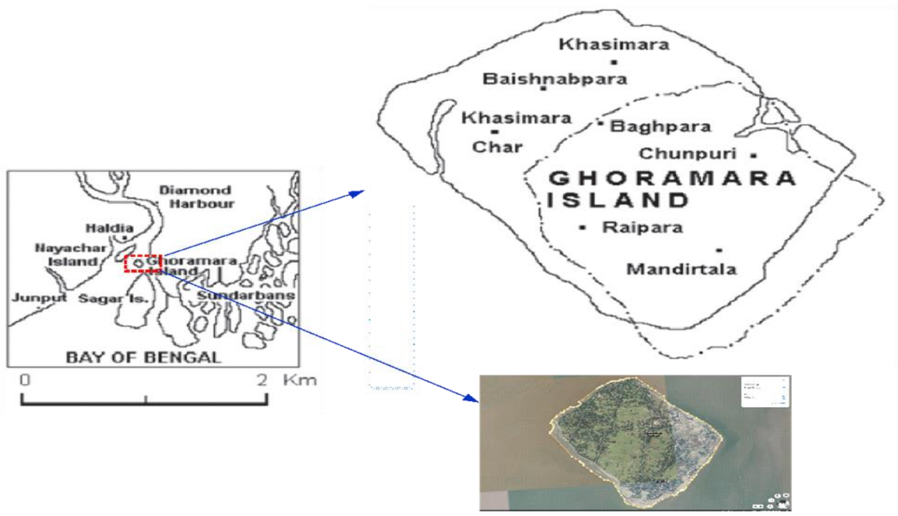


Figure 2: Ghoramara Location

2.1.1 Aim

- Develop and demonstrate various energy vectors integration, by means of high energy efficient converters and its control.
- 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.
- Increase of population awareness and customer engagement, such that rural to urban migration can be minimized.

2.1.2 Background Information

- Around 3000 residents and over 1100 houses.
- Utility grid is not available on the island.
- Two primary schools, one higher secondary school (420 students), and a primary health care center are available on the island.
- A few shops (around 30 in number) are in 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 main source of income is agriculture (mainly betel leaves, and rice) in which 85-90% of people are involved, and the remaining people are dependent on fishing.
- Two rice-cum-hauler mills are present in the island which are run by diesel engine.

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

2.1.3 Status of Commercial Infrastructure

- 150 kW Solar PV module already installed in the Ghoramara Island.
- Battery and Inverter are placed in the control room.
- Distribution line work is completed.
- Two electric three-wheelers are already deployed in the Ghoramara Island.
- EV Chargers and charging stations are installed on the Island.
- Solar High-mast light is deployed in the market area of the Ghoramara Island.

Figure 3: Solar PV Modules at Ghoramara

Figure 4: Battery Storage at Ghoramara

Figure 5: Inverter in Control room at Ghoramara

Figure 6: Distribution Line work completed at Ghoramara

Figure 7: Electric Three-Wheeler

Figure 8: EV Chargers at Ghoramara

Figure 9: Solar High-mast at Ghoramara

2.2 Overview of Tools and Solutions to be demonstrated

The following ecoTools will be demonstrated in Ghoramara Demo site:

Table 1: ecoTools demonstrated in Ghoramara Demo site.

ecoTool	Ghoramara Demo Site
ecoEMS	
ecoMicrogrid	✓
ecoPlanning	
ecoDR	✓
ecoPlatform	✓

ecoConverter	✓
ecoMonitor	✓
ecoCommunity	✓
ecoVehicle	✓
ecoResilience	✓

2.3 ecoMicrogrid

2.3.1 General Description

The deployment of the ecoMicrogrid tool at the Ghoramara Island pilot site utilizes a subset of the tool's capabilities, focusing on core functions that add significant value to the pilot, but also considering the existing limitations. The unique requirements of the Ghoramara site necessitate a tailored approach, deviating from the full functionalities of the tool. The functionalities that are being utilized include:

- **Demand Response Functionalities**: The ecoMicrogrid tool will be tested for its demand response functionalities.
- **SCADA Visualization and Control**: The system includes SCADA visualization for real-time monitoring and control, providing comprehensive oversight of the microgrid's operations.
- **Integration with Other ecoTools**: ecoMicrogrid is being integrated with other ecoTools like ecoPlatform-b, ecoCommunity, and ecoDR to enhance its capabilities.

2.3.2 Purpose of Deploying This Tool

The deployment of the ecoMicrogrid tool at the Ghoramara Island pilot site aims to demonstrate the tool's core capabilities and their impact on enhancing the microgrid's performance. The specific purposes include:

- **Demand Response Management**: To optimize energy consumption and manage demand efficiently, adapting to the specific energy usage patterns of Ghoramara Island.
- **Real-Time Monitoring and Control**: To provide comprehensive oversight through SCADA visualization, ensuring efficient and reliable operation of the microgrid.
- **Enhanced Integration**: To seamlessly integrate with other ecoTools like ecoPlatform-b, ecoCommunity, and ecoDR, enhancing the overall functionality and performance of the microgrid.

2.3.3 Demo Site Specific Challenges Faced During Deployment

The deployment of the ecoMicrogrid tool at the Ghoramara demo site faced several challenges that needed to be addressed to ensure a successful and seamless implementation. These include logistical difficulties due to the site's remote location, environmental factors that could affect the timeline, and limitations in available infrastructure.

- **Remote Location**: The remote location of the Ghoramara site presents logistical challenges, including transportation difficulties and maintaining the basic communication with the deployment team, as access to the internet was limited. Furthermore, the availability of basic and commonly used equipment and tools was lacking in the local market (many hours by car) making the planning and pre-works even more challenging.
- **Environmental Conditions**: Harsh environmental conditions, such as the rainy season lasting until September, had impact on the deployment of the microgrid system and has postponed the scheduled site visit of the European partners in Sept 2024.
- **Lack of Infrastructure:** The delays in the deployment of important infrastructure created a significant information gap, as the technical details of the relevant equipment were not available from early on for review and planning. The infrastructure related to ecoMicrogrid (i.e. the ecoConverter) was completely installed during the beginning of October. For the integration of the ecoMicrogrid, extra meter devices were installed to provide the necessary information.
- **Planning Difficulties**: Without a clear understanding of the current infrastructure's specifications, it was challenging to plan accurately for future developments or upgrades.
- Moreover, one of the challenges encountered was the lack of information on the **State-Of-Charge** (SOC) of the battery system at the Ghoramara site. This information is crucial for the functionality of the developed tools. Thus a SOC algorithm had to be developed and implemented. A brief description of the SOC algorithm is provided in section 6.1.

2.3.4 Deployment Timeline

The deployment of the ecoMicrogrid tool at the Ghoramara Island pilot site involved a series of activities planned to ensure successful integration and operation. Pre-deployment phase involved collecting all the required details and information to ensure the system's compatibility and functionality.

In Ghoramara, external commercial meters were utilized for collecting the required electrical parameters. Equipment installation was scheduled to happen alongside the deployment of ecoMicrogrid hardware. The ecoMicrogrid software had already been ported to the hardware ready for shipment, while in Athens, Greece. Integration with the installed equipment and microgrid assets occurred in early October 2024, including SCADA parametrization.

Final configuration was also performed, with adjustments made to ensure optimal performance and establishing communication with ecoCommunity and ecoPlatform-b. The integration with ecoPlatform-b enhances the continuous monitoring of the microgrid, promoting the long-term reliability and performance of the ecoMicrogrid.

Table 2: Deployment Status of ecoMicrogrid tool in Keonjhor Demosite

Task	Status	Expected Completion
Pre-Deployment Activities	Completed	-

Equipment Installation	Completed	-
Deployment of ecoMicrogrid Hardware	Completed	-
Software Configuration	Completed	-
Integration and Testing	Completed	-
Final Configuration	Completed	-
Establish Communication with ecoCommunity and ecoPlatform-B	Pending	October 2024
SCADA Integration	Completed	-
Ongoing Monitoring and Maintenance	Ongoing	Continuous

2.3.4.1 Current Status

The deployment phase of ecoMicrogrid on Ghoramara site was concluded with a site visit by ICCS-NTUA and PROTASIS partners in early October 2024 to ensure effective implementation. The demonstration of ecoMicrogrid is directly correlated with ecoConverter's operation, whose demonstration is anticipated to be performed by October 2024. During the site visit, the various works that took place regarding ecoMicrogrid deployment concerned the following:

- The metering panel construction and installation on ecoConverter with the external commercial meters and current transformers.
- A router panel construction and installation along with its switch and external antenna.
- The interconnection Ethernet network of all assets and tools with ecoMicrogrid.
- The actual communication establishment of ecoMicrogrid with all other assets.
- The configuration of SCADA-HMI system and the tool's database.
- The training of manager and operator persons on the ecoTool's features and handling.

Figure 10: ecoMicrogrid in control room at Ghoramara demo site.

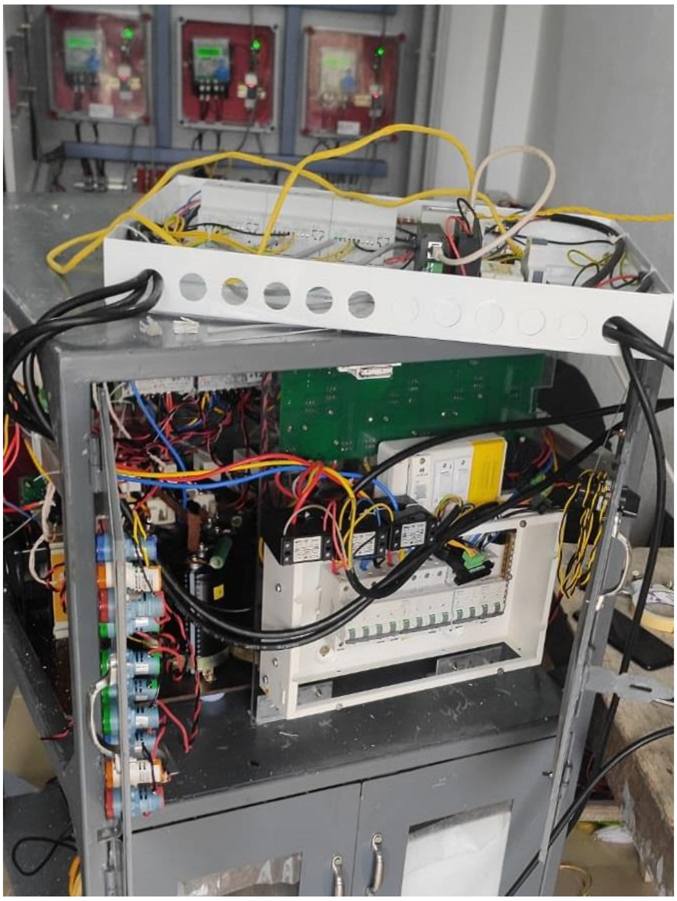


Figure 11: Metering panel construction for ecoConverter measurements at Ghoramara

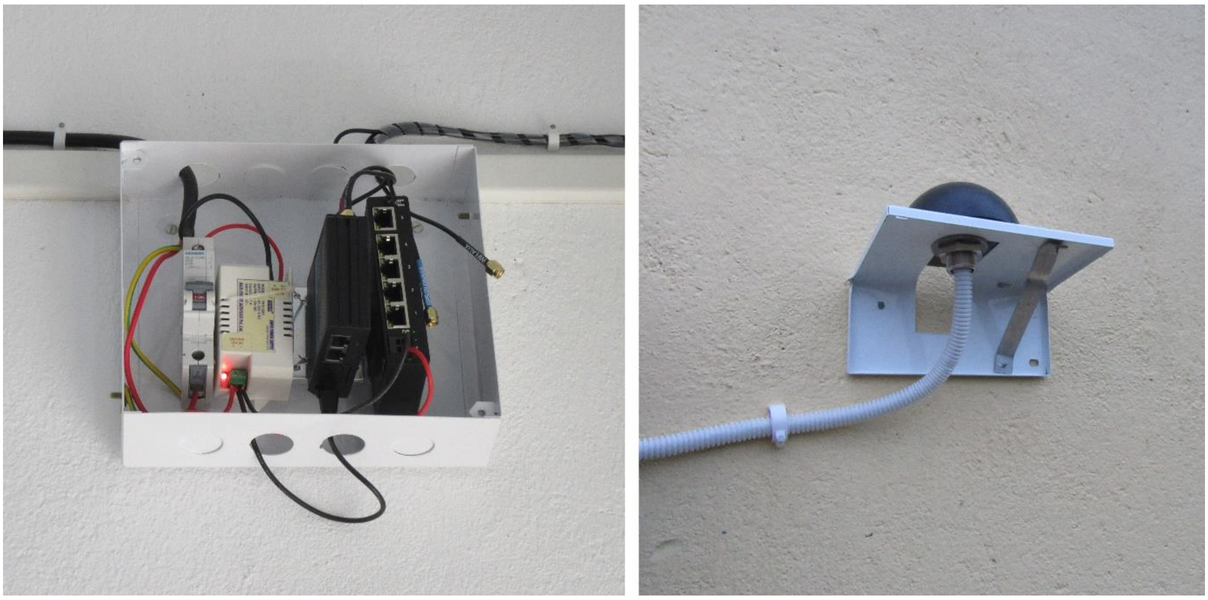


Figure 12: Router panel and external antenna placement at Ghoramara

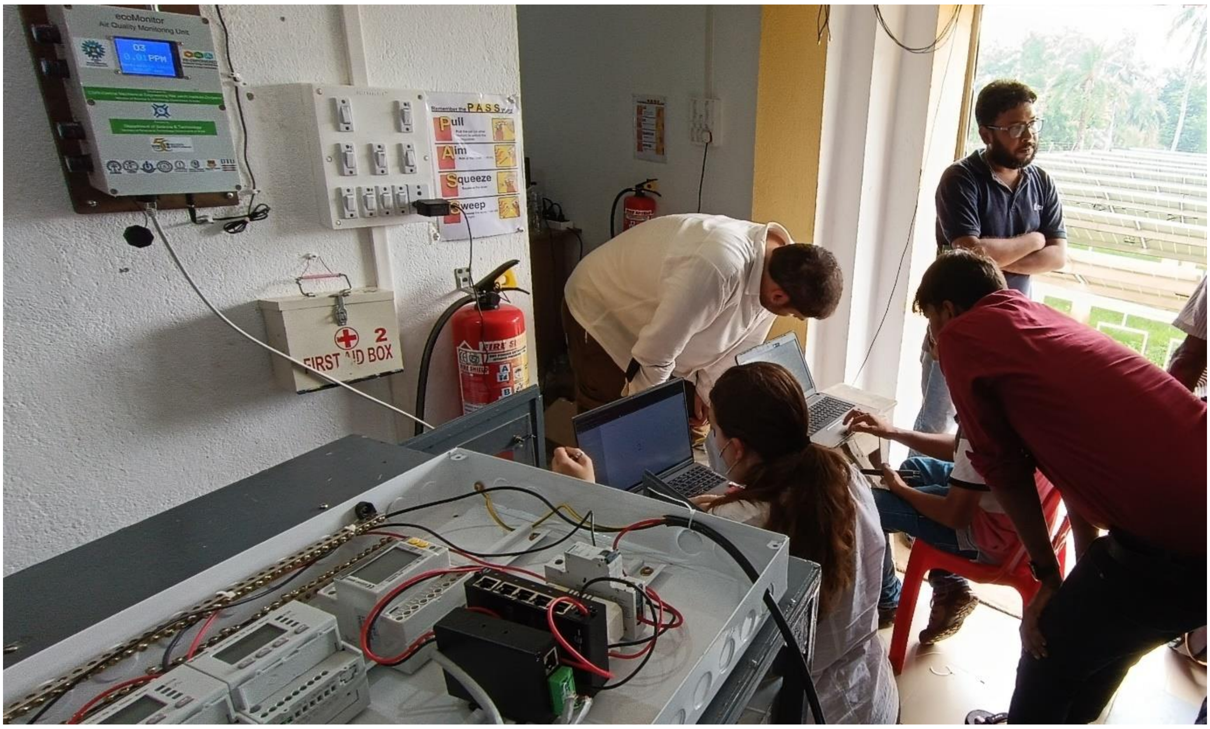


Figure 13: Work on communication establishment between ecoMicrogrid and rest of assets (ICCS-NTUA, PROTASIS, IIT KGP and CMERI colleagues in Ghoramara)

2.3.4.2 Future Plan

Following the completion of the deployment phase, several key activities will ensure the ongoing success and operation of the ecoMicrogrid system.

- **Establish Communication with ecoCommunity and ecoPlatform-b:** Scheduled for October 2024, this will facilitate continuous monitoring and improve the overall efficiency and reliability of the microgrid.

- **Ongoing Monitoring and Maintenance:** Continuous monitoring and maintenance activities will be conducted to ensure long-term reliability, performance, and optimization of the ecoMicrogrid system.

2.4 ecoDR

2.4.1 General Description

The ecoDR tool is an advanced smart meter with innovative features to enhance energy management and control. It encompasses a wide range of functionalities aimed at improving energy measurement, load control, and remote monitoring of non-critical loads. It incorporates advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities, allowing for efficient measurement of household energy consumption. Additionally, the smart meters can communicate with other ecoTools, such as ecoMicrogrid, to implement demand-side management services through non-critical load scheduling.

Key features of ecoDR include a static single-phase, two-wire energy meter with various parameters available for measurement, such as Irms, Vrms, active energy, power factor, apparent power, and load. The smart meters also come equipped with a visible indicator for poor power factor, an LCD for display, and support for MODBUS communication protocol.

Advanced functionalities integrated into the developed meters include an inbuilt programmable load and energy limiter, load-shedding controller, and two output ports for critical and non-critical loads. Additionally, the meters can support the management of non-critical loads through scheduling and control based on commands from the ecoMicrogrid.

2.4.2 Purpose of Deploying This Tool

The ecoDR smart meters maintain a log of events, collecting critical electrical parameters like Vpeak, Vrms, Ipeak, Irms, active energy, power factor, apparent power, and reactive power, along with timestamps. The relevant data are transmitted to ecoMicrogrid for computation of cost based on real-time pricing data. Further, the inbuilt load shedding controller functionality of the developed ecoDR tool creates a temporary local load shedding once the connected load exceeds the predefined threshold limit. In case overload persists, the variable cut-off delay between two successive overload trip events varies (increases), thereby improving the reliability of the system. This arrangement helps with the even distribution of energy amongst the consumers for the demo site (e.g. Ghoramara) where the energy demand is high compared to energy generation.

2.4.3 Demo Site Specific Challenges Faced During Deployment

Ghoramara site is a remote location presenting various challenges that had to be dealt with in order to accomplish ecoDR deployment. These include logistical difficulties, environmental factors that could affect the timeline, and limitations in available infrastructure. Late installation of the Ethernet network infrastructure, essential for tool's communication, serves as a characteristic example.

2.4.4 Deployment Timeline

2.4.4.1 Current Status

Deployed in the demo site in September 2024 and integrated with the rest ecoTools in early October 2024.

Figure 14: ecoDRs at Ghoramara site.

2.4.4.2 Future Plan

ecoDR deployment is recently completed and next steps involve continuous data collection and analysis as part of the demonstration activities.

2.5 ecoPlatform

2.5.1 General Description

ecoPlatform B is an advanced integration tool designed to facilitate seamless communication and data exchange between various ecoTools within a demo site. It leverages a dockerized architecture to ensure modularity, security, and ease of deployment across different environments. The platform comprises key subsystems including the Enterprise Service Bus (ESB), a centralized Database, a Storage Microservice, an API for data visualization, and a user-friendly Front-end Dashboard.

2.5.2 Purpose of Deploying This Tool

The primary purpose of deploying ecoPlatform B is to create a cohesive environment where multiple ecoTools can operate together efficiently. By standardizing data exchange protocols and providing robust storage and visualization capabilities, ecoPlatform B aims to enhance the operational efficiency and data management practices of sustainability initiatives at the demo sites. This integration supports informed decision-making and promotes sustainable practices through real-time data insights.

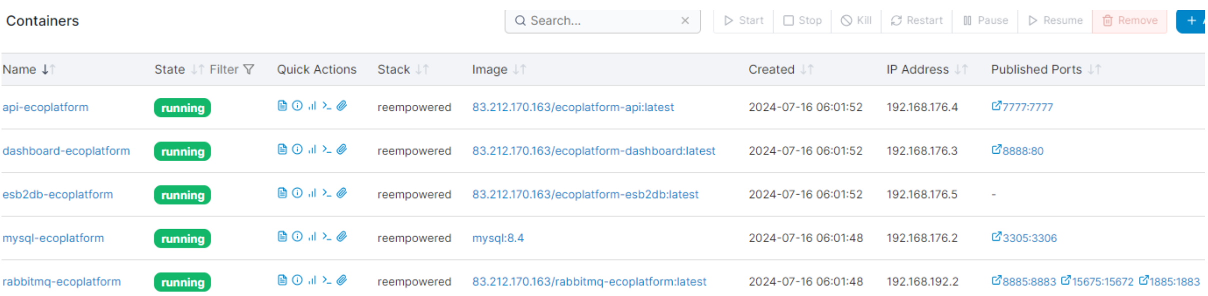
2.5.3 Demo Site Specific Challenges Faced During Deployment

Deploying ecoPlatform B at Ghoramara demo site presented unique challenges. These included adapting the platform to the specific technical infrastructure and data requirements, ensuring reliable network connectivity, and managing the diverse data formats from different ecoTools. Additionally, the need for localized data storage solutions and the integration of site-specific ecoTools required tailored deployment strategies to ensure seamless operation.

2.5.4 Deployment Timeline

2.5.4.1 Current Status

As of the latest update, ecoPlatform B has been successfully deployed at Ghoramara demo site by October 2024, with core subsystems like the ESB, Database, API, and Front-end Dashboard fully operational. Integration of key ecoTools with ecoPlatform_B such as ecoCommunity and ecoMicrogrid has been completed.


Containers

Search... Start Stop Kill Restart Pause Resume Remove

Name	State	Quick Actions	Stack	Image	Created	IP Address	Published Ports
api-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-api:latest	2024-07-16 06:01:52	192.168.176.4	7777:7777
dashboard-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-dashboard:latest	2024-07-16 06:01:52	192.168.176.3	8888:80
esb2db-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-esb2db:latest	2024-07-16 06:01:52	192.168.176.5	-
mysql-ecoplatform	running		reempowered	mysql:8.4	2024-07-16 06:01:48	192.168.176.2	3305:3306
rabbitmq-ecoplatform	running		reempowered	83.212.170.163/rabbitmq-ecoplatform:latest	2024-07-16 06:01:48	192.168.192.2	8885:8883 15675:15672 1885:1883

Figure 15: List of ecoPlatform B containers deployed at Ghoramara

2.5.4.2 Future Plan

Future plan for ecoPlatform B includes the finalization of data visualization features by mid-November and comprehensive demonstration and quality assurance by the end of November 2024. There are also plans to refine data integration processes and enhance the platform's scalability and interoperability to support a broader range of ecoTools and sustainability services.

2.6 ecoConverter

2.6.1 General Description

A 10 kW microgrid system was fabricated in the laboratory, in the framework of RE-EMPOWERED project, which was deployed to Ghoramara island for demonstration. Several ecoTools developed in the project will be validated in the framework of this hardware. The microgrid can integrate three different energy sources, i.e., solar, wind, and energy storage, and is able to feed islanded AC loads. Multiple power peaks may be generated under the presence of partial shading which may not be tracked accurately by a conventional P&O MPPT method. To address this issue, a Particle Swarm Optimization (PSO) based MPPT search algorithm is proposed that can find the global peak with good accuracy in less time. The use of PPC and plug-and-play type converters in the microgrid makes it more efficient and flexible.

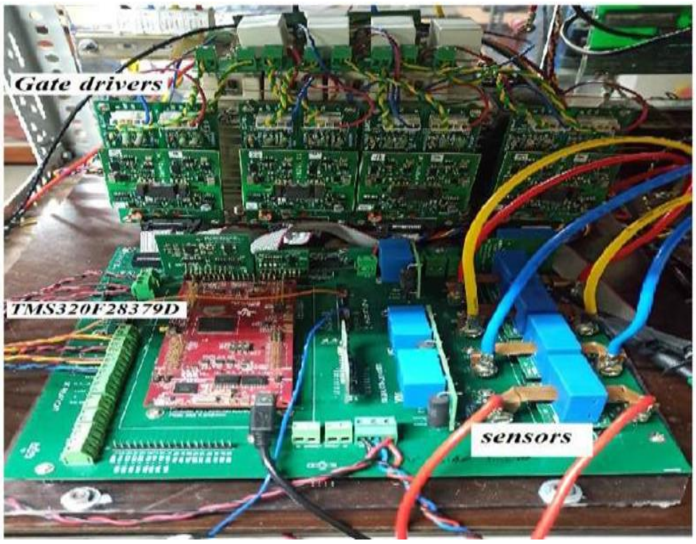


Figure 16: Plug and Play Type Microgrid converter

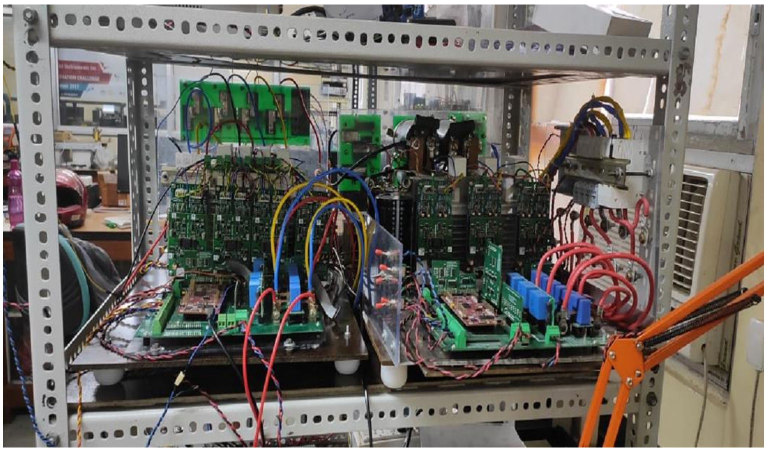


Figure 17: Communication Enabled ecoConverter

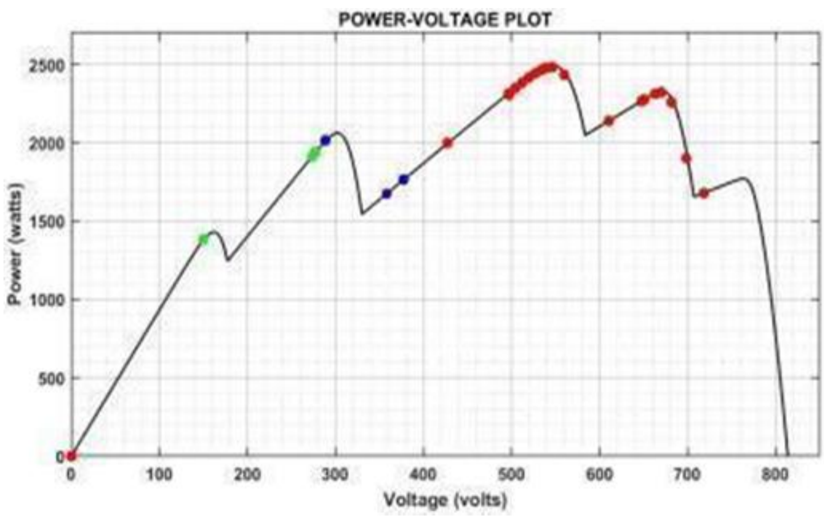


Figure 18: Power vs Voltage Plot of the ecoConverter

2.6.2 Purpose of Deploying This Tool

This tool is deployed because it has these features:

- 3 input and 1 output ports
- Lower losses
- High power capture during partial shading
- No shut down at low voltage MPP
- Particle Swarm Optimization (PSO) algorithm for global peak search
- Fast MPPT tracking
- Islanded operation

2.6.3 Demo Site Specific Challenges Faced During Deployment

Because of the remote location of the Ghoramara Island, a challenging issue encountered was the restricted availability from the vendor side for the deployment of the tool, which resulted in delay of the ecoConverter deployment on site. Furthermore, the rainy season and bad weather condition with duration of 3 to 4 months at that region of India, unavoidably, causes delays in all processes.

2.6.4 Deployment Timeline

2.6.4.1 Current Status

The ecoConverter was tested in the laboratory environment of IIT KGP. The deployment at the Ghoramara Island was done in late September 2024. While on the field, it was found that there is a necessity for some minor improvement modifications and should split the complex bulky system in two, separating converters from transformers. In this way, ecoConverter will be easier to be handled, arrange things into control room more properly and work can proceed smoothly.

Figure 19: EcoConverter at the Ghoramara demo site.

2.6.4.2 Future Plan

After the modifications are completed, the next steps involve more tests of the ecoConverter to be performed on the site to examine the performance and reliability in field conditions of the tool. The results will be presented as part of the demonstration activities.

2.7 ecoMonitor

2.7.1 General Description

ecoMonitor is a digital control platform equipped with multiple sensors and a microcontroller-based processing unit for real time monitoring of the local ambient air quality parameters, such as NO_2, O_3, SO_2, CO, PM2.5 and PM10 micro particles, including ambient temperature and relative humidity. The measured air quality data is transmitted to the central control station via MODBUS/MQTT gateway for display and further analysis.

The system is a battery powered by a solar panel-based charger unit. It is intended for use in an outdoor environment with remote monitoring to collect information about ambient air quality parameters.

In addition to remote monitoring, the tool features a local display unit with color indication, which alerts the local community once any of the air quality parameters exceed the maximum allowable limit.

2.7.2 Purpose of Deploying This Tool

This ecoMonitor data provides useful insights regarding possible corrective actions of air quality and helps in analyzing the impact of the Renewable Energy Resources (RES) integration on air quality.

2.7.3 Demo Site Specific Challenges Faced During Deployment

The ecoMonitor transfers the air quality data to the central control station through ethernet using MODBUS protocol. ecoMonitor is designed to operate mostly as a standalone unit making it relatively simple to integrate within the whole system. For its deployment, it requires only a single phase power supply, internet access and MODBUS protocol configuration for proper communication with ecoPlatform. However, stable and reliable internet access is not available which was essential for real-time data collection and transmission. This issue has been partially addressed by installing the necessary auxiliary internet infrastructure i.e. the external antenna.

2.7.4 Deployment Timeline

2.7.4.1 Current Status

The ecoMonitor tool has been deployed in September 2024 in the Ghoramara demonstration site, where it is monitoring real-time air quality parameters and displaying them on the local screen.

Figure 20: ecoMonitor at Ghoramara site.

2.7.4.2 Future Plan

The future plan includes continuous data collection and analysis to evaluate the ecoMonitor's performance in real-world conditions. This ongoing evaluation is intended to identify areas for potential improvement and optimize the ecoMonitor's functionality.

2.8 ecoCommunity

2.8.1 General Description

The ecoCommunity tool acts as a digital platform facilitating engagement and support for the energy community in the Ghoramara demo site. The energy community consumers and demo site administrators utilize a mobile application as the interface for the tool. The data associated with the tool is stored in the cloud database.

The deployment of the tool includes hosting the could database, installing the mobile application of the tool, as well as testing and verifying communication with other ecoTools.

The Google Firebase cloud service is utilised for the cloud database, and the server location is selected as Mumbai, India. The administrator instance of the mobile application is responsible for maintaining communication with ecoMicrogrid, and the storage of data in the cloud database. The consumer instance of the tool will use the data from the cloud database for visualization and user engagement.

The key modules of the ecoCommunity tool deployed at the Ghoramara demo site are “consumption”, “pricing”, “load booking”, “problem reporting”, “forum” and “help and support” modules. The user interface of the mobile app includes English, Hindi, and Bengali language options. The Hindi and Bengali language option for the tool improves the ease of using the app for the local energy community.

The energy consumption module relies on the ecoDR measurement which is obtained from ecoMicrogrid through the ecoPlatform. These measurements will be stored in the cloud database of the ecoCommunity tool for analysis or visualization. The real-time pricing indication data will be received from the ecoMicrogrid tool on an hourly basis.

The load-booking module utilizes the forecasted available energy data received from ecoMicrogrid. The energy availability for 1 Day + 24 Hours is published daily at 12:01 am by the ecoMicrogrid tool and will be utilized for generating the bookable timeslots in the ecoCommunity tool. The consumer users can book the time slots to use any available shared communal loads. The booking summary for 24 Hours will be published by ecoCommunity at midnight.

2.8.2 Purpose

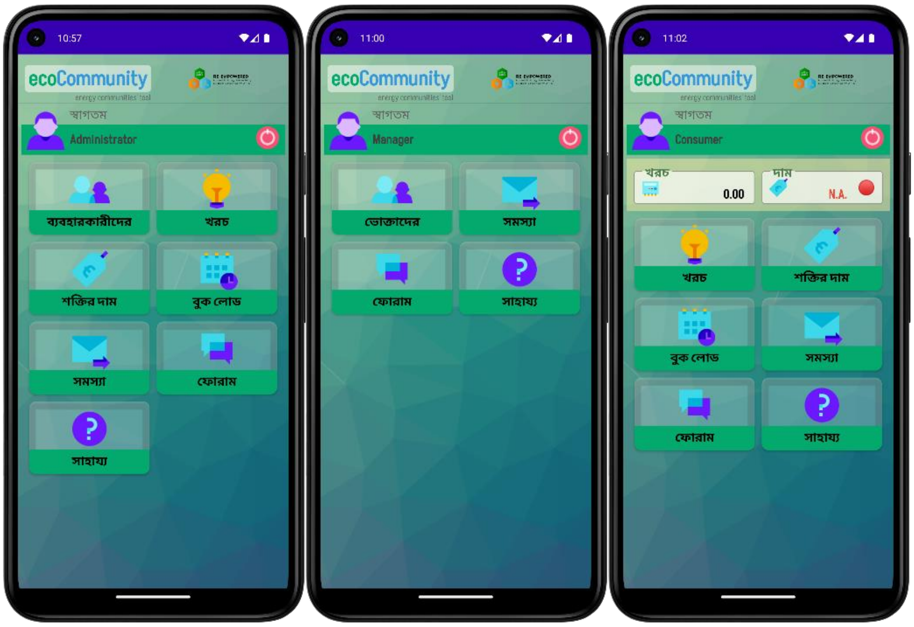
The purpose of the ecoCommunity tool in the Ghoramara demo site is to facilitate community engagement in the microgrid operation by providing access to real-time as well as historical consumption data, real-time variable pricing/status indication data, and community load management and coordination.

The access to consumption data enables energy users of the demo site to regulate or adjust their consumption based on personal and communal requirements. The real-time variable pricing indication provides suggestions to consumers on the time durations for which the energy prices are comparatively lower so that the non-critical loads can be connected without much energy charges for consumers who are liable to variable pricing tariffs. This pricing indication is also associated with a status indication which can be used by the energy community to understand the microgrid's operational status about energy availability and the system's efficiency. Based on the status indication, the community can take appropriate measures to maintain the stability and reliability of the systems by voluntarily disconnecting the non-critical loads.

The coordination and management of the communal loads is another aspect catered for by the tool. Based on the energy availability, a set of time slots will be displayed in the tool for the energy consumers to book for using the shared communal loads. This facilitates better coordination and use of the load and demand side management.

The problem reporting and help and support module is intended for the support of the energy community. The problem reporting and forum module facilitates a platform for feedback and suggestions from the energy community members. The forum provides a common space for energy users to share their experiences and suggestions on the microgrid system.

The help and support module supports the hosting of the manuals and other ecoTool-related documents. The demo site administrators can upload and update the documents through the mobile application interface.



(a) (b) (c)

Figure 21: Screenshots of ecoCommunity tool deployed in Ghoramara (a) administrator (b) manager (c) consumer

2.8.3 Demo Site specific Challenges faced during Deployment

The ecoCommunity tool is a digital platform with its prime interface as a mobile application and for its operation and effective use, energy users must have access to a smartphone and internet connectivity. This was a key challenge in the deployment of the tool. The challenge of the lack of a reliable network connection for mobile phones is addressed using the offline capabilities of the tool which will store an instance of the data and user input on the local database in the mobile phone and later synchronize with the cloud server. The lack of access to smartphones for many energy consumers is addressed using the manager module which is used by manager users to access the consumer modules on behalf of the consumer users.

2.8.4 Deployment Timeline

2.8.4.1 Current Status

The cloud database for the storage of data is hosted since November 2023 using Google Firebase service with the server location in Mumbai, India. The user interface text of the tool translated into Hindi and Bengali and has been reviewed by the demo site leader. The demo site specific version of the mobile application APK has been developed and tested for communication and data exchange with ecoMicrogrid via ecoPlatform by August 2024.
The details of consumers and managers participating in the demonstration as well as details on the energy meters and loads are currently being gathered through demo site leaders.

2.8.4.2 Future Plan

The tool database and APK is being parameterized and updated to include the details of the users participating in the demonstration, meter information, booking loads, help and support documents etc. The parameterized tool APK will finally be installed and demonstrated using the mobile phones of the demo site users. The parameterization and final installation are scheduled for October/November 2024.

Table 3: Deployment Timeline of ecoCommunity tool in Ghoramara demosite.

Sl. No.	Task	Status	Expected Completion
1	Creation of a cloud database for the storage of data. Server Location: Mumbai, India	Completed	-
2	Review and finalize the tool UI text translation - English to Hindi, Bengali.	Completed	-
3	Integration of demo site specific modules and development of APK for testing.	Completed	-
4	Deployment and testing of APK with demo site leaders and administrators.	Completed	-
5	Testing and verifying communication and data exchange with ecoTools	Completed	-
6	Gather details on tool users, managers, meters, loads etc.	In-progress	November 10^{th} 2024
7	Tool parameterization and configuration of the database for demonstration	In-progress	November 10^{th} 2024
8	Installation of application on the mobile phones of consumers/managers from demo site.	In-progress	November 10^{th} 2024

2.9 ecoVehicle

2.9.1 General Description

ecoVehicle tool considers the deployment of the means of electrified transportation such as e-three wheelers and e-boat and the charging infrastructure to facilitate the transportation needs through cleaner energy. The e-three wheelers are modified and customized in such a way that it can be easily converted to carry only goods when there are fewer passengers and vice versa. The vehicle's power train is upgraded so that it can be used for transportation of passengers (max 6 persons) and goods within the island. Similarly, a solar-powered e-boat will be deployed to transport 15 passengers for eco-friendly river travel between Ghoramara Island and Sagar Island, and vice versa. At Ghoramara island, PV-fed and battery-energy-storage-(BESS)-assisted 15kWp charging station is considered to provide charging facility to e-three wheelers and e-boat during sun and off-sun hours. Each of the deployed chargers are 3.3kW and the off-sun hour support is around 5 hours with 50% depth of discharge of the BESS system.

2.9.2 Purpose of Deploying This Tool

ecoVehicle tool is being deployed to provide greener means of transportation reducing the current consumption of gasoline for road and river transportation. Deployment of ecoVehicle tool will provide the data of the energy vectors associated with transportation for further analysis and base model for other cases of deployment.

2.9.3 Demo Site Specific Challenges Faced During Deployment

Due to the remote location of Ghoramara Island, a challenging issue encountered was the availability of the vendor for the deployment of the tool, which resulted in delay of the ecoVehicle deployment on site.

Additionally, a technical challenge faced was the availability of insolation data in order to size the battery pack, panels, and converter, and was overcame by using the forecast data from nearby location.

2.9.4 Deployment Timeline

2.9.4.1 Current Status

The customized electric three wheelers have been deployed and handed over to the Ghoramara Gram Panchayat in March 2024. Purchase order for solar power e-Boat has already been issued and the item was dispatched in September 2024. 15kWp PV-fed BESS-assisted charging station with three AC chargers (two for three wheelers and one for e-Boat) is deployed and is operational. One 1.5kW@48-volt DC charger with features such as: power factor correction, 3C/10 rate charging, battery temperature regulated charging and the dc-bus voltage regulation during temperature regulated charging and sudden connection and disconnection of the load is completed and sent for packaging. This charger will also be deployed in Ghoramara Island with the charging station.

Figure 22: Electric three-wheeler and EV Charger on Ghoramara site.

2.9.4.2 Future Plan

Evaluation of the charging infrastructure and means of transportation will be evaluated as one of the energy vectors. Developed and deployed Charging infrastructure will be promoted as a base model for future deployment sites and residential societies.

2.10 ecoResilience

2.10.1 General Description

ecoResilience tool deals with the development of cyclone resilient support structures for ground-mounted solar photovoltaic (PV) arrays and wind turbine systems along with the development, installation, and training of locally manufactured wind turbine system. In ground mounted solar PV support structure, the aerodynamic wind load is minimized by incorporating passive aerodynamic surfaces with the main frame of the solar PV panels. The placement of PV module frame on the central base support is optimized through numerical simulations, wind tunnel testing, and field tests to reduce the aerodynamic loads and moments. For wind turbine support structure, it is difficult to propose a passive system to reduce the loads. Hence, wind loads during cyclone is reduced by minimizing the tower height through mechanical operated chain pulley drive and removal of the blades connected with the generator as the cyclonic wind velocity is completely three dimensional. The hybrid tower has a ladder to access the wind turbine for the removal wind turbine blades during extreme weather conditions and the reattachment of blades after the cyclone to operate in normal conditions for the generation of wind energy. One complete small wind turbine system having a power rating of 3 kW with tilt up tower has to be designed and fabricated using the locally available materials at CSIR-CMERI, Durgapur utilizing technical expertise of ICCS-NTUA, Greece. In connection with this activity, an online workshop titled “Design and Development of Locally Manufactured Wind Turbines for Empowering Rural India (DWTERI-2023)” was organized by CSIR-CMERI Durgapur in collaboration with the ICCS-NTUA on 24 February 2023. The main focus of this online workshop was to teach basics of complete wind turbine design with some of the developed and installed wind turbine systems through appropriate tools developed by RURERG to students, technicians, faculties and entrepreneurs who are interested in the development of wind turbine for rural electrification

Basics of different types of wind turbines, design of aerofoil sections for wind turbines, interfacing of wind turbine with different energy vectors though converters, design of wind generators and blades using online tools developed by RURERG were presented in the workshop by experts from India & NTUA. A follow-up practical workshop hands on training on the development of wind turbine systems with support structures was organized in September 2024. It was organized in the CSIR-CMERI Durgapur, India in collaboration by the Smart grids Research Unit of the Electrical and Computer Engineering School NTUA (Smart RUE) and the Rural Electrification Research Group (RurERG) of the NTUA, as part of the RE-EMPOWERED project.

The designed small wind turbine has a rotor diameter of 4.3 m with a rated power of 3 kW at the designed wind speed of 10 m/s. It was intended to operate at a height of 18 m with a mean wind speed of 4.3 m/s and produce 4450 kWh per year. Students from electrical and mechanical engineering streams from diploma & engineering colleges and staffs from CSIR-CMERI collaborated in teams to construct a small wind turbine from scratch, utilizing basic tools, materials, and fabrication methods in the week-long workshop. Further, RE-EMPOWERED project partners from IIT Delhi and IIT Kharagpur also participated in the workshop. The blades were crafted from wood, the mounting frame from steel, and the tail from plywood. Copper wire was used for the coils, while Ferrite magnets encased in resin formed the stator and rotor of the generator.

The developed wind turbine is transported to the Ghoramara demo site and it is being installed along with commercially procured wind turbines (5 kW). A few training sessions will be organized to educate the locals to operate & maintain all eco- Resilience systems after installation of the systems.

2.10.2 Purpose of Deploying This Tool

The demo site Ghoramara Island often experiences severe cyclones as it is located in the tropical regions. It was affected severely by the past cyclones where many man-made structures, solar PVs, wind turbines & trees were damaged. Most of the commercially available technologies for ground mounted and rooftop PV arrays are designed with a maximum wind speed of 50 m/s (~ 180 kmph). The severe cyclones experienced at Ghoramama Island have a wind speed in excess of 200 kmph which have a tendency to damage PV systems. Hence, the development of cyclone resilient support structures for solar PV systems is under this project. Here, the developed support structure can withstand cyclonic loads produced at wind speeds higher than 250 kmph and able to continuously harness solar energy without any damage.

The proposed site, Ghoramara Island, also has a good wind profile for harnessing wind energy. However, frequent cyclones affect the installed wind energy systems. As the existing wind turbine system commissioned by an NGO to provide basic power needs of the high school got damaged due to cyclone, no attempt was made to install new wind turbine systems. Hence, we have come up with an option of retractable tower with an option to remove blades. The commercially available support structures have no arrangement to prevent the damage of wind turbine blades during cyclones. But our proposed wind turbine support structure is designed in such a manner that the wind loads during cyclone are reduced by minimizing the tower height and removal of blades. The proposed wind turbine with hybrid tower can withstand extreme weather conditions. It helps to increase exploitation of wind energy and the life span of wind turbine systems in the demo site.

Finally, a locally manufactured small wind turbine was included in the plans to be built at CSIR-CMERI, by capitalising the experience of ICCS-NTUA along with the assistance of local technicians and community members. This allows for using available resources of the region, as part of a sustainable process that strengthens local economies and facilitates knowledge sharing, while increasing the resilience of the system, as maintenance can be performed locally.

2.10.3 Demo Site Specific Challenges Faced During Deployment

The proposed demo site Ghoramara is situated at latitude of 22.23°N from the equator and it is severely affected by strong wind velocity and high tides resulting from cyclones. Often the

Ghoramara island is fully waterlogged to a height of 3 to 5 feet during heavy rain and high tide. However, the island is highly fertile and good for farming from post monsoon to summer.

The big problem with an island is that it does not have grid power. The local people use small solar PV systems mainly for light in the evening. The road is hardly 3 to 5 feet. Most of the villagers use cycles for commuting and few three-wheelers have come up recently. The water level around the island fluctuates severely by a few 10 feet daily. This causes a huge challenge in the transportation of items. Further, a maximum of 3 to 4 trips are available to commute to the island and they may also get affected during rough sea conditions. Transporting items to the installation site for their deployment is also highly challenging due to the non-availability of proper transportation vehicles.

Availability of manpower for deployment work of the tools at proposed demo site is very difficult. The working hours for labor on the island are very minimal due to ferry timing and the labor must commute to mainland every day. These make deployment very challenging and a huge rise in the capital cost.

Furthermore, the installation works are progressing very slowly due to limited power supply during the installation of the hybrid support structure, which is required for the welding process.

Finally, the local manufacturing of the small wind turbine at CSIR-CMERI posed a number of challenges, such as sourcing some of the required materials. Specifically, it was difficult to locate a CNC laser cutting workshop that could cut plywood pieces, and for this reason an alternative CNC milling workshop was found. In addition, sourcing birch plywood locally was a challenge, and for this reason it had to be sourced in other parts of India.

Figure 23: Tested support structure with passive add-on aerodynamic components for Solar PV to reduce aerodynamic loads due to cyclone: at CSIR-CMERI premises.

2.10.4 Deployment Timeline

2.10.4.1 Current Status

Design, development and testing of ground mounted solar PV support structure is performed at CSIR-CMERI Durgapur (See Fig. 23 for the tested PV support structure). The complete PV support structure was transported to the demo site for deployment and the preparation of foundation was delayed due to the rainy season. The deployment work is in progress and expected to be completed by the end of November 2024. Similar to PV support structure, the Hybrid wind turbine support structure is designed, fabricated, installed on field and tested at CSIR-CMERI. 5 kW wind turbine system was installed on the hybrid support structure and checked for operational difficulties (See Fig. 24 for the testing of wind turbine system). A few modifications were made to the support structure after testing such as an increase in number of guy wires & extended arms for more stability of the monopole part of the tower. The support structure with wind turbine systems was transported to the Ghoramara demo site in March 2024. The installation was delayed due to the non-availability of sufficient bidders to execute the work. At present installation of wind turbine is in progress and the wind turbine is expected to produce power by the end of November 2024.

Figure 24. Installed hybrid wind turbine support at CSIR-CMERI for testing

Figure. 25 Installation of hybrid support structure with wind turbine at Ghoramara site

- In September 2024, the small wind turbine manufacturing workshop, SWTERI-2024, was organized in the CSIR-CMERI labs in Durgapur, India by distributing a brochure among students & faculties across India & RE-EMPOWERED partners. ICCS-NTUA colleagues guided the workshop activities on-site. All the materials required for the fabrication of the 2.4 kW horizontal-axis small wind turbine,rated for 11 m/s, had been procured along with the necessary tools in advance. During the week-long workshop, electrical and mechanical engineering students and CSIR-CMERI staff collaborated in teams to construct the small wind turbine from scratch, utilizing basic tools, materials, and fabrication methods. The blades were crafted from wood, the mounting frame from steel, and the tail from plywood. Copper wire was used for the coils, while Ferrite magnets encased in resin formed the stator and rotor of the generator. This wind turbine is now being installed at Ghoramara Island on an existing wind turbine monopole structure.

Figure 24: Manufacturing of 2.4 kW small wind turbine system at CSIR-CMERI through organizing workshop SWTERI-2024 with the participation of ICCS-NTUA

- As part of the project execution plan to install the locally manufactured 2.4 kW wind turbine on the pre-existing monopole structure, the 18-meter monopole tower was decommissioned and brought down with the help of local manpower. All segments of the tower, including the guy wires and foundation, were inspected under the supervision of CSIR-CMERI.

Figure 25: Decommissioning of pre-existing wind turbine support structure with the help of Ghoramara local people.

2.10.4.2 Future Plan

The transported two numbers of solar PV support structures (2 kW) will be installed at the Demo site Ghoramara and connected with the other energy systems.

The hybrid wind turbine support structure with 5 kW wind turbine system will be installed at the proposed demo site and connected to the micro grid using power electronic interface developed by VNIT Nagpur.

The locally manufactured 2.4 kW small wind turbine system at CSIR-CMERI Durgapur will be deployed on the monopole tower structure at Ghoramara demo site and connected to the microgrid using converter developed by IIT Kharagpur in November 2024.

2.11 Main Achievements

- Commercial Deployment is already completed for the Ghoramara demo site.
- ecoVehicle is successfully developed and deployed in the site. Likewise, ecoMicrogrid, ecoMonitor, ecoDR, ecoPlatform have been deployed.
- ecoConverter has been installed

2.12 Contribution Per Partner

Table 4: Contribution chart per partners in Ghoramara Site

Involved partners	Contributions (Ghoramara Microgrid)
IIT KGP	Ghoramara Demo site leader. Engineering, installation and configuration of necessary preliminary equipment such as 160 kW microgrid having 150 kWp Solar PV, 10 kWp wind turbine as energy vectors with 720 kWh of BESS. Conducted the deployment and demonstration plan of Ghoramara. IIT KGP is taking charge of integrating the microgrid with the RE-EMPOWERED developed ecoConverter. Responsible for community engagement and facilitating communication with local citizens and arrangements for site works.
ICCS-NTUA	ICCS-NTUA took charge of the ecoMicrogrid tool deployment undertaking the tasks of the tool's deployment planning, engineering of peripheral necessary equipment, configuration and on-site installation. Works for communication establishment between ecoMicrogrid and all other assets. Also, took charge of the design and construction of the wind turbine for Ghoramara pilot site in the context of ecoResilience. Developer of ecoPlatform B.
PROTASIS	Leading the procurement and provision of the necessary hardware for ecoMicrogrid implementation. Contributed to the deployment of ecoMicrogrid at the site. Provide and implement the software for the collection of the data from the demo's site energy sources (PV plant, Energy Storage System and Wind Generator). Additionally, installed an SCADA-HMI system displaying the single line diagrams and measurement values, focusing on the real-time status of the microgrid.
CSIR-CMERI	Responsible for the development of ecoVehicle, ecoDR, ecoMonitor and ecoResilience tools. Provided specifications for ecoVehicle and ecoDR related preliminary equipment.
ICL	Developed and deployed the ecoCommunity tool and tested the interoperability with other ecoTools. Tested the data exchange with other ecoTools through ecoPlatform.

VNIT	Responsible for the development of ecoVehicle: Charging Infrastructure.

2.13 Conclusions

Due to the demo site's remote location, several obstacles have been surmounted, including land allocation, approval from local authorities, and difficult installations. However, all this has been successfully resolved and 160 kWp Microgrid has been installed and power has been given to the local people. Most of the ecoTools i.e. ecoMicrogrid, ecoConverter, ecoDR, ecoMonitor, ecoVehicle and ecoPlatform, are already deployed in the Ghoramara Demo Site. Full deployment of ecoResilience and of ecoCommunity is still in progress in the Ghoramara demo site. Timewise several uncertainties persist but a complete deployment of the remaining tools is expected to be possible by November 2024, along with the demonstration of all ecoTools in Ghoramara.

3 Keonjhar

3.1 Introduction

Kanheigola, Nola and Ranipada are small Villages/hamlets in Harichadanpur-Tehsil reserve forest in Keonjhar District of Odisha State, India. They are 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. The proposed site was ideal as a test bed and demonstration site as it already had some basic renewable energy facilities. These were upgraded and coupled with various available energy vectors to improve the living standards of the community. A total of 77 kWp Solar PV installations supplying power to approximately 1000 villagers, living in 306 households, were installed by OREDA in 2017-18.
Every house in these villages was provided with 100 W for meeting the basic facilities like 2 tube lights and fans only during nighttime (6 PM to 10 PM).

Figure 26: Location of Keonjhar

3.1.1 Aim

- Develop and demonstrate various energy vectors integration, by means of high energy efficient converters and its control.
- 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.
- Increase of population awareness and customer engagement, such that rural to urban migration can be minimized.

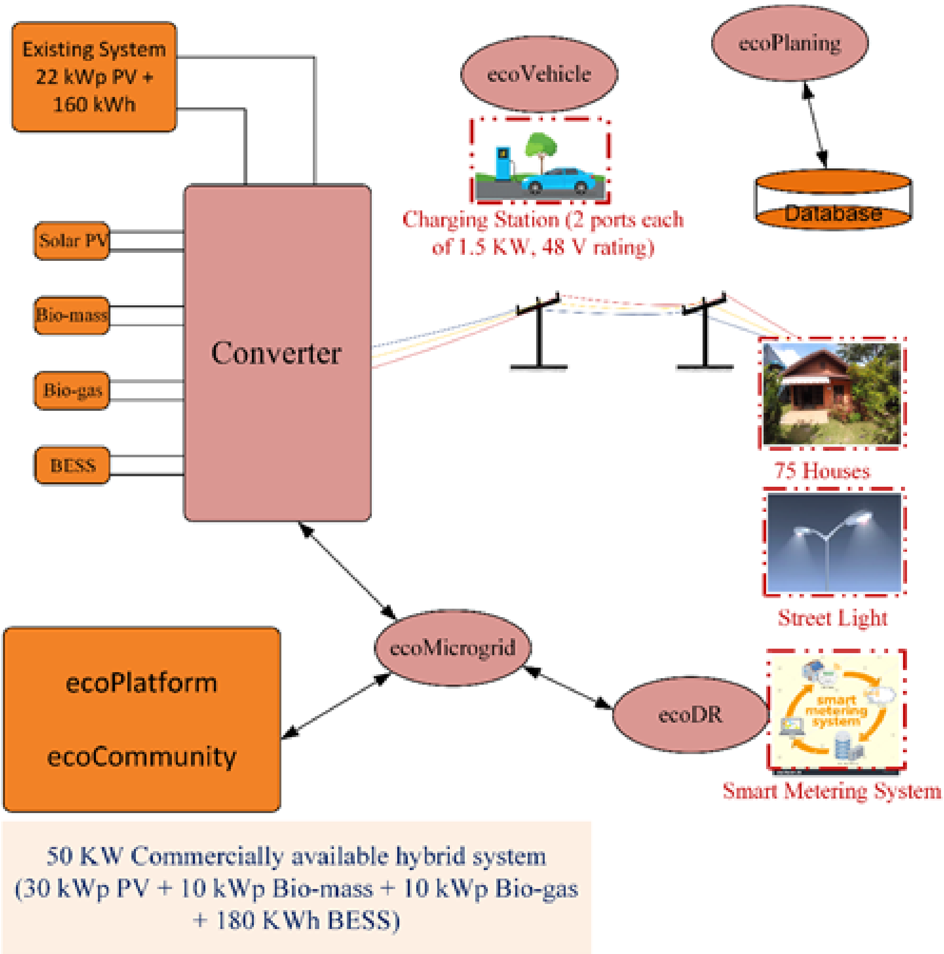


Figure 27: Keonjhar Energy System based on RE-EMPOWERED

3.1.2 Background Information

- 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 Bhubaneswar.
- At present, these villages are not connected to the main utility grid.
- A total of 77 kWp Solar PV installations are supplying to approximately 1000 villagers, living in 306 households **---- OREDA** in 2017-18.

3.1.3 Status of Commercial Infrastructure

- A new 30 kWp Solar PV plant has been commissioned.
- A 10 kWp Biomass plant installation has been completed.
- Civil work and the digester for a 10 kWp biogas plant have been completed.
- A control room containing a solar MPPT controller, inverter, 180 kWh BESS, etc. has been built.
- Two e-three wheelers with charging infrastructure have been deployed to the site.
- CCTVs have been installed.

30 kWp new solar PV plant | *Control room*

180 kWh BESS | *Biomass and biogas engine*

10 kW Biomass Plant

e-three wheeler with seating arrangements | *EV Charger*

Biogas Digester ***Computer***

Figure 28: Installed Commercial Infrastructure

3.2 Overview of Tools and Solutions to be demonstrated

The following ecoTools are to be demonstrated on Keonjhar Demo site.

Table 5: ecoTools demonstrated on Keonjhar.

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

3.3 ecoMicrogrid

3.3.1 General Description

The ecoMicrogrid tool is an Energy Management System (EMS) designed to optimize the overall performance of microgrids. The upcoming deployment of the ecoMicrogrid tool at the Keonjhar Demo Site will be specifically tailored to the electrical vector, considering technologies such as biomass, biogas, PVs, and battery storage technologies. The functionalities that will undergo testing include:

- **Energy Optimization:** The ecoMicrogrid tool will be tested to optimize energy usage across a variety of technologies, including biomass, biogas, PVs, and multiple battery storage. The goal of the tool will be to minimize operational cost of the MG maximizing the utilization of the renewables.
- **Consumption and Production Forecast:** The testing process will assess the reliability and effectiveness of the ecoMicrogrid tool in forecasting both energy

consumption and production within the electrical domain. This involves predicting trends and patterns to enhance overall efficiency.

- **Demand Response Functionalities:** ecoMicrogrid tool will be tested for its demand response functionalities, specifically tailored for the Keonjhar pilot site.
- **SCADA visualization:** The system will include SCADA visualization for real-time monitoring and control.
- **Integration with Other ecoTools:** The ecoMicrogrid will be integrated with other ecoTools like ecoPlatform-b, ecoCommunity, and ecoDR to enhance its capabilities.

3.3.2 Purpose of Deploying This Tool

The aim of deploying the ecoMicrogrid tool at the Keonjhar demo site is to optimize the performance of the microgrid by integrating advanced energy management functionalities. This deployment focuses on the electrical vector and leverages various renewable energy sources and storage technologies to enhance efficiency and reduce operational costs.

Keonjhar, a region known for its challenging environmental conditions, provides an ideal setting to test the ecoMicrogrid tool under real-world circumstances. The area supports a diverse energy infrastructure, including biomass, biogas, photovoltaic systems (PVs), and battery storage technologies.

The deployment of the ecoMicrogrid tool at Keonjhar serves the following purposes:

Minimizing Operational Costs: Implementing advanced management algorithms to reduce operational costs.

Reducing Storage Device Degradation: Employing strategies to minimize wear and tear on energy storage systems, extending their lifespan.

Improving Resilience and Reliability: Enhancing the resilience and reliability of the microgrid through advanced optimization strategies.

Increasing System Observability: Providing comprehensive monitoring capabilities to increase visibility of microgrid operations and performance.

Supporting Community Engagement: Involving the community in microgrid operations by providing access to real-time and historical consumption data, variable pricing, status indications, and tools for community load management and coordination.

3.3.3 Demo Site Specific Challenges Faced During Deployment

The deployment of the ecoMicrogrid tool at the Keonjhar demo site presented several hurdles that needed to be addressed to ensure a successful and smooth implementation. These challenges included logistical issues due to the site's remote location, environmental factors that could affect the timeline, and limitations in available infrastructure information.

- **Remote Location**: The remote location of the Keonjhar demo site presents logistical challenges, including difficulties with transportation and communicating with the deployment team, as access to the internet was absent. Furthermore, the availability of basic equipment and tools was lacking in the local market (many hours by car) making the planning and pre-works even more challenging.
- **Environmental Conditions**: Harsh environmental conditions, such as the rainy season lasting until September, impacted the deployment of the microgrid system and further delayed the scheduled site visit of July 2024.

- **Infrastructure Information**: The existing infrastructure has been recently deployed, but the technical details of the installed equipment are not yet available for review and planning. This lack of information poses challenges for precise planning and integration of new technologies.
- Moreover, one of the challenges encountered was the lack of information on the State-Of-Charge (SOC) of the battery system at the Keonjhar site. This information is crucial for the functionality of the developed tools. Thus, a SoC algorithm had to be developed and implemented. A brief description of the SoC algorithm is provided in section 6.1.

3.3.4 Deployment Timeline

The deployment of the ecoMicrogrid system at the Keonjhar demo site involved a series of activities designed to ensure successful integration and operation. The timeline outlines key tasks to be completed within specific time frames. Initially, pre-deployment testing at the ICCS-NTUA lab validated the system's compatibility and functionality, ensuring that the multiple storage devices and diverse technologies such as biomass and biogas are well-coordinated by ecoMicrogrid. Pre-testing validation of the tool was conducted, using the digital twin of the Keonjhar demo site, which was developed in the Real-Time Digital Simulator. The software was then successfully transferred to the hardware and ecoMicrogrid was prepared for shipping.

Completion of equipment installation at the Keonjhar demo site, except from some special equipment parametrization and configuration that was concluded in parallel with the deployment of ecoMicrogrid hardware and components during the ICCS-NTUA and PROTASIS visit in September 2024.

During the ICCS-NTUA and PROTASIS visit on Keonjhar site, the work was focused on integrating the installed equipment with the ecoMicrogrid. This includes integration with ecoDR and SCADA parametrization. Final configuration was also performed, with adjustments made to ensure optimal performance and establishing communication with ecoCommunity and ecoPlatform-b. The integration with ecoPlatform-b enhances the continuous monitoring of the microgrid, ensuring the long-term reliability and performance of the ecoMicrogrid.

Table 6: Deployment Status of ecoMicrogrid tool in Keonjhor Demosite

Task	Status	Expected Completion
Pre-Deployment Activities	Completed	-
Equipment Installation	Completed	-
Deployment of ecoMicrogrid Hardware	Completed	-
Software Configuration	Completed	-
Integration and Testing	Completed	-
Final Configuration	Completed	-
Establish Communication with ecoCommunity and ecoPlatform-b	Pending due to unavailability of internet	October 2024

SCADA Integration	Completed	-
Ongoing Monitoring and Maintenance	Ongoing	Continuous

3.3.4.1 Current Status

The deployment phase of ecoMicrogrid on Keonjhar site was concluded with a site visit by ICCS-NTUA and PROTASIS partners on late September 2024 to ensure effective implementation. ecoMicrogrid tool was successfully deployed and the demonstration phase is starting after the establishment of internet connection on 29 October 2024. During the site visit, various works took place regarding ecoMicrogrid deployment that concerned the following:

- A router panel construction and installation along with its switch and external antenna.
- The interconnection Ethernet or serial network between commercial energy meters or ecoDRs and the ecoMicrogrid.
- The actual communication establishment of ecoMicrogrid with all other assets.
- The configuration of SCADA-HMI system and the tool's database.
- The training of manager and operator persons on the ecoTool' s features and handling.

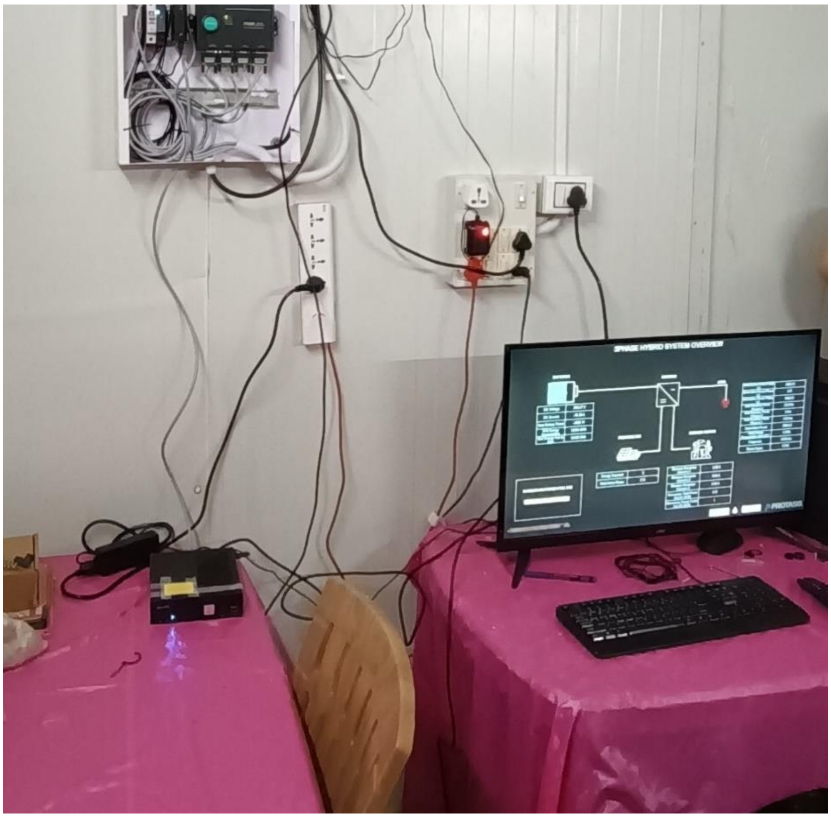


Figure 29: ecoMicrogrid PC in control room at Keonjhar demo site.

3.3.4.2 Future Plan

Following the completion of the deployment phase, several key activities will ensure the ongoing success and operation of the ecoMicrogrid system.

- **Establish Communication with ecoCommunity and ecoPlatform-b:** Scheduled for October 2024, this will facilitate continuous monitoring and improve the overall efficiency and reliability of the microgrid. Subject to internet access availability.
- **Ongoing Monitoring and Maintenance:** Continuous monitoring and maintenance activities will be conducted to ensure long-term reliability, performance, and optimization of the ecoMicrogrid system. Will be enhanced via remote accessibility using internet.

3.4 ecoPlanning

3.4.1 General Description

ecoPlanning is a tool designed to aid decision-makers in the mid-term planning and expansion of power systems for Non-Interconnected Islands (NIIs). It helps evaluate the need for new electricity generation units or the interconnection between NIIs or between NIIs and the mainland. For effective planning, various studies must be conducted. ecoPlanning supports four types of simulations and studies:

- 7-Year Energy Planning: Evaluates the adequacy of generation units to meet the electrical load over a seven-year period.
- RES Hosting Capacity: Assesses the capacity of the power system to integrate Renewable Energy Sources (RES) units.
- Monthly Energy Balance: Analyzes the satisfaction of energy balance equations for specific load time series on a monthly basis.
- Interconnections: Evaluates the feasibility and impact of implementing interconnections.

This tool also includes additional features developed under the RE-EMPOWERED project, focusing on demand response based on multi-energy vectors and considering interconnected power systems and multi-microgrids. These features have been validated through case studies related to the project's demo sites.

3.4.2 Purpose of Deploying This Tool

The deployment of the ecoPlanning tool aims to address the diverse needs and challenges at the Keonjhar demo site. This involves demonstrating the tool’s capability to assist in the planning phase for rural, isolated, or weakly interconnected systems by optimizing the integration of various energy technologies to boost renewable energy generation. ecoPlanning will also facilitate the design and development of high-RES energy systems, incorporating flexibility from Demand Side Management (DSM) and other energy carriers, such as cooling. This was highlighted by examining smart air conditioning DSM activities for Keonjhar.
Earlier system evaluations have simulated and assessed scenarios for new investments in RES capacity. The goals of the RE-EMPOWERED deployment include integrating new tool functionalities, simulating new technologies and synergies, and validating features like DSM flexibility (including cooling) and multi-microgrid cooperation. These functionalities will be tested through case studies related to the RE-EMPOWERED demo sites during the demonstration phase.

3.4.3 Demo Site Specific Challenges Faced During Deployment

ecoPlanning tool was thoroughly prepared and tested within the ICCS lab so no site-specific challenges were faced during the deployment. Access to the tool is granted via internet under a VPN client distributed to key persons, and the tool physically runs on ICCS premises.

3.4.4 Deployment Timeline

3.4.4.1 Current Status

The deployment of the ecoPlanning system at the Keonjhar Island demo site involves several key tasks to ensure successful integration and operation as well as interoperability of the various subsystems. The deployment of the ecoPlanning was completed in June 2024, and was performed on premises of the ICCS-NTUA lab, and access is granted for preselected users.

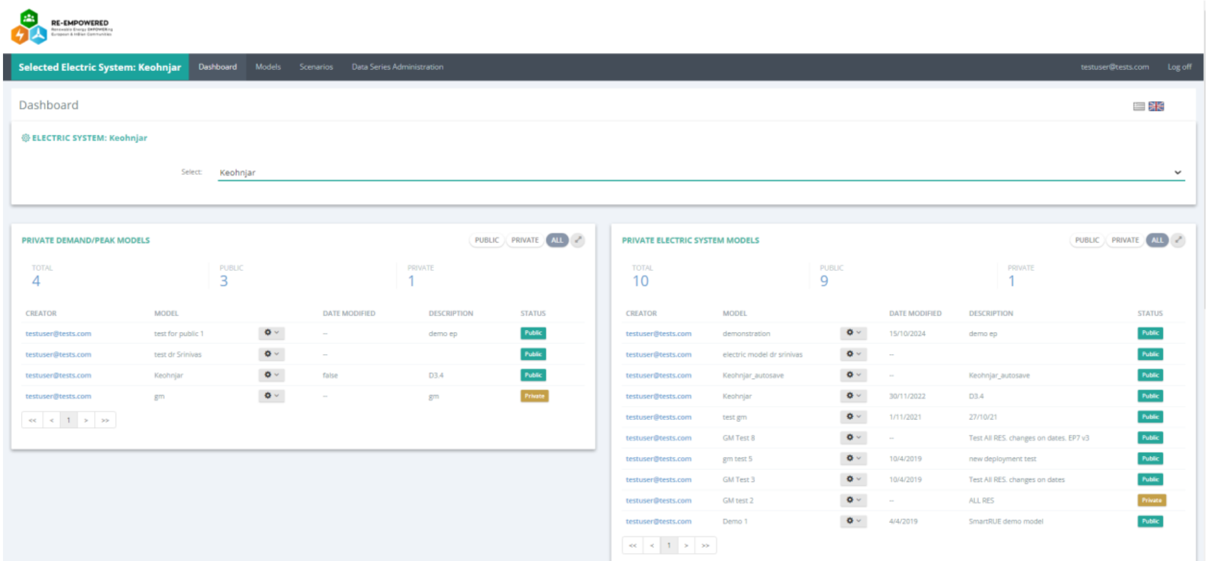


Figure 30: Dashboard - electrical and demand/peak models for Keonjhar.

The tool includes a database where all the necessary data are stored and works as the heartbeat of the tool. So, initial deployment, testing, validating the system's compatibility and stable connection with the Microsoft SQL Server has been performed. Following, identifying potential issues early to ensure a smoother deployment process has monitored the behaviour of various used technologies, such as Microsoft .Net Framework, AngularJs, HighCharts, Bootstrap, MVC.

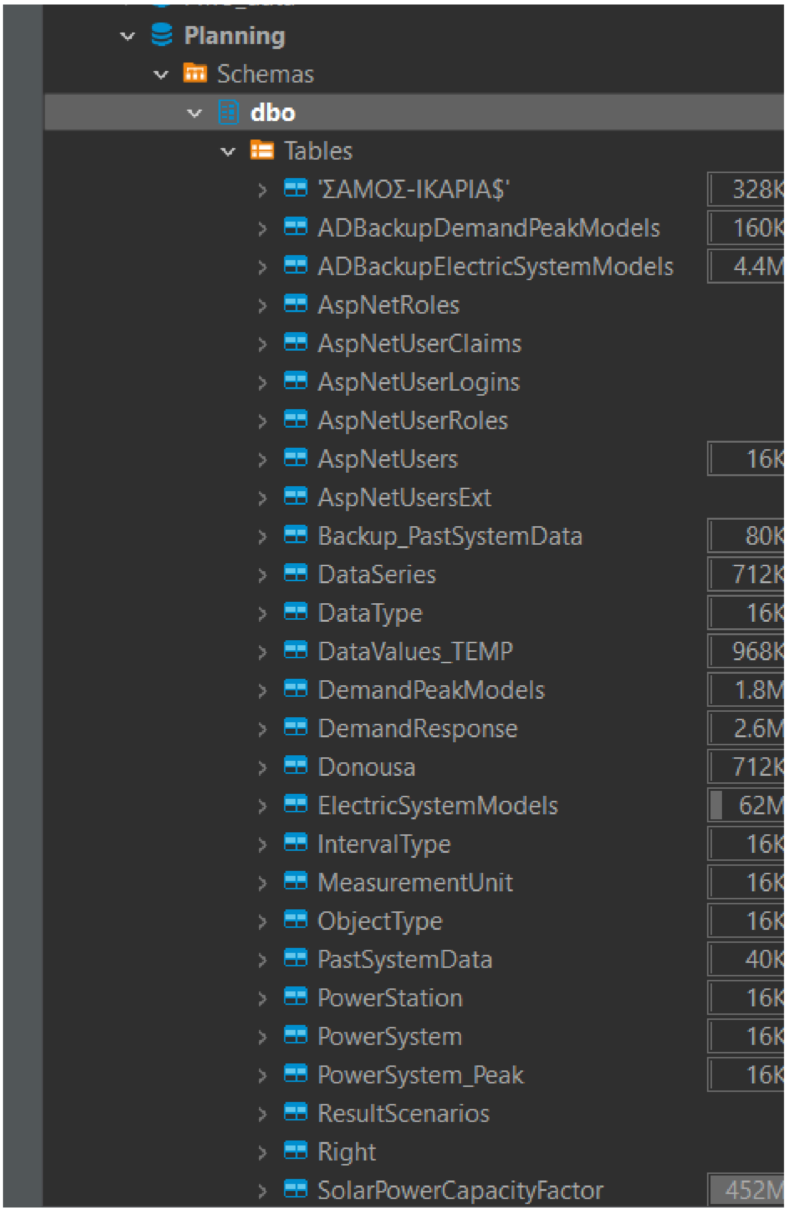


Figure 31: Database tables architecture for ecoPlanning.

Equipment installation is a critical step in the deployment process, so the server which is the key component for the tool deployment has been carefully installed and configured.

The deployment also includes configuring and integrating VPN clients in order to have access to the tool under private network for highest security. Also, a complete user management system (Microsoft Identity Framework) with user register, login, logout and hashed passwords stored in the database has been integrated and successfully deployed.

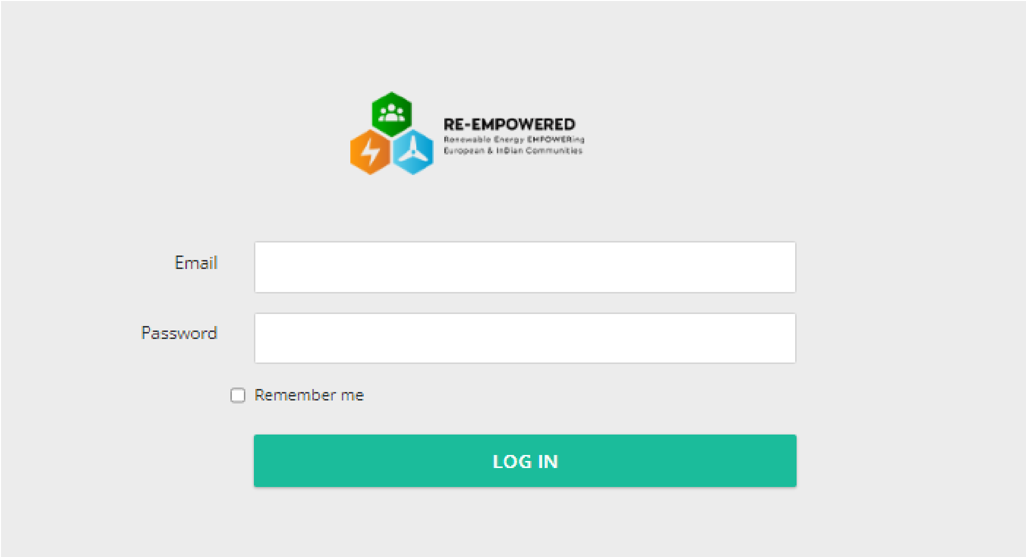


Figure 32: Landing log in page for ecoPlanning.

Table 7: Deployment Status of ecoPlanning tool in Keonjhar Demosite

Sl. No.	Task	Status	Expected Completion
1	Deployment Testing	Completed	-
2	Equipment Installation	Completed	-
3	Deployment of ecoPlanning	Completed	-
4	Software Configuration	Completed	
5	Integration and Testing	Completed	-
6	Establish Communication – access through VPN	Completed	-

3.4.4.2 Future Plan

As the deployment has been completed for ecoPlanning tool for the Keonjhar demo site since June 2024, the next steps are the preparation for the demonstration phase in late October 2024.

3.5 ecoDR

3.5.1 General Description

The ecoDR tool is an advanced smart meter with innovative features to enhance energy management and control. It encompasses a wide range of functionalities aimed at improving energy measurement, load control, and remote monitoring of non-critical loads. It incorporates advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities, allowing for efficient measurement of household energy consumption. Additionally, the smart meters can communicate with other ecoTools, such as ecoMicrogrid, to implement demand-side management services through non-critical load scheduling.

Key features of ecoDR include a static single-phase, two-wire energy meter with various parameters available for measurement, such as Irms, Vrms, active energy, power factor, apparent power, and load. The smart meters also come equipped with a visible indicator for poor power factor, an LCD for display, and support for MODBUS communication protocol.

Advanced functionalities integrated into the developed meters include an inbuilt programmable load and energy limiter, load-shedding controller, and two output ports for critical and non-critical loads. Additionally, the meters offer management of non-critical loads through scheduling and control based on commands from the ecoMicrogrid.

3.5.2 Purpose of Deploying This Tool

The ecoDR smart meters maintain a log of events, collecting critical electrical parameters like Vpeak, Vrms, Ipeak, Irms, active energy, power factor, apparent power, and reactive power, along with timestamps. The relevant data are transmitted to ecoMicrogrid for computation of cost based on real-time pricing data. Further, the inbuilt load shedding controller functionality of the developed ecoDR tool creates a temporary local load shedding once the connected load exceeds the predefined threshold limit. In case of overload persists, the variable cut-off delay between two successive overload trip events varies (increases), thereby improving the reliability of the system. This arrangement helps in evenly distribution of energy amongst the consumers for the demo site (e.g. Ghoramara) where the energy demand is high compared to energy generation.

3.5.3 Demo Site Specific Challenges Faced During Deployment

The ecoDR communicates with other ecoTool such as ecoMicrogrid through RF transmission based system using MODBUS protocol. There is a total of 10 Smart meters provided to the demo site. As the distances are long, providing Ethernet cable to communicate between the smart meter and ecoMicrogrid is not a practical solutions. Also using mobile sim card for communication is involved with recurring expenditure. In order to provide a cost effective solution, an RF communication based connectivity has been deployed in the demo site. RF-Master has all three types of communication port, namely RS485, RS232 and RJ45 and supports Modbus protocol. ecoMicrogrid is compatible with Modbus protocol. RF- Slaves are compatible with RS485 communication, however the smart meters supplied have a connector RS485-RJ45 (Main Output). In order for the communication between the smart meter and the RF-Slave to be established, this connector has been removed from the circuit.

3.5.4 Deployment Timeline

3.5.4.1 Current Status

The laboratory testing of the ecoTool has been completed since March 2024. Interoperability testing with ecoMicrogrid has been successfully completed. Also the RF based communication between smart meter and ecoMicrogrid has been tested. Ten (10) smart meters have been successfully deployed at the site establishing by late September 2024 the RF based communication.

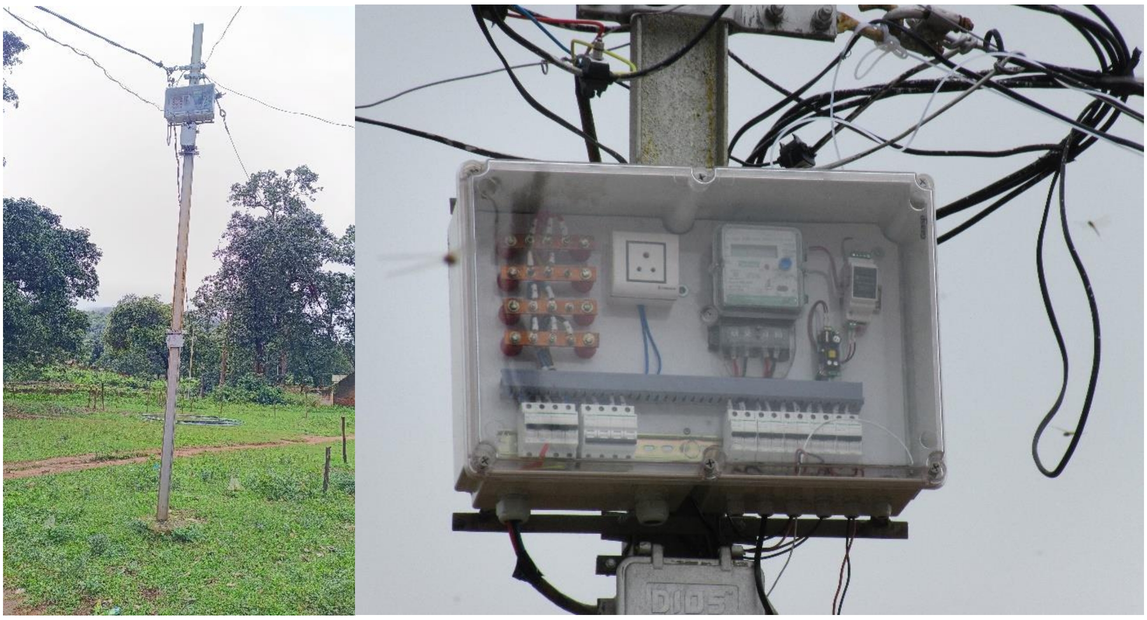


Figure 33: Smart meter at Keonjhar

3.5.4.2 Future Plan

The smart meters have been installed, and load limiters for each house will be deployed in the month of December 2024.

3.6 ecoPlatform

3.6.1 General Description

ecoPlatform B is an advanced integration tool designed to facilitate seamless communication and data exchange between various ecoTools within a demo site. It leverages a dockerized architecture to ensure modularity, security, and ease of deployment across different environments. The platform comprises key subsystems including the Enterprise Service Bus (ESB), a centralized Database, a Storage Microservice, an API for data visualization, and a user-friendly Front-end Dashboard.

3.6.2 Purpose of Deploying This Tool

The primary purpose of deploying ecoPlatform B is to create a cohesive environment where multiple ecoTools can operate together efficiently. By standardizing data exchange protocols and providing robust storage and visualization capabilities, ecoPlatform B aims to enhance the operational efficiency and data management practices of sustainability initiatives at the demo sites. This integration supports informed decision-making and promotes sustainable practices through real-time data insights.

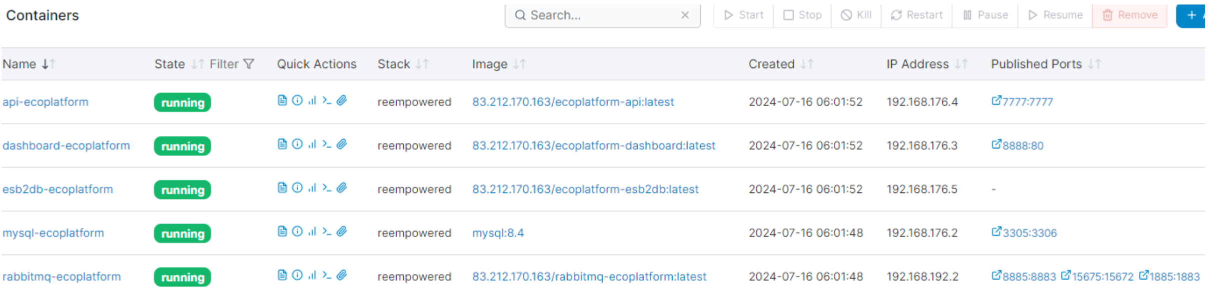
3.6.3 Demo Site Specific Challenges Faced During Deployment

Deploying ecoPlatform B at Keonjhar presented unique challenges. These included adapting the platform to the specific technical infrastructure and data requirements, ensuring reliable network connectivity, and managing the diverse data formats from different ecoTools. Additionally, the need for localized data storage solutions and the integration of site-specific ecoTools required tailored deployment strategies to ensure seamless operation.

3.6.4 Deployment Timeline

3.6.4.1 Current Status

As of the latest update, ecoPlatform B has been successfully deployed at Keonjhar demo site, with core subsystems like the ESB, Database, API, and Front-end Dashboard fully operational. Integration of key ecoTools with ecoPlatform_B such as ecoCommunity and ecoMicrogrid, has been completed by October 2024.


Containers

Name	State	Quick Actions	Stack	Image	Created	IP Address	Published Ports
api-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-api:latest	2024-07-16 06:01:52	192.168.176.4	7777:7777
dashboard-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-dashboard:latest	2024-07-16 06:01:52	192.168.176.3	8888:80
esb2db-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-esb2db:latest	2024-07-16 06:01:52	192.168.176.5	-
mysql-ecoplatform	running		reempowered	mysql:8.4	2024-07-16 06:01:48	192.168.176.2	3305:3306
rabbitmq-ecoplatform	running		reempowered	83.212.170.163/rabbitmq-ecoplatform:latest	2024-07-16 06:01:48	192.168.192.2	8885:8883 15675:15672 1885:1883

Figure 34: List of ecoPlatform B containers deployed at Keonjhar

3.6.4.2 Future Plan

Future plan for ecoPlatform B includes the finalization of data visualization features by mid-November 2024 and comprehensive demonstration and quality assurance by the end of November 2024. There are also plans to refine data integration processes and enhance the platform's scalability and interoperability to support a broader range of ecoTools and sustainability services.

3.7 ecoCommunity

3.7.1 General Description

The ecoCommunity tool acts as a digital platform facilitating engagement and support for the energy community in the Keonjhar demo site. The energy community consumers and demo site administrators utilize a mobile application as the interface for the tool. The data associated with the tool is stored in a cloud database.

The deployment of the tool deals with hosting the could database, installing the mobile application of the tool as well as testing and verifying communication with other ecoTools.

Google Firebase cloud service is utilized for deploying the cloud database and the server location is selected as Mumbai, India. The administrator instance of the mobile application is responsible for maintaining communication with ecoMicrogrid, and the storage of data in the cloud database. The consumer instance will utilize the data stored in the cloud database for visualization as well as to store the user inputs.

The key modules of the ecoCommunity tool deployed at the Keonjhar demo site are consumption, pricing, bills, load booking, problem reporting, forum and help and support modules. The mobile application user interface of the tool includes English, Hindi and Odia language options. The Hindi and Odia language option for the tool improves the ease of using the app for the local energy community.

The energy consumption module relies on the ecoDR measurement which is obtained from ecoMicrogrid through the ecoPlatform. These measurements will be stored in the cloud database of the ecoCommunity tool for analysis or visualization. The real-time pricing indication data will be received from the ecoMicrogrid tool on an hourly basis.

The load-booking module utilizes the forecasted available energy data received from ecoMicrogrid. The energy availability for 1 Day + 24 Hours is published daily at 12:01 am by the ecoMicrogrid tool and will be utilized for generating the bookable timeslots in the ecoCommunity tool. The consumer users can book the time slots to use any available shared communal loads. The booking summary for 24 Hours will be published by ecoCommunity at midnight.

3.7.2 Purpose of Deploying This Tool

The purpose of the ecoCommunity tool in the Keonjhar demo site is to facilitate community engagement in the microgrid operation by providing access to real-time as well as historical consumption data, real-time variable pricing/status indication data, and community load management and coordination.

The access to consumption data enables energy users of the demo site to regulate or adjust their consumption based on personal and communal requirements. The real-time variable pricing indication provides suggestions to consumers on the time durations for which the energy prices are comparatively lower so that the non-critical loads can be connected without much energy charges for consumers who are liable to variable pricing tariffs. This pricing indication is also associated with a status indication which can be utilized by the energy community to understand the operational status of the microgrid concerning the availability of energy and the efficiency of the system. Based on the status indication, the community can take appropriate measures to maintain the stability and reliability of the systems by voluntarily disconnecting the non-critical loads.

The coordination and management of the communal loads is another aspect which is catered for by the tool. Based on the energy availability, a set of time slots will be displayed in the tool for the energy consumers to book for using the shared communal loads. This facilitates better coordination and utilization of the load as well as facilitates demand side management.

The bills module generates bills for energy users based on their energy plans. The problem reporting and help and support module is intended for the support of the energy community. The problem reporting and forum module facilitates a platform for feedback and suggestions from the energy community members. The forum provides a common space for energy users to share their experiences and suggestions on the microgrid system. The help and support module supports the hosting of the manuals and other ecoTool-related documents. The demo site administrators can upload and update the documents through the mobile application interface.

(a) (b) (c)

Figure 35: Screenshots of ecoCommunity tool deployed in Keonjhar (a) administrator (b) users module (c) consumer

3.7.3 Demo Site specific Challenges faced during Deployment

The ecoCommunity tool is a digital platform with its prime interface as a mobile application and for its operation and effective use, energy users must have access to a smartphone and internet connectivity. This is a key challenge in the deployment of the tool. The challenge of the lack of a reliable network connection for mobile phones is addressed using the offline capabilities of the tool which will store an instance of the data and user input on the local database in the mobile phone and later synchronize with the cloud server. The lack of access to smartphones for many energy consumers is addressed using the manager module which is used by manager users on behalf of the consumers to access the consumer modules on behalf of the consumer users.

3.7.4 Deployment Timeline

3.7.4.1 Current Status

The cloud database for the storage of data was hosted using Google Firebase service in November 2023 with the server location in Mumbai, India. The user interface text of the tool translated into Hindi and Odia and has been reviewed by the demo site leader. The demosite specific version of the mobile application APK has been developed and tested for communication and data exchange with ecoMicrogrid via ecoPlatform since August 2024. The details of consumers and managers participating in the demonstration as well as details on the energy meters and loads are currently being gathered through demo site leaders and is updated in the database and APK for demonstration.

3.7.4.2 Future Plan

The parameterized tool APK is being installed and will be demonstrated using the mobile phones of the demo site users. The parameterization and demonstration are scheduled for October/November 2024.

Table 8: Deployment Status ecoCommunity tool in Keonjhor demosite.

Sl. No.	Task	Status	Expected Completion
1	Creation of a cloud database for the storage of data. Server Location: Mumbai, India	Completed	-
2	Review and finalize the tool UI text translation - English to Hindi and Odia.	Completed	-
3	Integration of domo site specific modules and development of APK for testing.	Completed	-
4	Deployment and testing of APK with demo site leaders and administrators.	Completed	-
5	Testing and verifying communication and data exchange with ecoTools	Completed	-
6	Gather details on tool users, managers, meters, loads etc.	Completed	-
7	Tool parameterization and configuration of the database for demonstration	In-progress	November 10^{th} 2024
8	Installation of application on the mobile phones of consumers/managers from demo site.	Scheduled	November 10^{th} 2024

3.8 ecoVehicle

3.8.1 General Description

ecoVehicle tool set considers the deployment of the means of electrified transportation such as e-Three wheelers and the charging infrastructure to facilitate the energy needs. The e-Three wheelers are modified and customized in such a way that it can be easily converted to carry only goods when there are fewer passengers and vice versa. The vehicle's power train is upgraded so that it can be used for transportation of passengers (max 6 persons) and goods within the island. In this demo site electric vehicle charging points receiving energy from islanded grid being installed. Each of the deployed chargers is of 3.3kW and the off-sun hour support is around 5 hours with 50% depth of discharge of the BESS system.

3.8.2 Purpose of Deploying This Tool

Considered tool is being deployed to provide greener means of transport reducing the current consumption of gasoline. Deployment of ecoVehicle tool will provide the data of the energy vectors associated with transportation for further analysis and base model for other cases of deployment.

3.8.3 Demo Site Specific Challenges Faced During Deployment

Considering the hilly regions of Keonjhar demo site, the e three-wheeler powertrain is upgraded to a 2 kW BLDC motor with a matching controller and suitable rear axle to carry max 500 kg payloads. The vehicle can be utilized for transportation of passengers (max 6 persons) and goods in the hilly regions at reduced speed.

3.8.4 Deployment Timeline

Both the e-three wheelers and its charging infrastructure have already been deployed at Keonjhar demo site. The e-three wheeler has been handed over to RANIPADA GRAMA SHAKTI SAMUHA in March 2024.

3.8.4.1 Current Status

The e-three-wheeler is already in operation. The installation of charging station was completed by June 2024.

Figure 36: EV loader and charging station at Keonjhar

3.8.4.2 Future Plan

The charging infrastructure and means of transportation will be evaluated as one of the energy vectors. A temperature regulated charger will be deployed in demo site at Keonjhar for evaluation and as an additional facility to ensure better life of the battery packs with three-wheelers.

3.9 Main Achievements

- The newly developed 50 kWp microgrid has been designed with the ability to operate in synchronization with the existing 22 kWp Solar PV Microgrid on the AC side. The project developed ecoTools such as ecoMicrogrid along with ecoCommunity and ecoPlanning have been successfully deployed.
- Successful development and deployment of site specific ecoTools such as ecoVehicle, ecoDR.
- Parametrization of ecoTools has been completed successfully according to site's specific features. (i.e. ecoMicrogrid, ecoCommunity, ecoPlanning, ecoPlatform)

3.10 Contribution Per Partner

Table 9: Contribution Chart Per Partner for Keonjhor Demosite

Involved partners	Contributions (Keonjhor Demosite)
IIT Bhubaneswar	Keonjhor Demosite leader. Engineering, installation and configuration of necessary preliminary equipment such as 50 kW microgrid having 30 kWp solar PV, 10 kWp biomass and 10 kWp biogas as energy vectors with 180 kWh of BESS. Conducted the deployment and demonstration plan of Keonjhor. IIT BBS is taking the responsibility of integrating the existing microgrid with the RE-EMPOWERED developed microgrid. Responsible for community engagement and facilitating communication with local citizens and arrangements for site works.
ICCS-NTUA	In charge of ecoMicrogrid deployment including planning, engineering, configuration and on-site installation of peripheral necessary equipment. Works for communication establishment between ecoMicrogrid and all other assets. Also, supported the customization and integration of ecoCommunity at Keonjhar demo-site.
PROTASIS	Leading the procurement and provision of the necessary hardware for ecoMicrogrid implementation. Contributed to the deployment of ecoMicrogrid at the site in cooperation with demo site leader IIT BBS and ICCS-NTUA. Provide and implement the software for the collection of the data from the demo's site energy sources (PV plant, Energy Storage System, Biomass Generator and Biofuel Generator). Additionally, installed a SCADA-HMI system displaying the single line diagrams and measurement values, along with a functionality of an algorithmic decision suggestion for connecting the biomass generator to the grid for its direct operation.
IIT Delhi	Responsible for community engagement and deployment of communication channel between ecoDR and ecoMicrogrid.
CSIR-CMERI	Responsible for the development of ecoVehicle and ecoDR tools. Provided specifications for ecoVehicle and ecoDR related preliminary equipment.
ICL	Developed and deployed the ecoCommunity tool and tested the interoperability with other ecoTools. Tested the data exchange with other ecoTools through ecoPlatform.
VNIT	Responsible for the development of ecoVehicle: Charging Infrastructure.

3.11 Conclusions

Due to the demo site's remote location, a number of obstacles have been surmounted, including land allocation, approval from local authorities, and difficult installations. However, all this has been successfully resolved and 50 kWp Microgrid has been installed and power has been given to the local people. Currently, most ecoTools have been implemented in the demo site, with the only one remaining the ecoCommunity, due to unavailability of internet. The 4G antenna works were finalized by 29 October 2024, providing access to the internet and enabling the possibility of a complete and functional demonstration to be performed.

4 Kythnos Island and Gaidouromantra microgrid

4.1 Introduction

Kythnos is a Greek island, (99.4 km2 – 1,568 inhabitants) part of the Cyclades complex in the Aegean Sea with a long history in sustainable energy installations. Kythnos island in fact hosts two separate demo sites, Kythnos power system containing the first wind farm in Europe constructed in 1982 and the first microgrid in Europe in 2001, in Gaidouromantra, a small valley next to the coast, in the southern part of Kythnos. Kythnos has been a versatile live testbed for smart grid technologies, which have been developed in the framework of several European projects. Based on this past experience, and since it is non-interconnected to the mainland electrical grid, leading to constraints in RES penetration, Kythnos provides an ideal demonstration site. The Gaidouromantra islanded microgrid electrifies a settlement consisting of 14 houses with 100% renewable energy coming from PVs and batteries since 2001. Besides being the first microgrid in Europe, in the Kythnos settlement advanced decentralized techniques for DSM techniques were demonstrated for the first time.

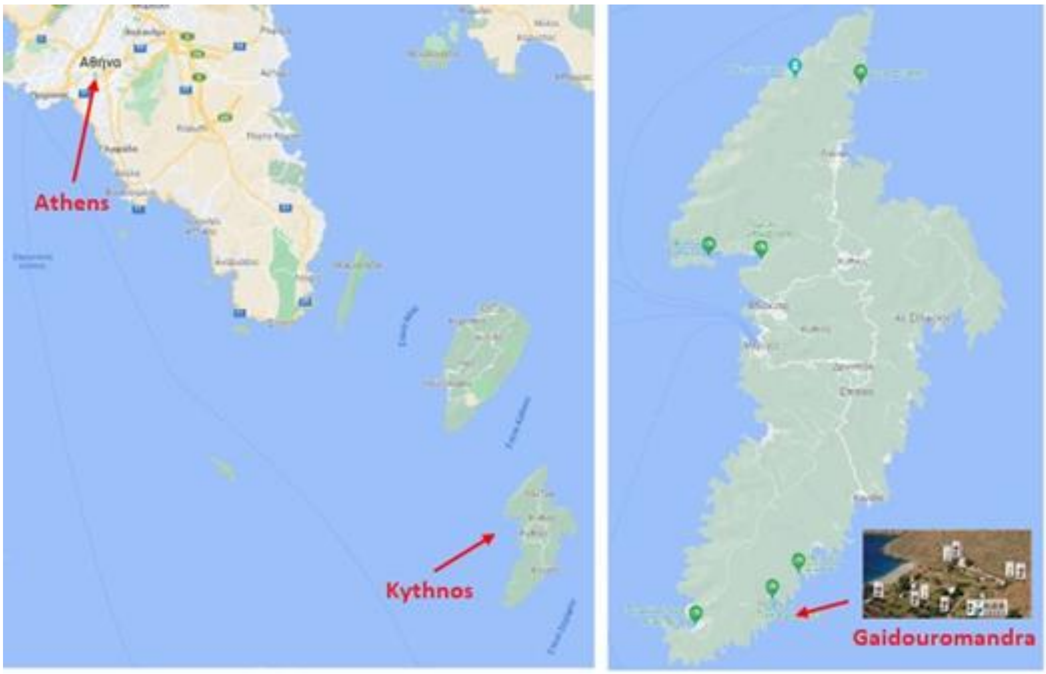


Figure 37: Kythnos and Gaidouromandra.

4.1.1 Aim

The main objectives for Kythnos demonstration sites through RE-EMPOWERED ecoTool-set implementation are as follows:

- By improved forecasting and multi-energy scheduling, to achieve optimal operation increasing RES utilization and reducing variable operating costs for the energy system.
- To increase stability and reliability in rural microgrids fostering customers confidence for energy service provision.
- To unlock the demand-side flexibility by achieving community engagement.

4.1.2 Background Information

<u>Kythnos power system</u>

- It is a non-interconnected to the mainland electrical grid
- Number of electricity customers (end consumers / producers – LV): 3,353
- Peak load: 3.118 MW
- Installed capacity of fossil fuel (diesel) Generation: 5.2 MW
- Installed capacity of renewable energy (RE) Generation units 908.65kW
- 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)

<u>Gaidouromantra microgrid</u>

- It is an islanded minigrid consisting of 14 vacation houses
- In total the supplying of the village is provided by the following installations: installed capacity of PVs: 20.8 kW, installed capacity of W/G: 3 kW, installed capacity of D/G: 22 kW.
- Extended metering network available.

4.1.3 Status of Commercial Infrastructure

- Required communication equipment (Ethernet gateway) for ecoMonitor has been installed
- Energy metering and data logging equipment have been placed in order to increase observability and controllability in the microgrid
- Environmental sensors along with the proper signal transducers and I/O modules have been adapted to the system
- Commercial software platform “Zenon” has been used for ecoMicrogrid’s Data Concentrator Module implementation and SCADA operation

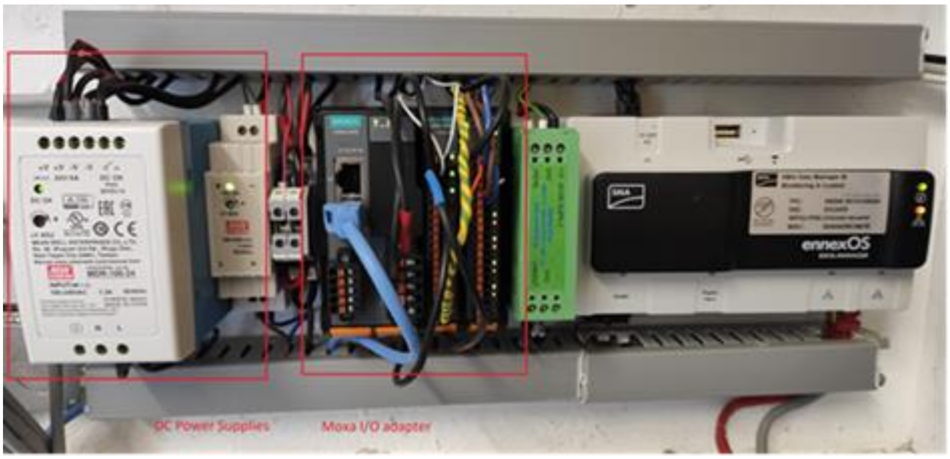


Figure 38: Modular I/O adapter with peripheral components installed in control room at Gaidouromantra

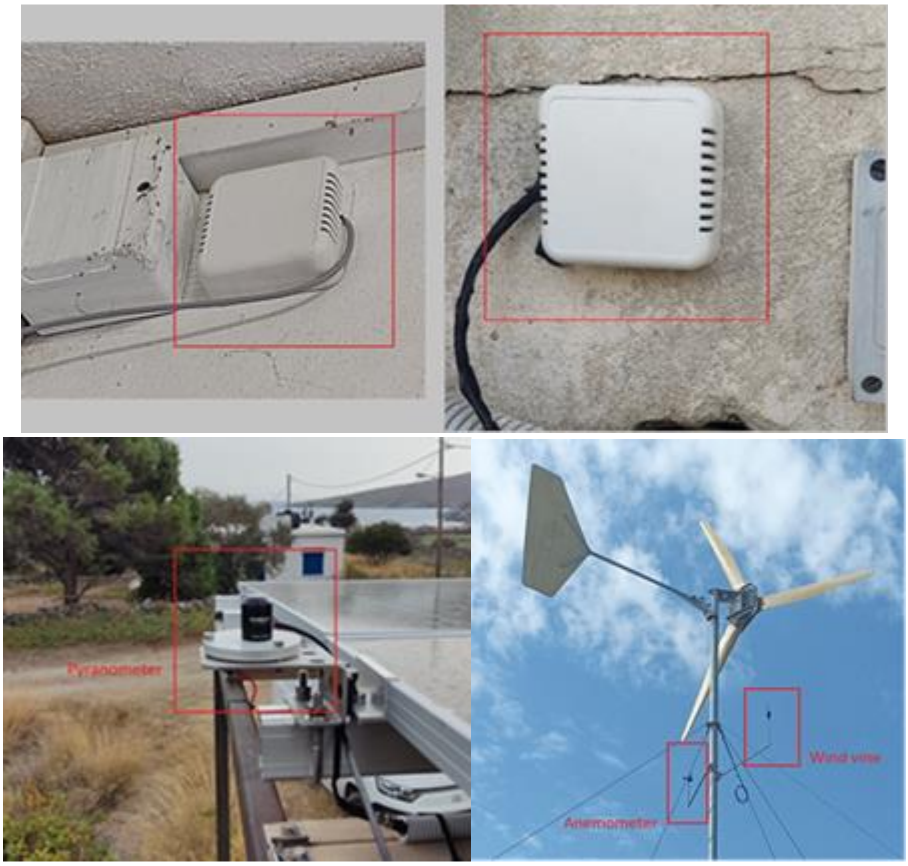


Figure 39: a) Indoor temperature sensor, b) Outdoor temperature sensor, c) Anemometer and wind vine installed on W/G pillar, d) Pyranometer with its bracket installed on the System House rooftop (Gaidouromantra)

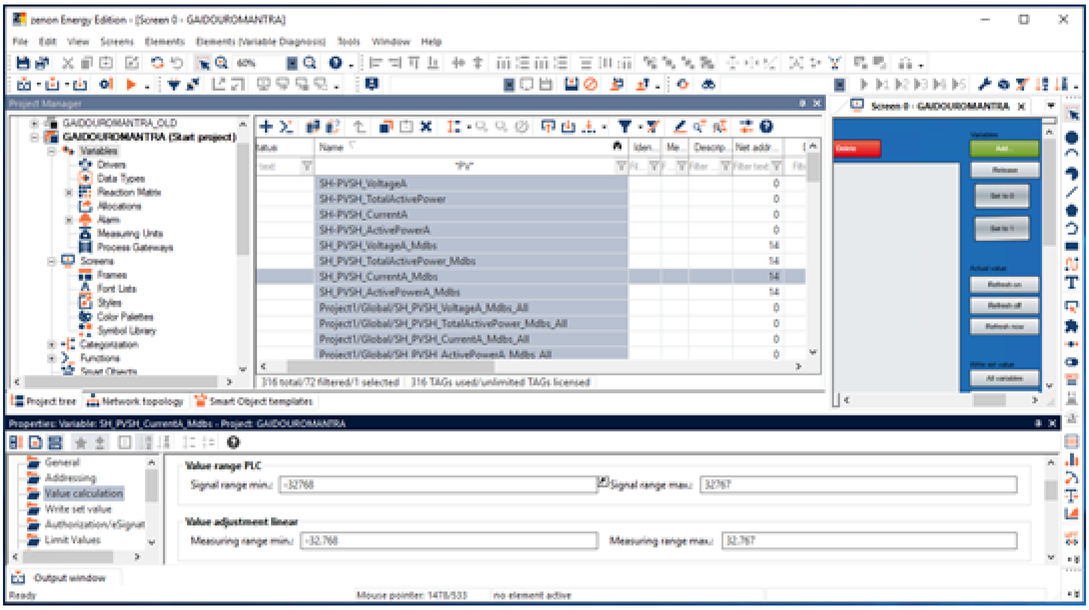


Figure 40: Zenon platform programming environment for Gaidouromantra

4.2 Overview of Tools and Solutions to be Demonstrated

The following ecoTools are to be demonstrated on Kythnos Demo site.

Table 10: ecoTools demonstrated on Kythnos demo

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

4.3 ecoEMS

4.3.1 General Description

In autonomous Non-Interconnected Power Systems (NIIPSs), the electrical networks typically include thermal units such as diesel generators, distributed renewable energy sources (RES), controllable loads, and storage devices. Some island power systems may connect with other isolated power systems or even the mainland, forming cooperative networks. However, most remain disconnected from the mainland, necessitating sophisticated coordination between RES and thermal units to optimize social welfare.

The foundation of Energy Management Systems (EMS) tools in these contexts is Day Ahead Scheduling (DAS), a central component of the energy market framework that integrates both energy and ancillary services markets. DAS aims to maximize social welfare while adhering to the technical and safety constraints of the power system and production units.

Central to DAS is the Unit Commitment (UC) process, which determines the set of production units to operate to meet the power system's energy requirements and defines the generation levels for each unit. This planning extends to one or more days in advance. Optimal Economic Dispatch (ED), executed closer to the delivery time, specifies the generation levels for each unit to minimize total production costs within a short-term horizon.

Given that each power system has its unique characteristics, the UC, DAS, and EMS objectives must be tailored accordingly, as a one-size-fits-all solution does not apply. Effective integration of UC and ED requires accurate forecasts of electrical load and RES output, enabling the creation of optimal and feasible management schedules. This approach leverages storage systems and available RES energy to reduce reliance on thermal units and enhance the system's environmental footprint.

The solution to the DAS problem involves:

- Optimally determining the start-up and shutdown orders for thermal units, committing flexible loads, and issuing dispatch orders for each production unit to meet the energy balance constraint for each Dispatch Hour (DH) of each Dispatch Day (DD).
- Defining Ancillary Services such as Primary, Secondary, and Tertiary Reserves for every DH of each DD.

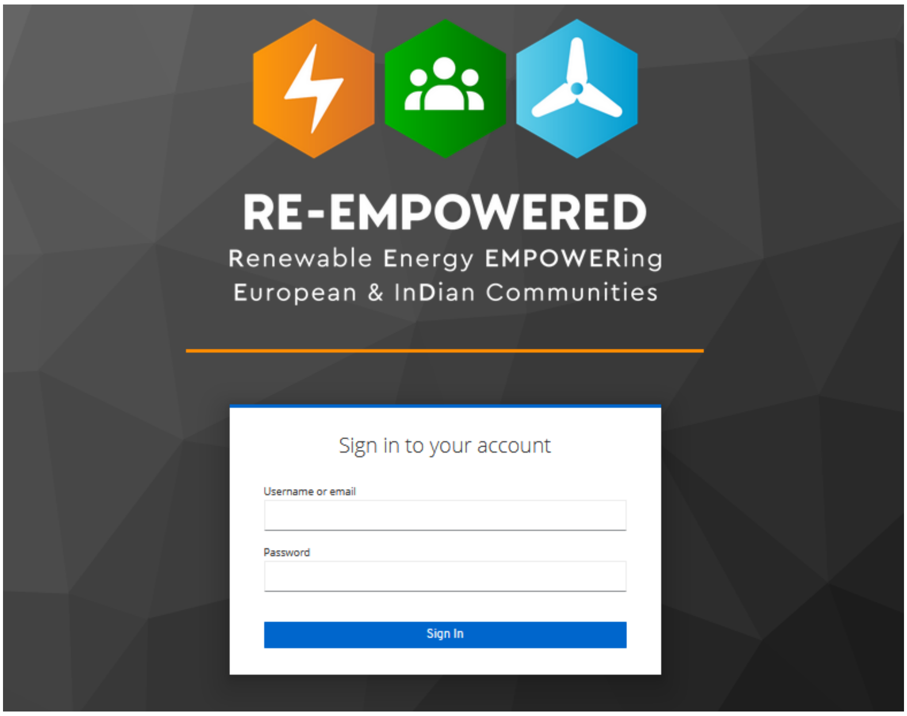


Figure 41: Landing log in page for ecoEMS.

4.3.2 Purpose of Deploying This Tool

The ecoEMS tool is being implemented at the Kythnos demo site to address various objectives aligned with the specific needs and challenges of the site. This deployment acts as a practical exercise to validate the tool's performance in real-world conditions, ensuring its readiness for broader application. Testing with actual users is essential to gauge the tool's efficiency and dependability.

The main goals of this deployment are focused on optimizing Kythnos's electrical system and reducing operational expenses. The deployment objectives include:

- Enhancing overall performance: The tool aims to improve the efficiency of energy distribution and usage across different vectors, thereby optimizing the performance of the electrical system.
- Minimizing operational costs: By utilizing sophisticated management algorithms, the tool seeks to lower the expenses related to its operation.
- Augmenting reliability: The deployment incorporates advanced optimization methods to enhance the reliability of the demo site ensuring a consistent energy supply.
- Increasing system observability: The tool enhances monitoring capabilities, providing a comprehensive view of the electrical system's operation and performance.

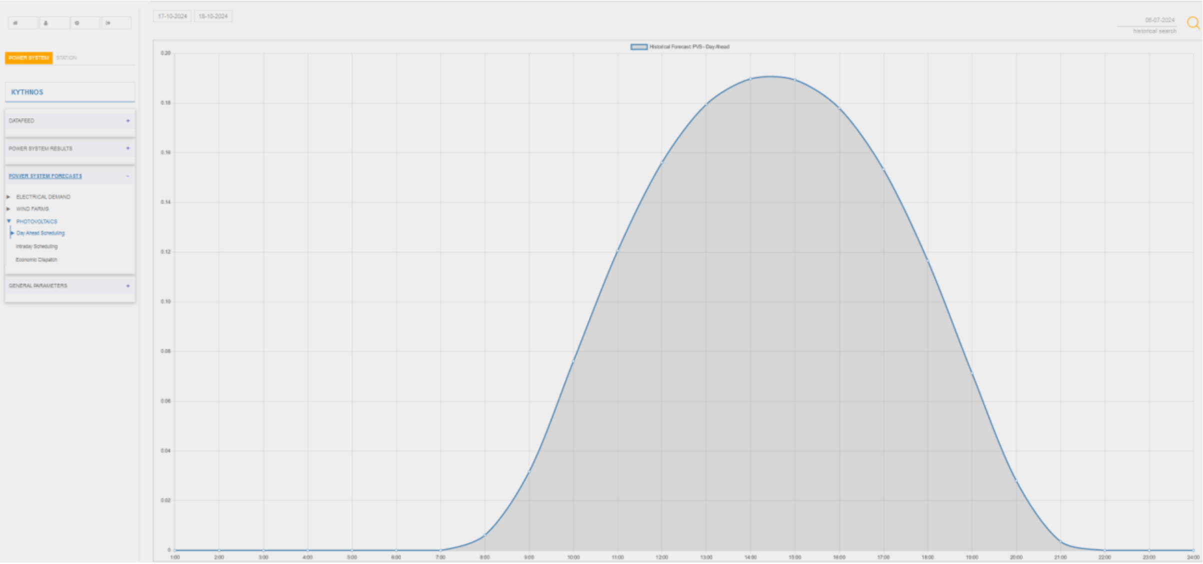


Figure 42: Page of PV forecasts in ecoEMS for Kythnos demo site.

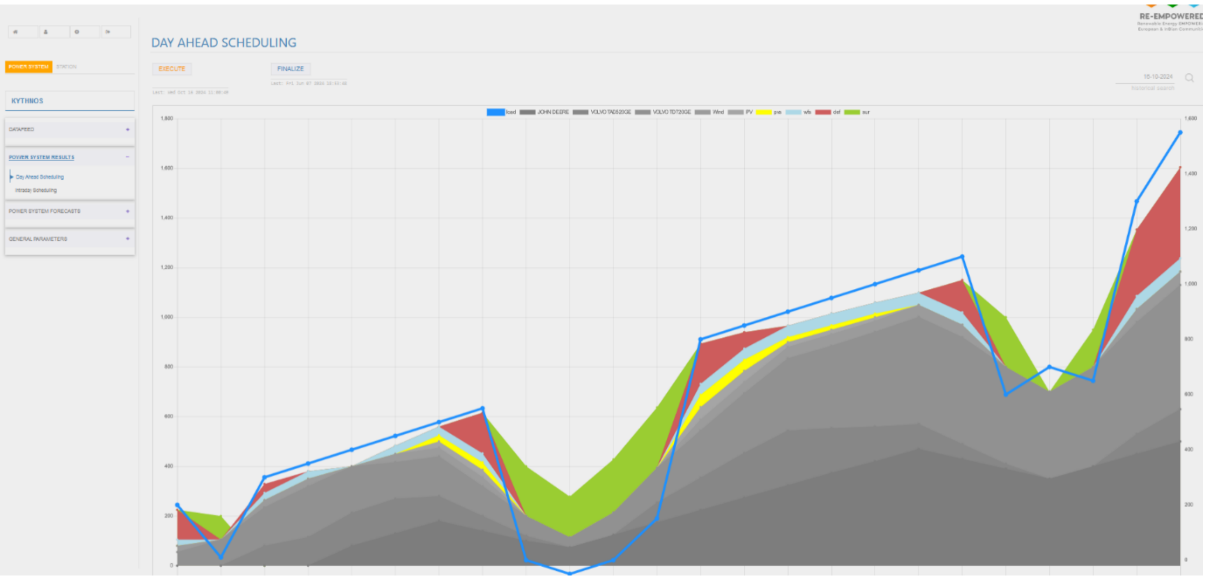


Figure 43: Demo output of ecoEMS scheduling algorithm for Kythnos demo site.

4.3.3 Demo Site Specific Challenges Faced During Deployment

Although the ecoEMS tool was meticulously prepared and tested within the ICCS lab to avoid site-specific limitations and challenges, the continuous online communication highlighted the need for a staging environment before official deployment. In this pre-deployment stage, it was essential to ensure that the ecoEMS tool was fully ready for real-world use by identifying and mitigating potential issues to facilitate a smoother deployment.

The ecoEMS tool operates physically at the ICCS lab and is accessible online via a VPN client provided to key personnel, ensuring high security. This compact solution integrates all functionalities into a single system that is easy to monitor and restore if any issues arise. The design aims to simplify deployment by minimizing complexity and making management more straightforward.

However, integrating the system with various data sources in the field presents specific challenges:

- Data contradiction: Ensuring the ecoEMS tool works seamlessly with the diverse field devices on the island, including different communication protocols and data formats. This challenge was addressed by enhancing an additional module that standardizes all data formats.
- Communication Failures: During the operation of the Kythnos power system, some communication failures with the SCADA disrupted the flow of critical data necessary for the tool's optimal performance. These failures, caused by outdated firmware, led to forecast model failures and crashes in the ecoEMS model. These reliability issues with the communication network have been resolved at the demo site.

4.3.4 Deployment Timeline

4.3.4.1 Current Status

Deploying the ecoEMS at the Kythnos Island demo site required several essential tasks to ensure successful integration and operation. Conducting staging tests at the ICCS-NTUA lab was crucial for verifying system compatibility and functionality, as well as for identifying potential issues early to facilitate a smoother deployment.

Staging the software modules was a critical phase in the deployment process. Key components such as the Data Manager, Module Manager, Application Manager, the database, and the web server must all be coordinated into a cohesive solution. Setting up a system for real-time monitoring and scheduling regular maintenance checks was vital for ensuring ongoing reliability and performance. The deployment at Kythnos completed by May 2024, also included the integration of the ecoPlatform to enhance overall system functionality.

Table 11: Deployment Status of ecoEMS tool in Kythnos Demosite

Sl. No.	Task	Status	Expected Completion
1	Staging Testing	Completed	-
2	Server setup	Completed	-
3	Deployment of ecoEMS	Completed	-
4	Software Configuration	Completed	
5	Integration and Testing	Completed	-
7	Establish Communication ecoPlatform-B	Completed	-
9	Establish Communication with SCADA from Kythnos demo site	Completed	-

4.3.4.2 Future Plan

As the deployment has been completed for ecoEMS tool for the Kythnos demo site and the other services (e.g. the SCADA of the island) are working, the demonstration phase has been started and next steps include the continuation and completion of the demonstration phase in late October 2024.

4.4 ecoMicrogrid

4.4.1 General Description

The ecoMicrogrid tool is an Energy Management System (EMS) designed to optimize the overall performance of microgrids. In the Gaidouromantra pilot, all functionalities of the tool will be utilized to their fullest extent. The system incorporates both electrical and cooling vectors, configured to address the unique characteristics of the Gaidouromantra demo site. Key aspects to be validated include:

- **Multi-Vector Energy Optimization**: The ecoMicrogrid will showcase its ability to optimize both electrical and cooling vectors. Even though the Gaidouromantra microgrid currently lacks a district cooling system, an HVAC system in the System House (control room of the microgrid), coupled with the building's thermal dynamics, is considered a substitute for the thermal system. Ref. [2], [3]
- **Consumption and Production Forecast**: The reliability of the ecoMicrogrid's forecasting capabilities as supportive functionalities for the tool will be examined. The implementation in ecoMicrogrid involves relatively simplified forecasting approaches, aligning with the specific nature of the application. Ref. [2], [3]
- **Outage and Fault Detection**: Gaidouromandra's deployment enables the validation of the ecoMicrogrid's outage and fault detection mechanisms. The implementation of the outage detection algorithm for the Gaidouromantra Microgrid underwent certain modifications to adapt to the microgrid's network topology and data granularity. Additionally, the algorithm accounts for potential communication failures of smart meters. Ref. [3]
- **Demand Response Functionalities**: Demand-side management (DSM) schemes at Gaidouromandra will implement and test Concept 1 (Suggestion to private-owned loads to participate in dedicated time slots) and Concept 3 (Involving flexible and communal loads in DSM). Ref. [2], [3]
- **SCADA visualization:** The system will include SCADA visualization for real-time monitoring and control.
- **Integration with Other ecoTools:** The deployment of the ecoMicrogrid is complemented by the integration with other ecoTools, specifically the ecoPlatform-b, ecoCommunity and ecoDR. These tools are designed to cooperate harmoniously within the ecosystem.
  - **Integration with ecoPlatform-b:** This facilitates the communication service bus and real-time status visualization of the microgrid. A dedicated dashboard tailored to microgrid needs has been developed, leveraging the capabilities of ecoPlatform-b. This dashboard serves both users and operators for quick and easy assessment of the operational status.
  - **Integration with ecoCommunity:** This tool bridges the gap with end-users by implementing demand-side management functionalities such as load booking and dynamic pricing. Predefined message queues and payload messages will be used for this purpose. Ref. [3]
  - **Integration with ecoDR**: The developed meters focus on advanced metering infrastructure with inbuilt load controller and protection functionalities. In

addition to measurement of household energy consumption, it facilitates remote monitoring and remote control of non-critical loads.

The ecoMicrogrid system is accommodated in industrial hardware selected to meet the specific requirements of data handling and environmental conditions at the pilot site. The hardware hosts all the software components and modules of the ecoMicrogrid, including data storage modules. All collected data are stored locally within the ecoMicrogrid storage device. The transport module is responsible for data communication with ecoPlatform-b and ecoCommunity. To ensure compliance with GDPR requirements, both ecoPlatform-b and ecoCommunity are hosted within the EU.

4.4.2 Purpose of Deploying This Tool

The deployment of the ecoMicrogrid tool serves a multifaceted purpose, aligned with the evolving needs and challenges of Gaidouromantra's microgrid. This practical step aims to fully validate the ecoMicrogrid tool under real conditions, ensuring its readiness for widespread use. Testing the tool in an environment with real users is crucial for assessing its effectiveness and reliability.

The primary objective of the deployment is to optimize the performance of Gaidouromantra's microgrid by minimizing operational costs. Objectives of the deployment include:

- **Enhancing overall performance**: The primary objective is to optimize the microgrid's performance by improving energy distribution and consumption efficiency across multiple vectors.
- **Minimizing operational costs**: By implementing advanced management algorithms, the tool aims to reduce the costs associated with operating the microgrid.
- **Reducing storage device degradation**: The tool employs strategies to minimize wear and tear on energy storage systems, thereby extending their lifespan.
- **Improving resilience and reliability**: Leveraging advanced optimization strategies, the ecoMicrogrid tool enhances the resilience and reliability of the microgrid, reducing downtime and ensuring stable energy supply.
- **Increasing system observability**: The tool provides comprehensive monitoring capabilities, increasing the visibility of the microgrid's operations and performance.
- **Supporting community engagement**: The deployment aims to involve the community in the operation of the microgrid by providing access to real-time and historical consumption data, real-time variable pricing, status indications, and tools for community load management and coordination.

4.4.3 Demo Site Specific Challenges Faced During Deployment

Before the official deployment, Gaidouromantra was selected as the testing ground for the ecoMicrogrid tool. The site was chosen primarily because of its high data accessibility maturity level at the time. Pre-deployment testing was crucial in ensuring that the ecoMicrogrid tool was thoroughly prepared for real-world application. This phase allowed for the identification and mitigation of potential issues, ensuring a smoother deployment process.

The ecoMicrogrid is presented as a single hardware device, offering a comprehensive solution that consolidates all functionalities into a unified system. This design is intended to streamline deployment by reducing complexity and facilitating easier management. However, integrating this system with the numerous field devices available in the field poses certain challenges:

- **Compatibility and Data Integration**: Ensuring that the ecoMicrogrid system is compatible with the wide variety of field devices present at the Gaidouromantra site. This includes dealing with different communication protocols and data formats.
- **Deployment of New Fiber High-Bandwidth Network:** At the Gaidouromantra pilot site, a new fiber high-bandwidth communication network was deployed to support the advanced functionalities of the ecoMicrogrid tool. This network was designed to provide high-speed, reliable communication across the microgrid. However, the deployment faced significant challenges:
  - **Coverage Gaps:** The new fiber network did not reach some areas of the microgrid, creating gaps in communication coverage. These gaps could impede the performance of the ecoMicrogrid system by isolating critical data points.
- **Utilization and Modification of Old Serial Communication Network:** To address the coverage gaps, the old serial communication network, which is 20 years old was utilized and modified to cover the areas not reached by the new fiber network.
  - **Reliability Issues:** The old network had numerous reliability problems due to its age and outdated technology. Frequent communication failures and data transmission errors could affect the overall performance and accuracy of the ecoMicrogrid system.
  - **Limited Bandwidth:** The old serial network has lower bandwidth compared to the new fiber network; this might affect future scenarios where high bandwidth might be required.
  - **Lower Compatibility and Interoperability:** Serial communication networks generally have lower compatibility and interoperability compared to modern IP/Ethernet networks, making integration with contemporary devices more challenging.
- **Communication Failures:** During the operation of the Gaidouromantra microgrid, some communication failures occurred with the smart meters. These failures disrupted the flow of critical data necessary for the optimal performance of the ecoMicrogrid tool. The communication failures were primarily due to outdated firmware in the smart meters, which caused reliability issues with the communication network.

Solutions to Integration Challenges

- **Protocol Converters and Gateways:** Implementing devices or software solutions that can translate between different communication protocols, ensuring seamless data exchange between the ecoMicrogrid system and the diverse field devices.
- **Additional Sensors and Data Acquisition**: Deploying supplementary sensors and data acquisition systems to capture missing data for specific assets, ensuring comprehensive data coverage.
- **Utilization and Modification of Old Serial Communication Network:** To address the coverage gaps, the old serial communication network, which is 20 years old was utilized and modified to cover the areas not reached by the new fiber network.

- **Firmware Update for Smart Meters:** To resolve the communication failures, a firmware update was performed on the smart meters. This update aimed to enhance the compatibility and reliability of the smart meters with the existing communication network.

4.4.4 Deployment Timeline

The deployment of the ecoMicrogrid system at Gaidoyromantra, has been successfully completed. This process included several key tasks to ensure successful integration and operation.

Pre-Deployment Testing: Initial testing at the ICCS-NTUA lab validated the system's compatibility and functionality, identifying potential issues early for a smoother deployment.

Equipment Installation: Critical components such as the Ethernet gateway, data logger, energy meters, environmental sensors, and modular I/O adapter were carefully installed and configured.
Software Configuration: The Zenon software platform was configured and integrated as the Data Concentrator Module, collecting data from field devices, performing preliminary processing, and registering data to an SQL database for analysis.
Data Integration: Protocol converters and gateways were implemented to manage different communication protocols and standardize data formats. Thorough testing ensured effective network performance, device communication, and data accuracy.
Integration with ecoTools: The deployment also involved integrating the ecoMicrogrid with other ecoTools, specifically ecoPlatform and ecoCommunity, to enhance overall functionality.

Establishing a system for real-time monitoring and scheduling regular maintenance checks are essential for ongoing reliability and performance. The deployment of the ecoMicrogrid has been complemented by the integration with other ecoTools, specifically the ecoPlatform and ecoCommunity.

The ecoMicrogrid tool has already been deployed at the Gaidouromantra pilot site. A maintenance visit in June 2024 resolved many issues that arose since the initial deployment. Despite delays in equipment shipping causing further delays in the integration with ecoDR, remote testing of communication with ecoMicrogrid had in the meanwhile been conducted, and currently the system is complete.

Table 12: Deployment Status of ecoMicrogrid tool in Keonjhor Demosite

Sl. No.	Task	Status	Expected Completion
1	Pre-Deployment Testing	Completed	-
2	Equipment Installation	Completed	-
3	Deployment of ecoMicrogrid hardware	Completed	-
4	Software Configuration	Completed	
5	Integration and Testing	Completed	-
6	Final On-Site Configuration	Completed	-

7	Establish Communication with ecoCommunity and ecoPlatform-b	Completed	-
8	Establish Communication with ecoDR	Completed	-
9	SCADA Integration	Completed	-
10	Ongoing Monitoring and Maintenance	Ongoing	Continuous

4.4.4.1 Current Status

The ecoMicrogrid tool was successfully deployed at the Gaidouromantra pilot site in May 2024. A maintenance visit in June 2024 resolved several issues that had arisen since the initial deployment. Despite delays in equipment shipping causing further delays in the integration with ecoDR, remote testing of communication with ecoMicrogrid had in the meanwhile been conducted, and currently the system is complete.

Currently, the system is undergoing testing demonstration activities, providing valuable feedback for further tool adaptation. Data collection is ongoing to assess the performance of both the tool and the pilot site.

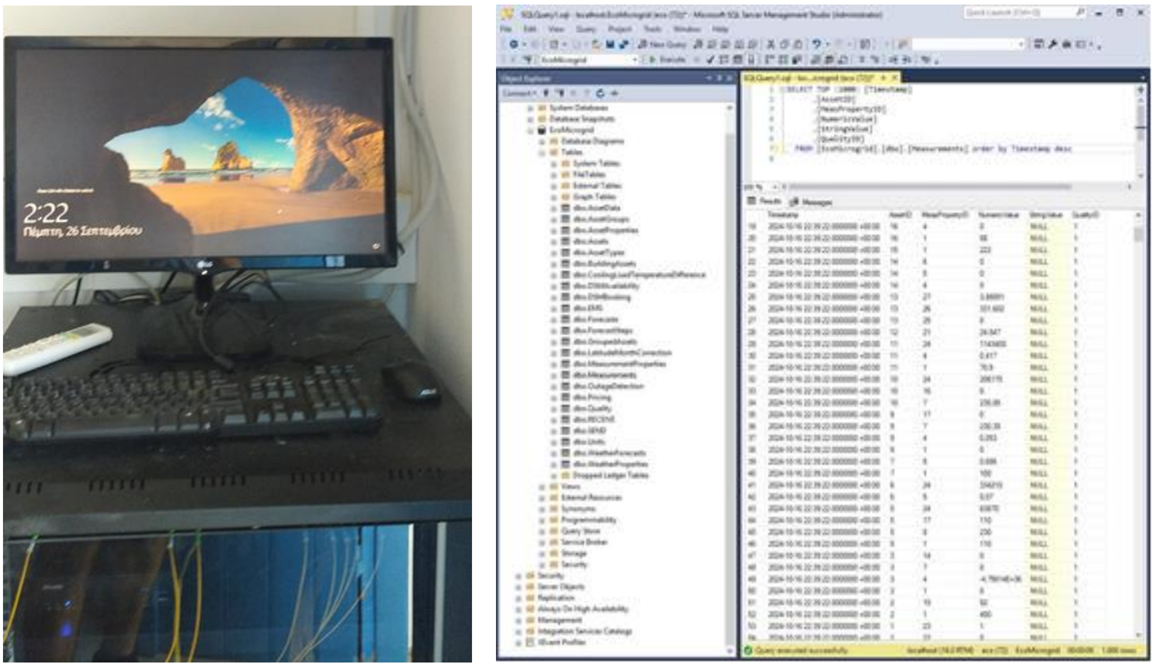


Figure 44:: ecoMicrogrid deployed on site and data – base gathering data at Gaidouromantra

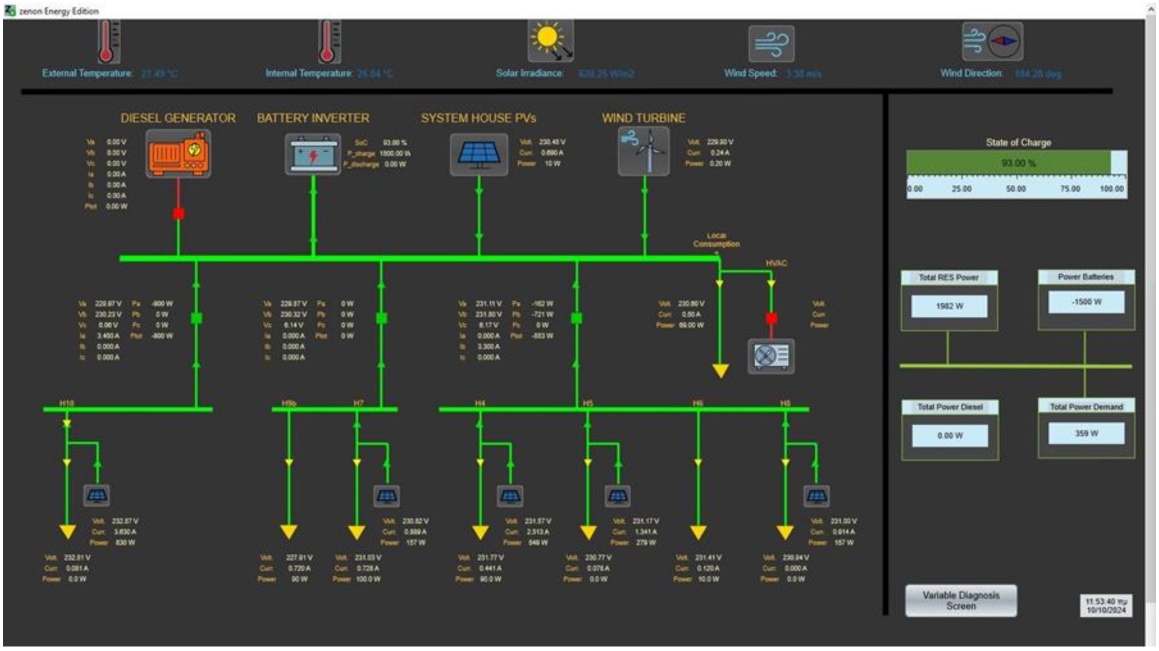


Figure 45: ecoMicrogrid SCADA environment at Gaidouromantra site.

4.4.4.2 Future Plan

The ongoing testing demonstration activities will continue to provide valuable feedback. This feedback will be used to make necessary adjustments and enhancements to the ecoMicrogrid tool, ensuring it meets the evolving needs of the pilot site. Continuous data collection and analysis will be conducted to thoroughly assess the performance of the ecoMicrogrid system, identifying areas for improvement and optimization. Scheduled maintenance visits will ensure the system remains in optimal condition, addressing any issues promptly and maintaining high reliability and performance.

4.5 ecoPlanning

4.5.1 General Description

ecoPlanning is a tool designed to aid decision-makers in the mid-term planning and expansion of power systems for Non-Interconnected Islands (NIIs). It helps evaluate the need for new electricity generation units or the interconnection between NIIs or between NIIs and the mainland. For effective planning, various studies must be conducted. ecoPlanning supports four types of simulations and studies:

- 7-Year Energy Planning: Evaluates the adequacy of generation units to meet the electrical load over a seven-year period.
- RES Hosting Capacity: Assesses the capacity of the power system to integrate Renewable Energy Sources (RES) units.
- Monthly Energy Balance: Analyzes the satisfaction of energy balance equations for specific load time series on a monthly basis.
- Interconnections: Evaluates the feasibility and impact of implementing interconnections.

This tool also includes additional features developed under the RE-EMPOWERED project, focusing on demand response based on multi-energy vectors and considering interconnected power systems and multi-microgrids. These features have been validated through case studies related to the project's demo sites.

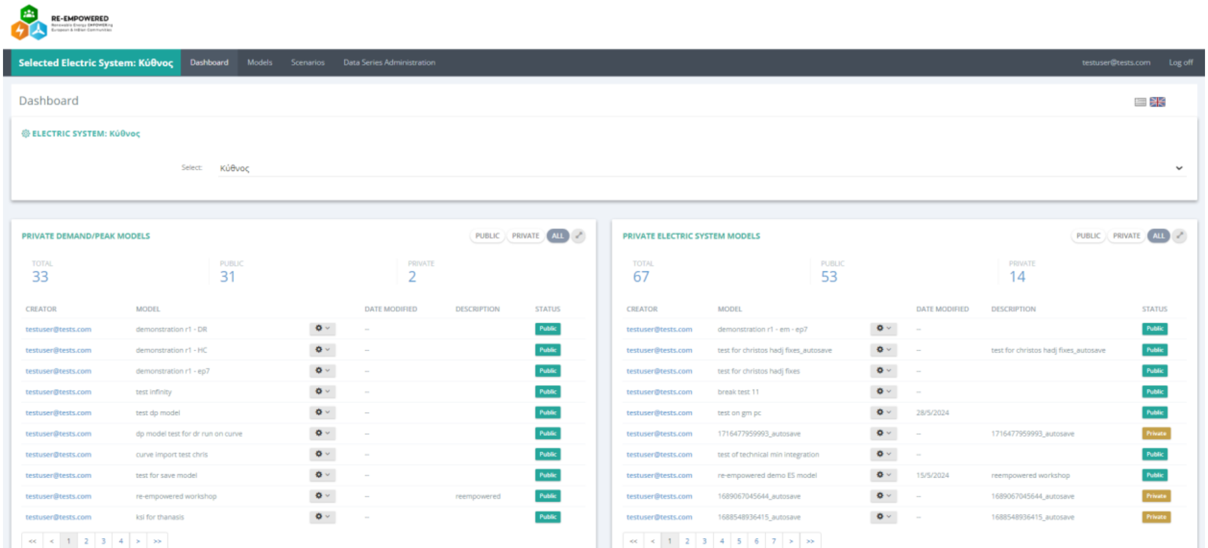


Figure 46: Dashboard - electrical and demand/peak models for Kythnos.

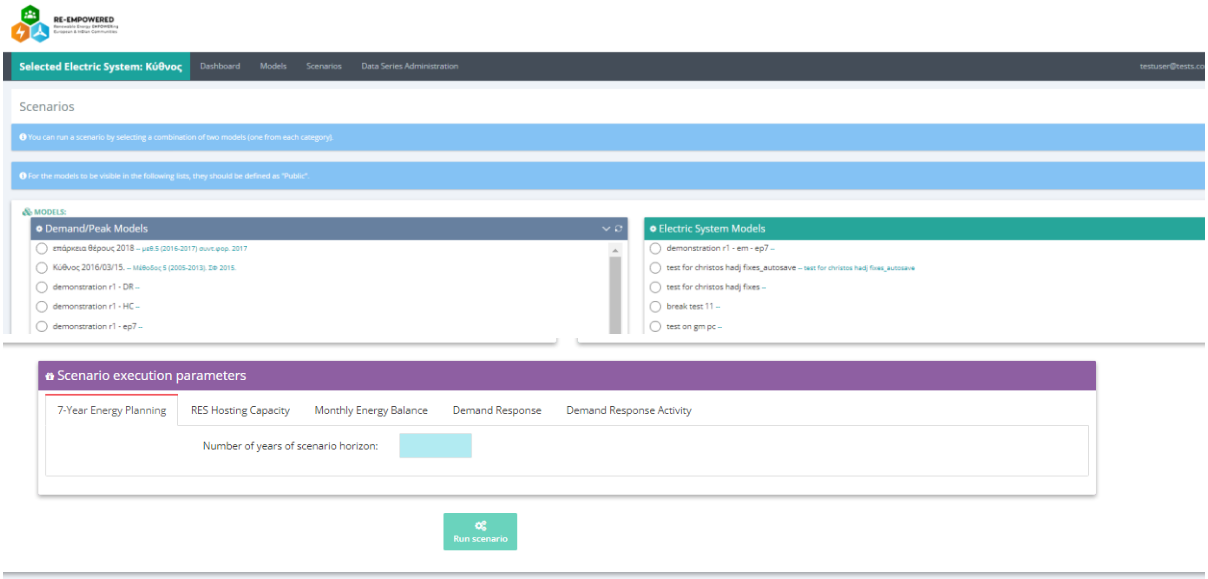


Figure 47: Study selection for simulation for Kythnos demo site.

4.5.2 Purpose of Deploying This Tool

The deployment of the ecoPlanning tool aims to address the diverse needs and challenges at the Kythnos demo site. This involves demonstrating the tool's capability to assist in the planning phase for rural, isolated, or weakly interconnected systems by optimizing the integration of various energy technologies to boost renewable energy generation. ecoPlanning will also facilitate the design and development of high-RES energy systems, incorporating flexibility from Demand Side Management (DSM) and other energy carriers, such as cooling. This was highlighted by examining smart air conditioning DSM activities for Kythnos.

Earlier system evaluations have simulated and assessed scenarios for new investments in RES capacity. The goals of the RE-EMPOWERED deployment include integrating new tool functionalities, simulating new technologies and synergies, and validating features like DSM flexibility (including cooling) and multi-microgrid cooperation. These functionalities will be tested through case studies related to the RE-EMPOWERED demo sites during the demonstration phase.

4.5.3 Demo Site Specific Challenges Faced During Deployment

ecoPlanning tool was thoroughly prepared and tested within the ICCS lab so no site-specific challenges were faced during the deployment. Access to the tool is granted via internet under a VPN client distributed to key persons, and the tool physically runs on ICCS premises.

4.5.4 Deployment Timeline

4.5.4.1 Current Status

The deployment of the ecoPlanning system at the Kythnos Island demo site involves several key tasks to ensure successful integration and operation as well as interoperability of the various subsystems. The deployment of the ecoPlanning is completed by June 2024, is performed on premises of the ICCS-NTUA lab, and access is granted for preselected users.

The tool includes a database where all the necessary data are stored and works as the heartbeat of the tool. So, initial deployment testing validating the system's compatibility and stable connection with the Microsoft SQL Server has been performed. Following, identifying potential issues early to ensure a smoother deployment process has monitored the behaviour of various used technologies, such as Microsoft .Net Framework, AngularJs, HighCharts, Bootstrap, MVC.

Equipment installation is a critical step in the deployment process, so the server which is the key component for the tool deployment has been carefully installed and configured.

The deployment also includes configuring and integrating VPN clients in order to have access to the tool under private network for highest security. Also, a complete user management system (Microsoft Identity Framework) with user register, login, logout and hashed passwords stored in the database has been integrated and successfully deployed.

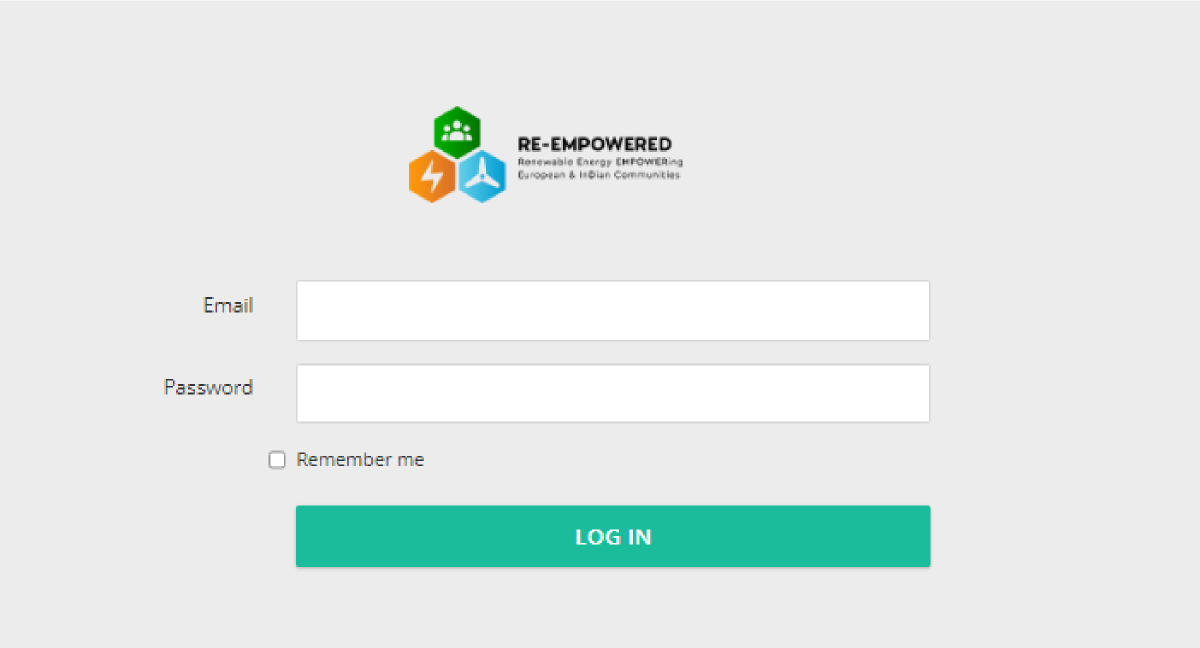


Figure 48: Landing log in page for ecoPlanning.

Table 13: Deployment Status of ecoPlanning tool in Kythnos Demosite

Sl. No.	Task	Status	Expected Completion
1	Deployment Testing	Completed	-
2	Equipment Installation	Completed	-
3	Deployment of ecoPlanning	Completed	-
4	Software Configuration	Completed	
5	Integration and Testing	Completed	-
6	Establish Communication – access through VPN	Completed	-

4.5.4.2 Future Plan

As the deployment has been completed for ecoPlanning tool for the Kythnos demo site, the next steps are the preparation for the demonstration phase in late October 2024.

4.6 ecoDR

4.6.1 General Description

The ecoDR tool is an advanced smart meter with innovative features to enhance energy management and control. It encompasses a wide range of functionalities aimed at improving energy measurement, load control, and remote monitoring of non-critical loads. It incorporates advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities, allowing for efficient measurement of household energy consumption. Additionally, the smart meters can communicate with other ecoTools, such as ecoMicrogrid, to implement demand-side management services through non-critical load scheduling.

Key features of ecoDR include a static single-phase, two-wire energy meter with various parameters available for measurement, such as Irms, Vrms, active energy, power factor, apparent power, and load. The smart meters are also equipped with a visible indicator for poor power factor, an LCD for display and support for MODBUS communication protocol.
Advanced functionalities integrated into the developed meters include an inbuilt programmable load and energy limiter, load-shedding controller, and two output ports for critical and non-critical loads. Additionally, the meters offer management of non-critical loads through scheduling and control based on commands from the ecoMicrogrid.

4.6.2 Purpose of Deploying This Tool

The purpose of deploying the ecoDR tool in Gaidouromandra is to enhance energy efficiency by remotely monitoring and controlling the HVAC system at the demo site's central control station. It tracks key electrical parameters, offering valuable insights into HVAC performance. The collected data are utilized by ecoMicrogrid, enabling effective energy management of the cooling vector.

4.6.3 Demo Site Specific Challenges Faced During Deployment

The ecoDR is a smart meter with load control capabilities, featuring an Ethernet interface that supports the Modbus TCP protocol for communication. Although the installation process follows standard procedures, several challenges arose during deployment to ensure successful implementation:

- **Lack of CE conformity:** As a prototype developed primarily for the Indian market, the ecoDR was not designed to meet CE requirements, which are mandatory for deployment in the EU. This presented significant challenges, as the device needed to operate in a regulatory environment for which it was not originally intended.
- **Transcontinental Transportation:** Transporting research equipment from one continent to another presented logistical challenges, including navigating bureaucratic procedures and dealing with delays that impacted the project schedule. The devices arrived with minor damages that required repairs, further complicating the deployment process.
- **Nonstandard Modbus implementation:** The ecoDR's Modbus implementation follows a non-standard approach, complicating its integration with other ecoTools. This required custom solutions to ensure compatibility and smooth communication between devices.

4.6.4 Deployment Timeline

4.6.4.1 Current Status

After ecoDR's arrival, the deployment phase of the tool on Gaidouromantra site was concluded with a site visit by ICCS-NTUA in September 2024. The tool was successfully integrated with the HVAC system in the control room and the demonstration phase has already started.

Figure 49: ecoDR deployment at Gaidouromantra control room. Interposed to HVAC power supply.

4.6.4.2 Future Plan

After ecoDR successful deployment on Gaidouromantra demo site, the demonstration activities following involve continuous data collection and analysis to be conducted in order to carry out performance evaluation in a real scenario.

4.7 EcoPlatform

4.7.1 General Description

ecoPlatform B is a sophisticated integration tool designed to enable seamless communication and data exchange among various ecoTools within a demo site. It employs a dockerized architecture, ensuring modularity, security, and ease of deployment across diverse environments. The platform includes essential subsystems such as the Enterprise Service Bus (ESB), a centralized Database, a Storage Microservice, an API for data visualization, and a user-friendly Front-end Dashboard.

4.7.2 Purpose of Deploying This Tool

The main purpose of deploying ecoPlatform B is to create a unified environment where multiple ecoTools can operate together efficiently. By standardizing data exchange protocols and offering robust storage and visualization capabilities, ecoPlatform B aims to improve the operational efficiency and data management practices of sustainability initiatives at the demo sites. This integration supports informed decision-making and promotes sustainable practices through real-time data insights.

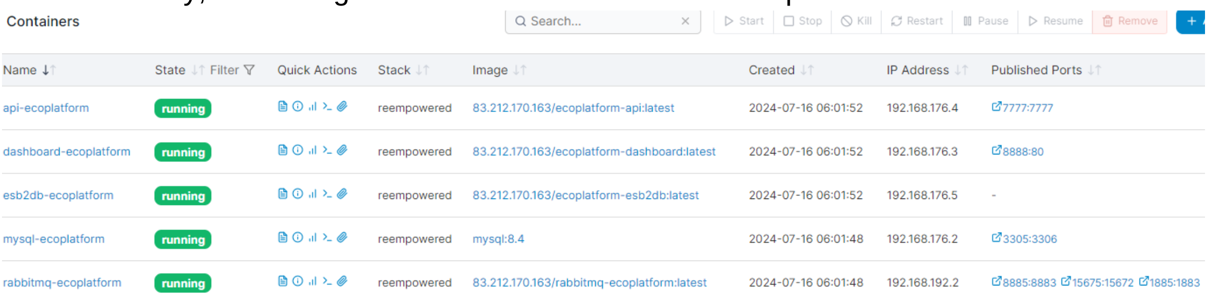
4.7.3 Demo Site Specific Challenges Faced During Deployment

Deploying ecoPlatform B at Kythnos and Gaidouromandra included some challenges, such as adapting the platform to the specific technical infrastructure and data requirements, ensuring reliable network connectivity, and managing the diverse data formats from different ecoTools. Additionally, the need for localized data storage solutions and the integration of site-specific ecoTools required tailored deployment strategies to ensure seamless operation.

4.7.4 Deployment Timeline

4.7.4.1 Current Status

As of the latest update, ecoPlatform B has been successfully deployed at the Kythnos and Gaidouromandra demo sites by October 2024, with core subsystems like the ESB, Database, API, and Front-end Dashboard fully operational. Integration of key ecoTools such as ecoCommunity, ecoMicrogrid and ecoMonitor has been completed.


Containers

Search...

Start Stop Kill Restart Pause Resume Remove

Name	State	Quick Actions	Stack	Image	Created	IP Address	Published Ports
api-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-api:latest	2024-07-16 06:01:52	192.168.176.4	7777:7777
dashboard-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-dashboard:latest	2024-07-16 06:01:52	192.168.176.3	8888:80
esb2db-ecoplatform	running		reempowered	83.212.170.163/ecoplatform-esb2db:latest	2024-07-16 06:01:52	192.168.176.5	-
mysql-ecoplatform	running		reempowered	mysql:8.4	2024-07-16 06:01:48	192.168.176.2	3305:3306
rabbitmq-ecoplatform	running		reempowered	83.212.170.163/rabbitmq-ecoplatform:latest	2024-07-16 06:01:48	192.168.192.2	8885:8883 15675:15672 1885:1883

Figure 50: List of ecoPlatform B containers deployed at Kythnos/Gaidouromantra

4.7.4.2 Future Plan

Future plan for ecoPlatform B includes finalizing data visualization features by the end of November 2024 and conducting comprehensive demonstration and quality assurance. There are also future plans to expand the deployment to additional demo sites, refine data integration processes, and enhance the platform's scalability and interoperability to support a broader range of ecoTools.

4.8 ecoMonitor

4.8.1 General Description

ecoMonitor is a digital control device equipped with multiple sensors and a microcontroller-based processing unit for real time monitoring of the local ambient air quality parameters, such as NO2, O3, SO2, CO, PM2.5 and PM10 micro particles, including ambient temperature and

relative humidity. The measured air quality data is transmitted to the ecoPlatform via a MODBUS/MQTT gateway for display and further analysis.
In addition to remote monitoring capabilities, ecoMonitor includes a local display unit with color indication, which alerts the community when any air quality parameter exceeds the maximum allowable limits.

4.8.2 Purpose of Deploying This Tool

The primary purpose of deploying ecoMonitor is to enhance public safety through the continuous monitoring of key air quality indicators, allowing for the identification of pollution levels that may pose health risks to the local community. The collected air quality data empowers authorities to make informed decisions regarding air quality management and policy development, facilitating timely interventions and promoting healthier living conditions.

4.8.3 Demo Site Specific Challenges Faced During Deployment

The deployment of ecoMonitor at the demo site encountered several specific challenges that needed to be addressed to ensure successful implementation:

- **Need for a Gateway**: The ecoMonitor does not support the MQTT protocol, necessitating the use of a Modbus to MQTT gateway for integration with the ecoPlatform tool. This requirement introduces compatibility issues and adds complexity to the system architecture. Additionally, the extra configuration and setup involved extended the deployment timeline.

- **Transcontinental Transportation**: Transporting research equipment from one continent to another presented logistical challenges, including navigating bureaucratic procedures and dealing with delays that impacted the project schedule. The devices arrived with minor damages that required repairs, further complicating the deployment process.
- **Non-standard Modbus Implementation**: The ecoMonitor's Modbus implementation follows a non-standard approach, complicating its integration with other ecoTools. This deviation from standard protocols necessitates custom solutions to achieve compatibility, adding further complexity to the deployment.
- **Environmental Protection Considerations**: While the ecoMonitor is designed for outdoor use, its packaging could be further enhanced to better withstand exposure to environmental challenges. Consequently, the chosen location for the device was carefully selected to minimize its exposure to adverse environmental conditions, ensuring optimal performance and longevity.

4.8.4 Deployment Timeline

4.8.4.1 Current Status

The deployment phase of ecoMonitor at the Kythnos site was successfully concluded during a site visit by ICCS-NTUA in September 2024. The tool has been fully deployed, and the demonstration phase is now underway. During the site visit, the following key activities related to the ecoMonitor deployment were carried out:

- **Mounting of ecoMonitor:** The ecoMonitor was installed at the School of Merichas in Kythnos, positioned under an external wall and beneath a shelter to prevent direct exposure to water.
- **Supportive Equipment:** An electrical panel was set up, containing all necessary electrical equipment, including miniature circuit breakers, a power supply, and the Modbus to MQTT gateway.
- **Communication Integration:** Successful communication integration was achieved for the ecoMonitor.

Figure 51: ecoMonitor deployment at the school of Kythnos and its communication router panel.

4.8.4.2 Future Plan

The recently initiated demonstration activities will involve continuous data collection and analysis aimed at evaluating the performance of the ecoMonitor in a real-world scenario. This ongoing assessment aims to identify potential areas for improvement and optimize the ecoMonitor's functionality.

4.9 ecoCommunity

4.9.1 General Description

The ecoCommunity tool acts as a digital platform facilitating engagement and support for the energy community in the Gaidouromantra microgrid. The energy community consumers and demo site administrators utilize a mobile application as the interface to the tool. The data associated with the tool is stored in the cloud database.

The deployment of the tool deals with hosting the could database, installing the mobile application of the tool, as well as testing and verifying the communication with other ecoTools.

The Google Firebase cloud service is utilized for the cloud database and the server location is selected as the Netherlands to confirm the GDPR requirements for handling of personal data of the tool users. The administrator instance of the mobile application is responsible for the communication with ecoMicrogrid and the storage of data in the cloud database. The consumer instance of the mobile application will utilize the cloud database for visualization as well as to store new user inputs.

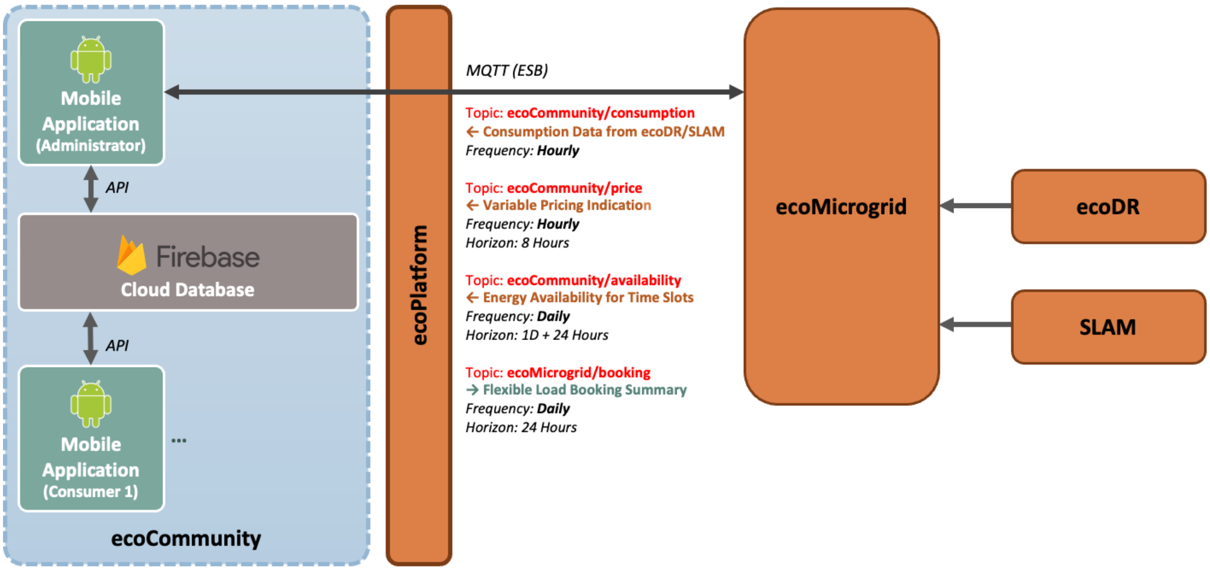
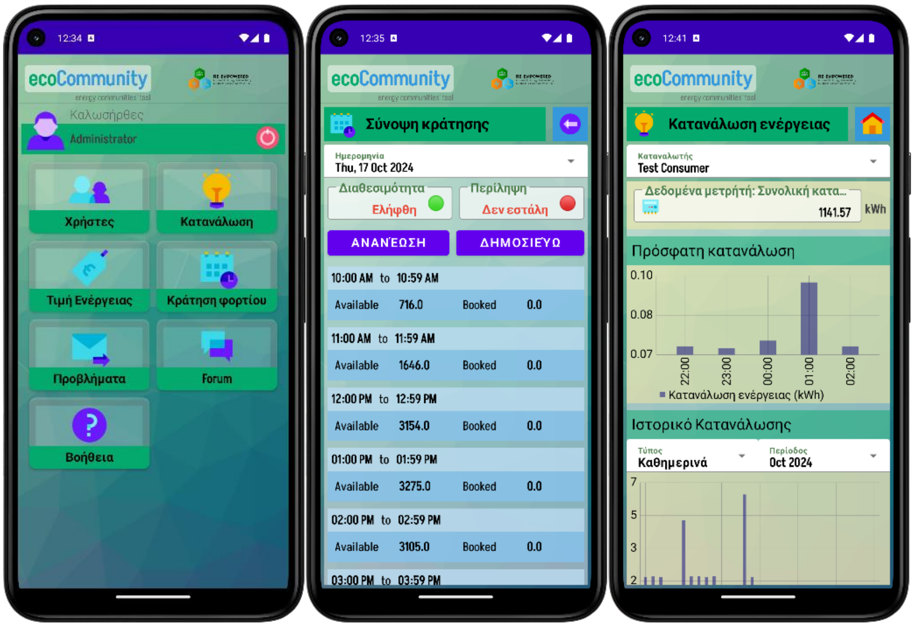


Figure 52: Communication architecture of ecoCommunity with other ecoTools in Gaidouromantra microgrid.

The key modules deployed at the Gaidouromantra microgrid are consumption, pricing, load booking, problem reporting, forum and help and support modules. The user interface of the mobile application of the tool includes English and Greek language options. The Greek language option for the tool improves the ease of using the app for the local energy community.

The energy consumption module relies on the ecoDR, and other smart meters (SLAM) measurements obtained from ecoMicrogrid through the ecoPlatform. These measurements will be stored in the cloud database of the ecoCommunity tool for any analysis or visualization at a later stage. The real-time pricing indication data will be received from the ecoMicrogrid tool on an hourly basis. The load-booking module utilizes the forecasted available energy data received from ecoMicrogrid. The energy availability for 1 Day + 24 Hours is published daily at 12:01 am by the ecoMicrogrid tool and will be utilized for generating the bookable timeslots in the ecoCommunity tool. The consumer users can book the time slots to use the noncritical loads (water pumps). The booking summary for 24 Hours will be daily published by ecoCommunity at midnight.



(a) (b) (c)

Figure 53: Screenshots of ecoCommunity tool deployed in Gaidouromantra microgrid (a) administrator (b) load booking summary (c) consumption

4.9.2 Purpose of deploying this Tool

The purpose of the ecoCommunity tool in the Gaidouromantra microgrid demo site is to facilitate community engagement in the microgrid operation by providing access to real-time as well as historical consumption data, real-time variable pricing/status indication data, and community load management and coordination.

The access to consumption data enables energy users of the demo site to regulate or adjust their consumption based on personal and communal requirements. The real-time variable pricing indication provides suggestions to consumers on the time durations for which the energy prices are comparatively lower so that the non-critical loads can be connected without much energy charges for consumers who are liable to variable pricing tariffs. This pricing indication is also associated with a status indication which can be utilized by the energy community to understand the operational status of the microgrid concerning the availability of energy and the efficiency of the system. Based on the status indication, the community can take appropriate measures to maintain the stability and reliability of the systems by voluntarily disconnecting the non-critical loads.

The coordination and management of the communal loads is another aspect which is catered for by the tool. Based on the energy availability, a set of time slots will be displayed in the tool for the energy consumers to book for using the shared communal loads. This facilitates better coordination and utilization of the load as well as facilitates demand side management.

The problem reporting and help and support module is intended for the support of the energy community. The forum provides a common space for energy users to share their experiences and suggestions on the microgrid system. The help and support module supports the hosting of the manuals and other ecoTool-related documents. The demo site administrators can upload and update the documents through the mobile application interface.

4.9.3 Deployment Timeline

4.9.3.1 Current Status

The cloud database for the storage of data is hosted using Google Firebase service with the server location in the Netherlands to confirm the GDPR requirements. The user interface text of the tool translated into Greek has been reviewed by the demo site leader. The demosite specific version of the mobile application APK has been developed and tested for communication and data exchange with ecoMicrogrid via ecoPlatform through MQTT topic relevant to various modules. The details of consumers participating in the demonstration as well as details on the energy meters and loads are gathered through demo site leaders and are updated in the database and APK. The final APK is installed on the demo site users as part of demonstration of the tool by July 2024.

4.9.3.2 Future Plan

As the deployment of the tool is completed, the tool is currently being demonstrated and evaluated starting from early October 2024 with the involvement of residents from the Gaidouromantra community.

Table 14: Deployment Status of ecoCommunity tool in Gaidouromantra demosite

Sl. No.	Task	Status	Expected Completion
1	Creation of a cloud database for the storage of data. Server Location: Netherlands	Completed	-
2	Review and finalize the tool UI text translation - English to Greek.	Completed	-
3	Integration of domo site specific modules and development of APK for testing.	Completed	-
4	Deployment and testing of APK with demo site leaders and administrators.	Completed	-
5	Testing and verifying communication and data exchange with ecoTools	Completed	-
6	Gather details on tool users, managers, meters, loads etc.	Completed	-
7	Tool parameterization and configuration of the database for demonstration	Completed	-
8	Installation of application on the mobile phones of consumers/managers from demo site.	Completed	-

4.10 ecoResilience

4.10.1 General Description

In rural and particularly remote areas where extending the electrical grid is difficult, low-cost renewable energy technologies designed for small-scale electricity generation, such as the locally manufactured small wind turbine (LMSWT), can enhance energy access for rural communities. LMSWTs provide an economical solution for creating mini-grids in regions with favorable wind conditions. By using locally sourced materials, tools, and production methods, these turbines significantly lower the initial costs of rural electrification projects. Moreover, providing proper maintenance training to local users and technical partners reduces operation and maintenance expenses, minimizing the need for personnel transportation and dependence on global supply chains.

The LMSWTs developed in this project are designed to be grid-connected, featuring a rotor diameter of 4.3 meters and a rated power of 3 kW at a wind speed of 10 m/s. These turbines can produce 4450 kWh annually when installed at a hub height of 12 meters in a location with an average wind speed of 4.5 m/s, typical for a small wind turbine site. The ICCS-NTUA has developed a series of openly accessible design and analysis tools aimed at empowering local SWT manufacturers, and these tools have been used for the development of LMSWTs within the ecoResilience tool.

4.10.2 Purpose of Deploying This Tool

The LMSWT was strategically deployed at the Gaidouromantra demo site with several key objectives. One primary goal was to provide auxiliary services to the microgrid, particularly by reducing the operating hours of the diesel generator. This is especially crucial during the windy summer months when consumer loads are at their peak, thereby enhancing the overall efficiency and sustainability of the microgrid. By harnessing wind energy, the LMSWT helps in lowering fuel consumption and emissions associated with diesel generators, contributing to a cleaner energy mix and more resilient power supply for the community.

Additionally, the project aimed to demonstrate the feasibility and advantages of simple and cost-effective maintenance procedures. These procedures are designed to be easily performed by local project partners and the user community, ensuring that the system remains operational without requiring extensive external support. This aspect of the deployment highlights the importance of local capacity building and empowerment, fostering a sense of ownership and self-reliance among the community members.

Furthermore, the deployment served as a practical field test for evaluating the effectiveness of the SWT design tools developed by the ICCS-NTUA. It also assessed the local manufacturing process when applied by untrained individuals, such as students. This hands-on experience provided valuable insights into the real-world applicability and scalability of the SWT design and manufacturing methodologies. The involvement of students in the project underscores the educational dimension, offering them practical exposure and enhancing their skills in renewable energy technologies.

Overall, the deployment of the LMSWT at the Gaidouromantra demo site was a comprehensive effort to enhance microgrid performance, promote sustainable energy practices, and build local expertise in renewable energy systems.

4.10.3 Demo Site Specific Challenges Faced During Deployment

The deployment of the LMSWT encountered several challenges, which impacted to an extent the project's execution. One of the primary difficulties was the extensive labor required for manufacturing both the SWT and its tower. Coordinating this effort with a group of volunteer students proved challenging, as it required detailed planning and scheduling to ensure the project was completed within the designated time frame. The reliance on volunteers introduced a variability in availability and expertise, sometimes complicating the manufacturing process.

Additionally, selecting the installation site for the tower involved a complex process that necessitated the active involvement and consensus of the local community. This process was time-consuming and demanded considerable effort in negotiations and discussions to address the various concerns and preferences of community members. Ensuring community buy-in was crucial for the project's success but required a delicate balance of addressing differing opinions and achieving a mutually acceptable solution.

Concerns regarding the visual impact and potential acoustic noise emissions of the LMSWT further complicated the deployment. Some local residents were concerned about how the turbine would alter the landscape's aesthetic, while others were worried about noise pollution. These concerns necessitated additional community meetings and informational sessions to provide reassurances and evidence from similar installations to mitigate fears.

The project also faced logistical challenges related to the procurement of materials. Disruptions in global trade, influenced by various factors such as geopolitical tensions and economic instability, made it difficult to source certain materials locally. These disruptions led to delays and forced the project team to seek alternative suppliers, often at higher costs due to sudden price increases driven also by inflation. The volatility in material costs proved that this could be an added an extra layer of financial strain to the budget of such projects.

Moreover, transporting materials, components, and personnel to the island was frequently delayed due to high wind conditions. The island's geographic location and weather patterns introduced an element of unpredictability to the logistics, causing delays that could have impacted the overall project timeline. These transportation challenges highlighted the importance of contingency planning and flexibility in scheduling to accommodate unforeseen delays.

In summary, the deployment of the LMSWT at the Gaidouromantra demo site was a multifaceted endeavor that required overcoming numerous challenges. These included coordinating extensive volunteer labor, engaging the local community in site selection, addressing concerns about visual and acoustic impacts, navigating disruptions in material procurement, and managing transportation delays. Each of these challenges underscored the complexity of implementing renewable energy projects in remote locations and the necessity for comprehensive planning, community engagement, and adaptive project management strategies.

4.10.4 Deployment Timeline

4.10.4.1 Current Status

In December 2022, the LMSWT and tower designed for the Gaidouromantra demo site on Kythnos Island were manufactured locally at NTUA with a student team, were then installed at the Gaidouromantra demo site.

Figure 54: a) manufactured at ICCS-NTUA in the framework of RE-EMPOWERED, b) installed at Gaidouromantra

The LMSWT was maintained during a field visit in September 2023, as part of a maintenance workshop. In addition, two meteorological sensors were installed on the small wind turbine tower, an anemometer for measuring wind speed and a wind vane for measuring wind direction. The maintenance procedure was based on the locally manufactured small wind turbine maintenance manual developed by the Wind Empowerment association.

Figure 55: a) Locally manufactured SWT and tower lowered for maintenance, b) LMSWT being maintained by project partners and user community.

Table 15: The LMSWT, as part of ecoResilience, has been fully deployed at the Gaidouromantra demo site. Below are the specific tasks that have been completed

Sl. No.	Task	Status	Expected Completion
1	Design of LMSWT and tower	Completed	-
2	Workshop organization (materials, participants, etc.)	Completed	-
3	Implementation of manufacturing workshop at the NTUA	Completed	-
4	Site visit for the installation of the LMSWT at the Gaidouromantra demo site	Completed	-
5	Installation of LMSWT and tower at Gaidouromantra	Completed	-

6	Commissioning of LMSWT and trouble shooting	Completed	-
7	First maintenance visit and LMSWT inspection after one year	Completed	-

4.10.4.2 Future Plan

As the deployment has been completed for the ecoResilience tool for the Kythnos demo site, the next steps are the continuation of the demonstration phase. This phase includes longer term operation of the tool, and acquisition of relevant measurements.

4.11 Main Achievements

- Preliminary works and installations for the reception of all ecoTools have been completed.
- ecoTools to be deployed in both Kythnos Demo sites have been site specifically developed successfully.
- Parametrization of ecoTools has been completed successfully according to site's specific features. (i.e. ecoMicrogrid, ecoEMS, ecoCommunity, ecoPlanning, ecoPlatform)
- All ecoTools have already been successfully deployed including, ecoDR and ecoMonitor which were received from India in September 2024.
- Troubleshooting for the already deployed ecoTools has been completed.
- Demonstration phase has been started for all ecoTools deployed in Kythnos.

4.12 Contribution Per Partner

Table 16: Each partner's contribution in both Kythnos island demo sites is presented in the following tables.

Involved partners	Contributions (Kythnos power system & Gaidouromandra microgrid)
ICCS-NTUA	Kythnos demo-site leader. Engineering, installation and configuration of necessary preliminary equipment. Conducted the deployment and demonstration plan of Kythnos power system and Gaidouromantra microgrid. ICCS-NTUA is taking charge of the deployment of ecoEMS, ecoMicrogrid and ecoPlanning tools. Constructed and deployed the wind turbine in Gaidouromantra pilot site, in the context of ecoResilience. Supported the customization and integration of ecoCommunity at Kythnos demo-site. Undertook the deployment of ecoDR and ecoMonitor. Significantly contributed to the creation of the SCADA-HMI system.
DAFNI	Responsible for community engagement and facilitating communication with local citizens and arrangements for site works. Support on installation site works. Supported the creation of the deployment and demonstration plan of Kythnos demo site.

	Contributed to the installation of the wind turbine at Gaidouromantra site. DAFNI intensely supported the deployment in Gaidouromantra microgrid through maintenance works, repairs after a local fire, installation of smart meters and an optic fiber network. DAFNI has also executed preparatory actions for preparation for the installation of ecoMonitor at the local high school.
PROTASIS	Leading the procurement and provision of the necessary hardware. Contributed to the deployment of ecoMicrogrid at the Gaidouromantra. Provide and implement the software for the collection of the data from the demo's site energy sources (PV plant, Energy Storage System, Wind Turbine and a Diesel generator). Additionally, installed an SCADA-HMI system displaying the single line diagrams and measurement values, along with a functionality of controlling the diesel generator and the HVAC through commands.
CSIR-CMERI	Responsible for the development of ecoMonitor and ecoDR tools. Leading the ecoMonitor and ecoDR activities. Provided specifications for ecoMonitor and ecoDR related preliminary equipment.
ICL	Developed and deployed the ecoCommunity tool and tested the interoperability with other ecoTools. Tested the data exchange with other ecoTools through ecoPlatform.

4.13 Conclusions

On the grounds of peculiarity of Kythnos demo sites being rural area and vacation destination, several difficulties were to be overcome such as communication issues and residents reaching, without however missing the typical equipment related problems. Nevertheless, the testing ground is prepared, all the ecoTools to be deployed have been developed and tested while also all of them have already been deployed with all issues resolved. Moreover, demonstration phase has started. Specifically, a complete and functional demonstration is ongoing as from October 2024.

5 Bornholm Island

5.1 Introduction

Bornholm Island is a Danish Island located in the Baltic Sea. The island itself is rather small with an area of 589 km^2, a coastline of 158 km and a population of 40.000. Bornholm is fairly well developed in terms of renewable energy resources (RES) but the demonstration activities will seek to increase energy efficiency and increase the RES penetration by efficient generation and demand management. Demonstration activities plus work with population awareness and customer engagement will benefit the overall green agenda for Bornholm.

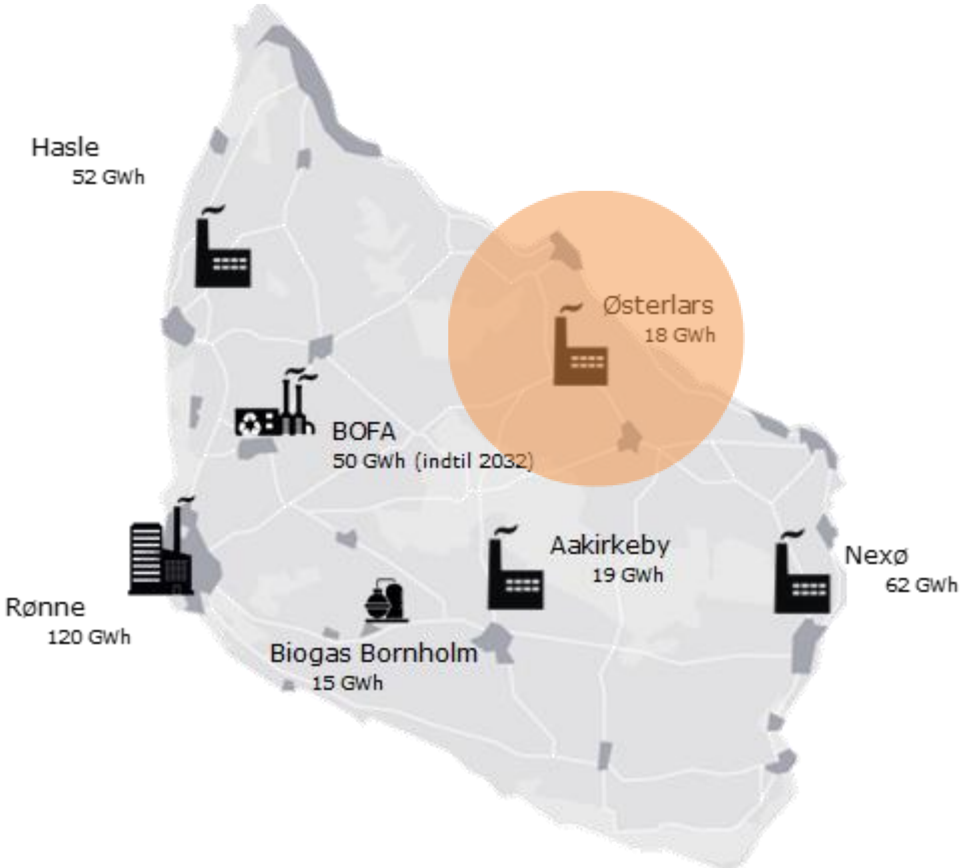


Figure 56: Yearly heat production on Bornholm. Demo site marked in orange.

More precisely the location of the demonstration site on Bornholm is located in Østerlars (see orange marker on the map above) and in Gudhjem. In Østerlars one of BV's four primary heat plants is located.

5.1.1 Aim

The aims of the demonstration site on Bornholm builds upon an already highly developed energy system with a high penetration of renewable energy sources. In short the aims are as follows:

- Develop and implement a fully functional system (set of ecoTools) to control the usage of renewable energy to produce district heating in favorable situations.
- Test and demonstrate various ecoTools with reliable connection and required datapoints for a functional energy management system.

- Establish required installations for a demand-side-management system in buildings with various functionalities, energy consumption and usage patterns.

5.1.2 Background Information

- The project partner BV is a district heating company on Bornholm named **B**ornholms **V**arme (translates to Bornholms Heat)
- BV is a subsidiary company of Bornholms Energy & Supply, a local multidisciplinary utility company.
- Seven district heating customers are used as project participants
  - 4 private households
  - 1 Swimming pool
  - 1 Church
  - 1 Elementary school
- The heating plant in Østerlars is equipped with 4 x 0,6 MW electric boilers, which represent the beginning integration of the electrical system and the district heating system in BV.

Figure 57: Østerlars Heat Plant - Fact sheet

5.1.3 Status of Commercial Infrastructure

- Required equipment for DSM system has been installed
- DSM equipment has a wired connection to each district heating unit
- DSM equipment is logging high resolution data to BV data platform, from where data to project is distributed.
- A new software has been acquired to allow two-way data transfer to and from the SCADA system which operates on a local network.

The following figures show the dataflow from the DSM equipment to the relevant ecoTools, example data streams and data from the SCADA system.

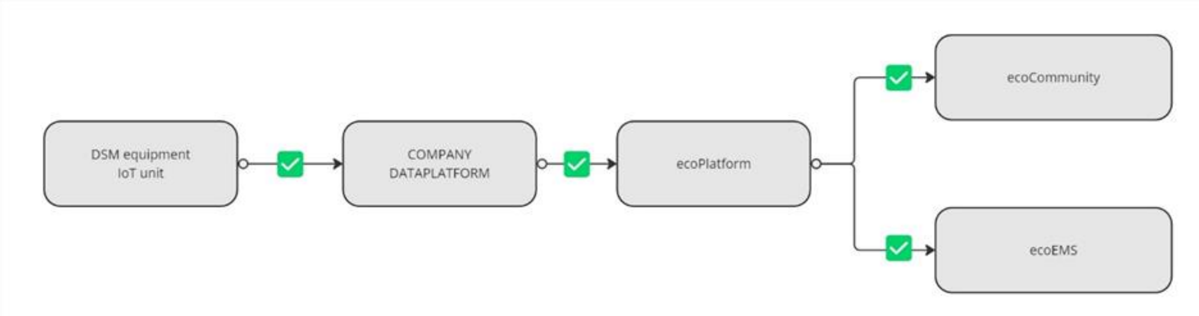
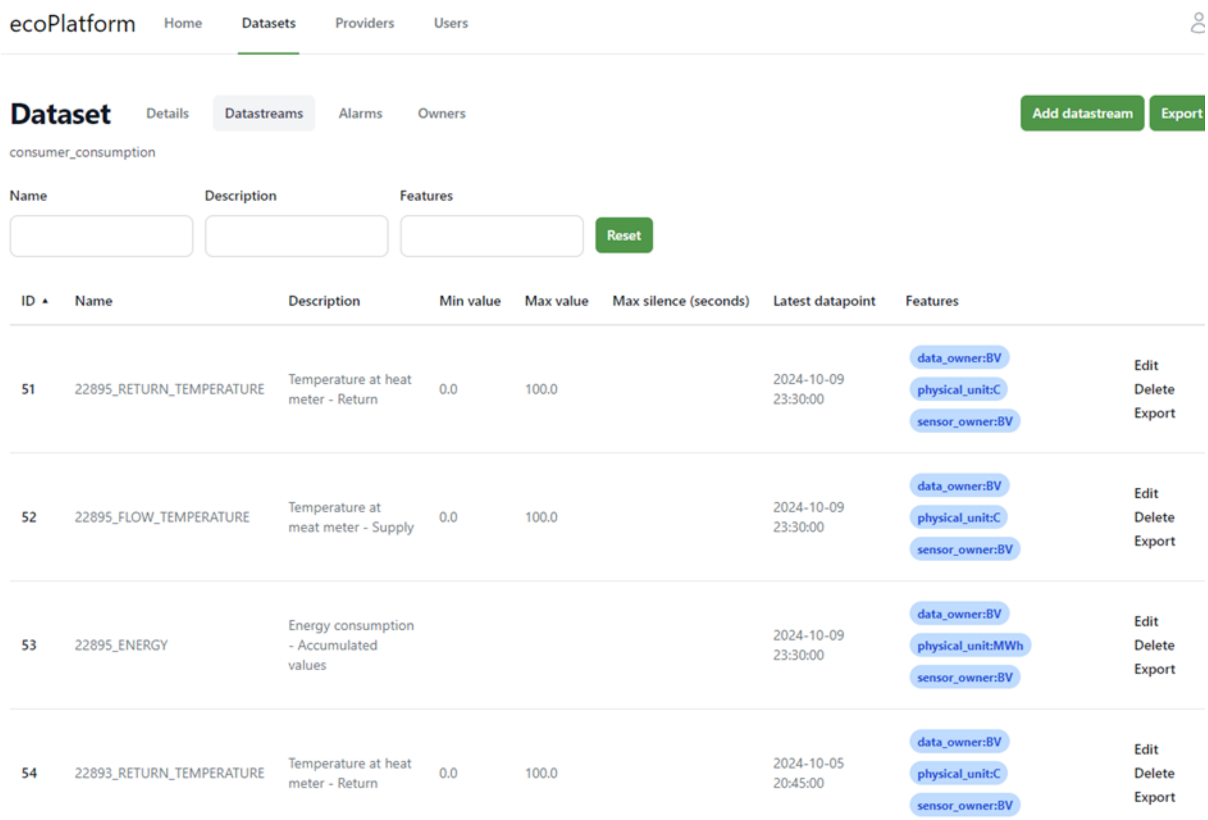


Figure 58: Dataflow from the DSM equipment to ecoTools



ID	Name	Description	Min value	Max value	Max silence (seconds)	Latest datapoint	Features	
51	22895_RETURN_TEMPERATURE	Temperature at heat meter - Return	0.0	100.0		2024-10-09 23:30:00	data_owner:BV physical_unit:C sensor_owner:BV	Edit Delete Export
52	22895_FLOW_TEMPERATURE	Temperature at meat meter - Supply	0.0	100.0		2024-10-09 23:30:00	data_owner:BV physical_unit:C sensor_owner:BV	Edit Delete Export
53	22895_ENERGY	Energy consumption - Accumulated values				2024-10-09 23:30:00	data_owner:BV physical_unit:MWh sensor_owner:BV	Edit Delete Export
54	22893_RETURN_TEMPERATURE	Temperature at heat meter - Return	0.0	100.0		2024-10-05 20:45:00	data_owner:BV physical_unit:C sensor_owner:BV	Edit Delete Export

Figure 59: Example of some of the data streams in ecoPlatform with data from the DSM equipment

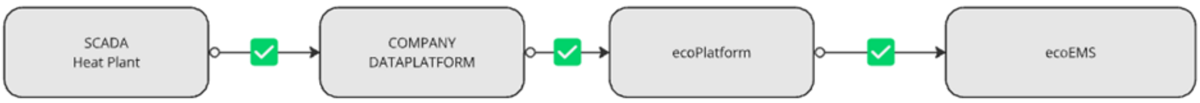


Figure 60: Dataflow for the data coming from the SCADA system within the heat plant towards the ecoTools

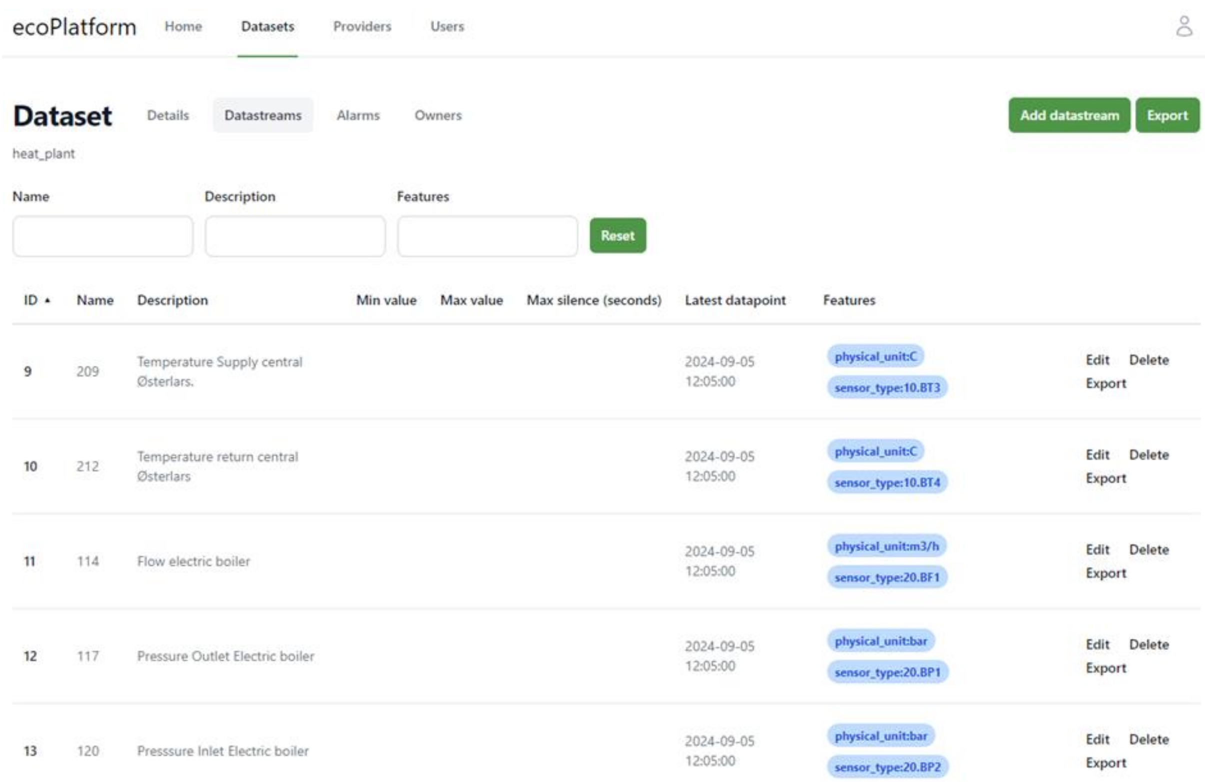


Figure 61: Example of some of the data streams in ecoPlatform with data from the SCADA system

5.2 Overview of Tools and Solutions to be Demonstrated

The following ecoTools will be demonstrated on Bornholm:

Table 17: ecoTools demonstrated on Bornholm site.

ecoTool	Bornholm Demo Site
ecoEMS	✓
ecoMicrogrid	
ecoPlanning	
ecoDR	✓
ecoPlatform	✓
ecoConverter	
ecoMonitor	✓
ecoCommunity	✓
ecoVehicle	
ecoResilience	

In the following, each ecoTool and its status is presented.

5.3 ecoEMS

5.3.1 General Description

The ecoEMS tool is designed as an Energy Management System to optimize the operation of power systems for Non-Interconnected Islands (NIIs). It includes various optimization algorithms, demand response techniques, and a communication framework.

Key features of the tool include a user-friendly interface, a database with power station information, and reporting capabilities. Its goal is to provide a 24x7 power supply at low cost by utilizing multiple energy vectors. The system employs energy storage, Renewable Energy Sources (RES), and demand forecasting to achieve optimal performance. This document also covers the lab validation and testing of the tool.

ecoEMS is an internet-based tool that supports multiple users with different permissions. It can generate reports in .csv format and uses HighCharts, HTML5, and JavaScript for visualization. The main objectives of the EMS software are to ensure optimal Day Ahead Scheduling (DAS), Economic Dispatch (ED), and support intraday energy market processes for Non-Interconnected Isolated Island Power Systems (NIIPSs). It aims to minimize operational costs, maximize RES penetration, and adhere to safety regulations and technical limitations.

5.3.2 Purpose of Deploying This Tool

During the development and testing phases for the demo sites on Kythnos and Bornholm islands, a digital twin model was employed to simulate the development server before its deployment to the production server. This approach leveraged the availability and maturity of data access. Real-time site measurements are sent to the ecoEMS database through the ecoPlatform, where the ecoEMS tool processes the necessary data for optimization and then sends the resulting orders back to the demo sites.
In terms of deployment, the production and development servers are eventually consolidated, removing any distinction between them. This allows peripheral modules to operate in automated mode based on a time scheduler to identify and address any potential bugs.
To thoroughly evaluate and test the ecoTool, and to assess aspects such as information flow, algorithm adequacy, optimization decisions, and system stability, the ecoEMS system is deployed once on the production server. Continuous testing is performed to ensure the software's performance and stability.

In the next figures we can see the tool receiving data from the ecoPlatform, validating the interoperability of the ecoTools after the deployment phase. Firstly, we land on the log in page, following we can see dummy data being exchanged about the forecasts of the PV and the Demand Side Management and finally data being produced from ecoEMS and being transmitted to ecoPlatform for consumption by other ecoTools.

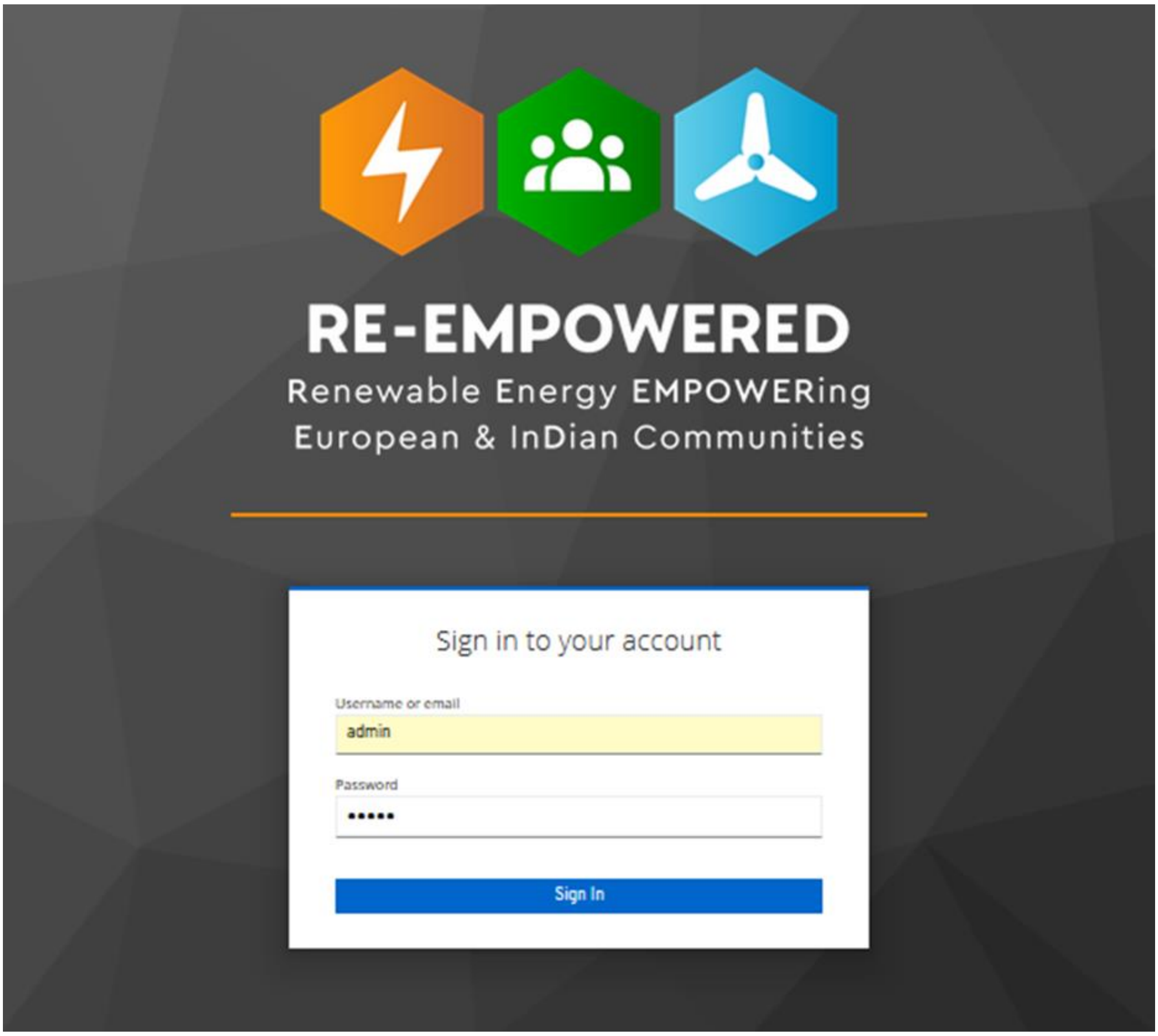


Figure 62: Landing log in page for ecoEMS.

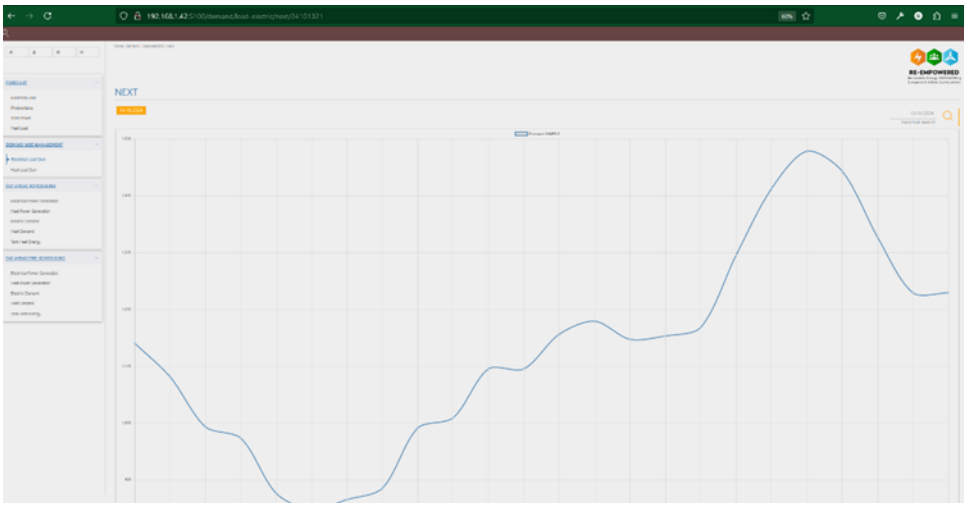


Figure 63: Page of wind forecasts in ecoEMS for Bornholm demo site.

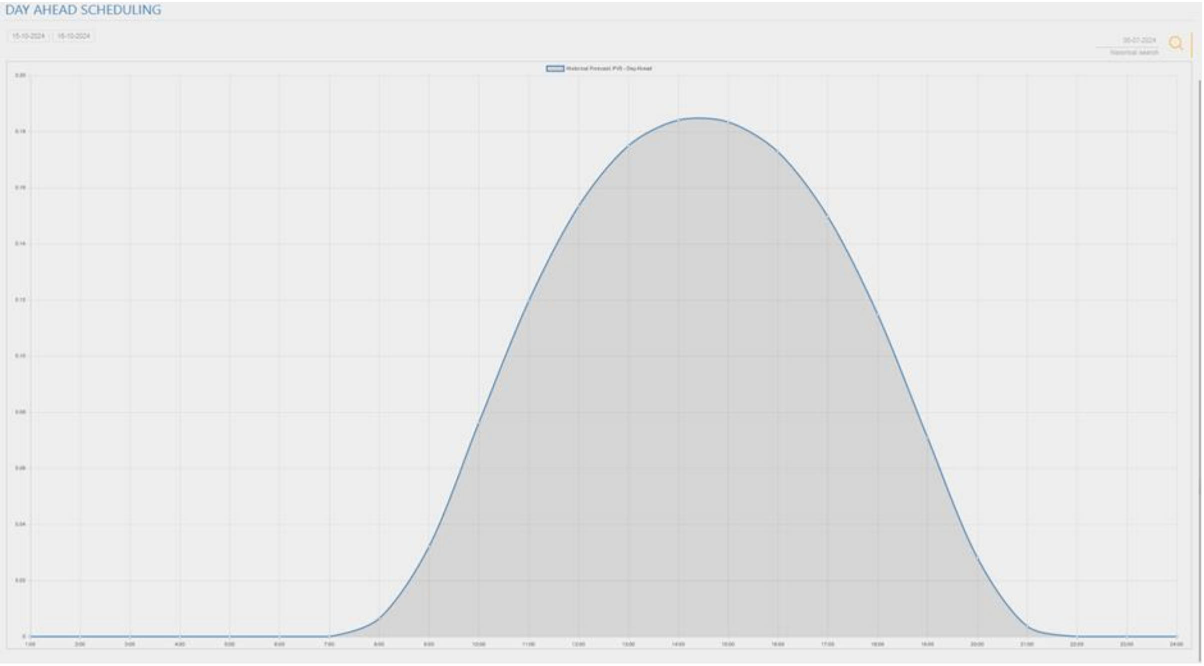


Figure 64: Page of pv forecasts in ecoEMS for Bornholm demo site.

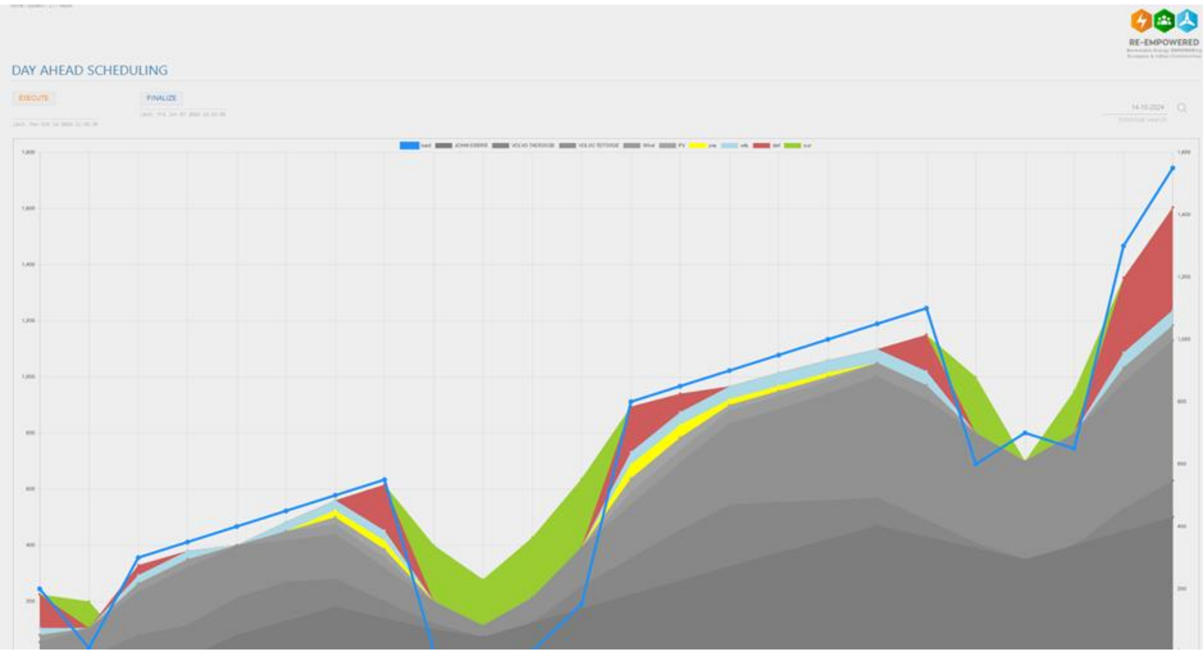


Figure 65: Demo output of ecoEMS scheduling algorithm for Bornholm demo site.

5.3.3 Demo Site Specific Challenges Faced During Deployment

The ecoEMS tool is hosted at the ICCS-NTUA lab and accessible online through a VPN client provided to essential personnel, ensuring robust security. This streamlined solution consolidates all functionalities into a single, easily monitored system, simplifying management and restoration if issues occur. The design reduces complexity to facilitate easier deployment. However, integrating the tool with diverse field data sources presented challenges, particularly in ensuring compatibility with various devices on the island that use different communication protocols and data formats. This issue was resolved by adding a module that standardizes all data formats.

5.3.4 Deployment Timeline

5.3.4.1 Current Status

ecoEMS has been successfully deployed and operational at the demo site by September 2024. The deployed version has integrated key functionalities like MQTT communication, robust data storage, visualization tools and sophisticated optimization algorithms. They are instrumental in ensuring smooth operation of optimizing the various energy vectors within the demo site.

5.3.4.2 Future Plan

As the deployment has been completed for ecoEMS tool for the Bornholm demo site, ecoEMS is being prepared for full demonstration in November 2024.

5.4 ecoDR

5.4.1 General Description

The ecoDR tool is an advanced smart meter with innovative features to enhance energy management and control. It encompasses a wide range of functionalities aimed at improving energy measurement, load control, and remote monitoring of non-critical loads. It incorporates advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities, allowing for efficient measurement of household energy consumption. Additionally, the smart meters can communicate with other ecoTools, such as ecoMicrogrid, to implement demand-side management services through non-critical load scheduling.

Key features of ecoDR include a static single-phase, two-wire energy meter with various parameters available for measurement, such as Irms, Vrms, active energy, power factor, apparent power, and load. The smart meters also come equipped with a visible indicator for poor power factor, an LCD for display, and support for MODBUS communication protocol.

Advanced functionalities integrated into the developed meters include an inbuilt programmable load and energy limiter, load-shedding controller, and two output ports for critical and non-critical loads. Additionally, the meters offer management of non-critical loads through scheduling and control based on commands from the ecoMicrogrid.

5.4.2 Purpose of Deploying This Tool

This ecoDR tool does the remote monitoring and controls the energy consumption of a small electric heater. It maintains a log of events, collecting critical electrical parameters like Vpeak, Vrms, Ipeak, Irms, active energy, power factor, apparent power, and reactive power, along with timestamps. The relevant data are transmitted to ecoPlatform for computation of cost based on real-time pricing data.

5.4.3 Demo Site Specific Challenges Faced During Deployment

The ecoDR tool is a smart meter with advanced features designed to enhance energy management and control. Despite its a standardized installation process, several challenges emerged during deployment, necessitating fundamental adjustments to ensure a successful implementation:

Regulatory Compliance: Designed primarily for the Indian market, the ecoDR prototype did not initially meet CE standards, which are mandatory for deployment in the EU. Adapting the device to operate within this regulatory environment presented significant challenges, as it required modifications beyond its original specifications.

Logistical Hurdles: Transporting research equipment across continents posed logistical issues, including bureaucratic complexities and delays that impacted project timelines. Additionally, the devices arrived with minor damage that needed repairs, adding further delays to deployment.

Integration Compatibility: The ecoDR's Modbus implementation differs from standard approaches, making integration with other ecoTools more complex. Custom solutions were necessary to ensure compatibility and reliable communication between devices.

Given these challenges, the ecoDR device could not be installed directly at the Bornholm Energy and Utilities (BEOF), as it did not meet mandatory EU requirements and required a controlled environment. As a result, the device was relocated to DTU, which offers both a compliant laboratory setting and secure testing facilities within the same climatic region, ensuring safe setup and operational reliability. ecoDR is being connected through the internet with ecoPlatform and the Bornholm demo-site, minimizing the impact of this relocation on the project activities.

5.4.4 Deployment Timeline

5.4.4.1 Current Status

Following ecoDR's arrival at DTU, along with a complementary electric heater to demonstrate load control capabilities for flexibility decisions, deployment activities commenced in late October 2024. The tool was successfully installed and integrated with the electric heater in DTU's control room, simulating its intended operation at the Bornholm Energy and Utilities (BEOF) site. The demonstration phase is now underway.
However, delays in the tool's shipment from India impacted the overall timeline, and additional regulatory compliance requirements introduced further setbacks upon arrival.

Figure 66: ecoDR Installed at DTU laboratory on a rolling platform.

5.4.4.2 Future Plan

With ecoDR now operational in DTU's controlled laboratory environment, demonstration activities will advance with its integration into the ecoPlatform for ongoing data collection and analysis. This connection will enable performance evaluation under simulated real-world conditions. Moving forward, efforts will focus on completing the demonstration phase and assessing the tool's functionality and effectiveness.

5.5 ecoPlatform

5.5.1 General Description

The ecoPlatform is a key component within the RE-EMPOWERED project, created to enable the smooth integration and efficient operation of diverse tools. It serves as an open, cloud-based platform that ensures secure data acquisition, communication, and storage, thereby facilitating the effective control and management of distributed energy resources (DERs). Two versions of the ecoPlatform have been developed: ecoPlatform-A and ecoPlatform-B, each tailored to meet the specific needs of different demo sites. ecoPlatform-A is currently in use at the Bornholm demo site.

5.5.2 Purpose of Deploying This Tool

The primary purpose of deploying the ecoPlatform is to advance the integration of renewable energy sources (RES) and enhance the overall efficiency of multi-energy systems. The ecoPlatform plays a critical role within the ecoToolset by facilitating optimal operation, high flexibility, and efficiency. It is vital tool for the exchange of information mainly among ecoEMS, ecoMicrogrid, ecoDR, ecoMonitor and ecoCommunity and other assets that will be present at the demo-sites. The ecoPlatform supports several project objectives, including:

- Increasing the penetration and utilization of RES.
- Implementing digitalization and ICT solutions.
- Improving energy access and environmental quality.
- Promoting knowledge exchange among project partners.

By serving as the interface between power grid components and the external network, the ecoPlatform facilitates secure and reliable data exchange, supporting informed decision-making and enabling the smooth operation of the ecoTools suite, particularly ecoEMS, ecoMicrogrid, ecoDR, ecoMonitor, and ecoCommunity. It also plays a crucial role in achieving effective communication and storage of data among the interconnected systems.

5.5.3 Demo Site Specific Challenges Faced During Deployment

Deploying the ecoPlatform across diverse demo sites—European sites like Bornholm and Kythnos, and Indian sites such as Keonjhar and Ghoramara—presented unique challenges:
The edge device for the Bornholm demo site required robust security measures to monitor communication channels continuously and report any errors promptly. This ensured a high level of protection critical for local data storage.

5.5.4 Deployment Timeline

5.5.4.1 Current Status

ecoPlatform is now successfully deployed and fully operational for the Bornholm demo site since June 2024. It offers advanced control capabilities and features an integrated alarm system, which is particularly useful in scenarios requiring strict control measures.

ecoPlatform includes key functionalities such as MQTT communication, data exchange in JSON and CSV formats, reliable data storage, and powerful data visualization tools.

All partners have received their login credentials, along with a dataset specific API key and secret, enabling them to subscribe to and publish data through the platform. They are instrumental in ensuring efficient interaction between various energy management tools within the demo sites. The various datasets created by the corresponding ecoTool and demo site leader to exchange data with the inclusion of demo site-specific measurement data and forecasts are shown in Figure 67.

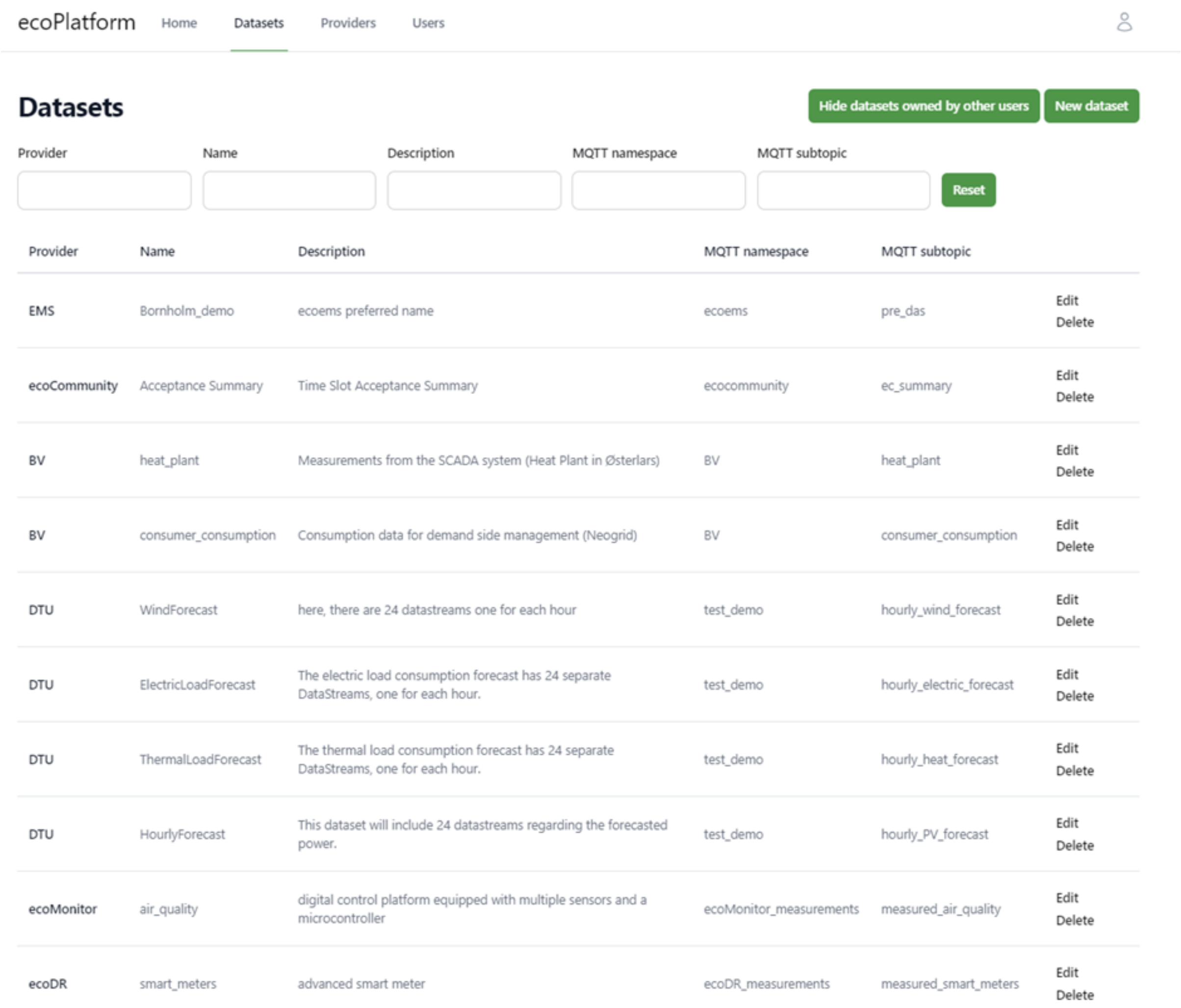


Figure 67: Datasets created by the ecoTool leaders for ecoEMS, ecoMicrogrid, ecoDR, ecoMonitor, and ecoCommunity, enabling secure interaction and data exchange at the Bornholm demo site.

5.5.4.2 Future Plan

The ongoing development aims to refine ecoPlatform's capabilities and explore new functionalities that further support the goals of the RE-EMPOWERED project, ultimately contributing to a more resilient and efficient renewable energy ecosystem.
Additionally, addressing the recent SSL certificate renewal is a priority, ensuring that all data exchanges through the ecoPlatform are performed securely and in compliance with data sharing agreements. Despite the recent challenge of the SSL certificate expiration and the complexities encountered during manual renewal and configuration with Nginx, a resolution pathway is in place. The committed efforts of our team and domain providers are expected to rectify the issue shortly. Consequently, secure and compliant data exchanges at the Bornholm demo site will be re-established, reaffirming our dedication to data integrity and security.

5.6 ecoMonitor

5.6.1 General Description

ecoMonitor is a digital control platform equipped with multiple sensors and a microcontroller-based processing unit for real time monitoring of the local ambient air quality parameters, such as NO_2, O_3, SO_2, CO, PM2.5 and PM10 micro particles, including ambient temperature and relative humidity. The measured air quality data are transmitted to the central control station via MODBUS/MQTT gateway for display and further analysis.

In addition to remote monitoring, the tool features a local display unit with color indication, which alerts the local community once any of the air quality parameter exceeds the maximum allowable limit.

5.6.2 Purpose of Deploying This Tool

This ecoMonitor data provides useful insights regarding possible corrective actions of air quality and helps in analyzing the impact of the Renewable Energy Resources (RES) integration on air quality.

5.6.3 Demo Site Specific Challenges Faced During Deployment

The deployment of ecoMonitor at Bornholm's demo site, similar to ecoDR, encountered several challenges that required adjustments to the initial plan for successful implementation:

Protocol Compatibility: ecoMonitor does not support the MQTT protocol, necessitating a Modbus-to-MQTT gateway for integration with the ecoPlatform. This additional configuration increased complexity and extended the deployment timeline.

Logistical and Transit Challenges: Transporting the ecoMonitor from India introduced logistical obstacles, including navigating customs processes and delays. The devices arrived with minor damage requiring repairs, which further delayed deployment.

Non-standard Modbus Implementation: ecoMonitor's Modbus approach created integration challenges with other ecoTools, necessitating custom solutions to ensure compatibility.

Environmental Suitability: While ecoMonitor is built for outdoor use, its packaging could benefit from enhanced protection against environmental factors, preferably in a controlled indoor environment. The device’s placement was chosen to reduce exposure to adverse conditions, optimizing its performance and durability.

Given these challenges, the ecoMonitor could not be deployed at Bornholm demo site. It required a controlled laboratory environment that DTU provides, along with EU-compliant testing facilities. DTU’s lab setup in a similar climate ensures reliable testing and secure operations. ecoMonitor is being connected through the internet with ecoPlatform, minimizing the impact of this relocation on the project activities.

5.6.4 Deployment Timeline

5.6.4.1 Current Status

Deployment of ecoMonitor at DTU’s Lyngby Campus began upon the device's arrival in late October 2024 from Bornholm. The tool has been fully set up, and the demonstration phase has started, with the following key activities completed:

Installation: ecoMonitor was positioned in DTU’s controlled lab environment to ensure stable operation.

Communication Integration: Initial setup for continuous data flow is started, in order to enable uninterrupted data capture for the demonstration phase.

Figure 68: ecoMonitor Installed at DTU premises on a rolling platform.

5.6.4.2 Future Plan

The demonstration phase will focus on continuous data collection and analysis to assess ecoMonitor’s performance under simulated real-world conditions. This ongoing evaluation aims to identify areas for refinement and optimize ecoMonitor’s functionality for future deployments.

5.7 ecoCommunity

5.7.1 General Description

The ecoCommunity tool acts as a digital platform facilitating engagement and support for the energy community in the Bornholm demo site. The energy community consumers and demo site administrators utilize a mobile application as the interface to the tool. The data associated with the tool is stored in the cloud database.

The deployment of the tool deals with hosting the cloud database, installing the mobile application, as well as testing and verifying the communication with other ecoTools.

The Google Firebase cloud service is utilized for the cloud database and the server location is selected as the Netherlands to confirm the GDPR requirements for handling of personal data of the tool users. The administrator instance of the mobile application is responsible for the communication with ecoEMS and Neogrid devices through ecoPlatform, and the storage of the data in the cloud database. The consumer instance of the mobile application will utilize the cloud database for visualization of the stored data as well as to store new user inputs.

The key modules deployed at the Bornholm demo site are consumption, temperature control, problem reporting, forum and help and support modules. The user interface of the mobile application of the tool includes English and Danish language options. The Danish language option for the tool improves the ease of using the app for the local energy community.

The energy consumption module relies on the Neogrid measurement which is obtained from through the ecoPlatform. These measurements will be stored in the cloud database of the ecoCommunity tool for analysis or visualization.

The temperature control module utilizes the forecasted centralised co-optimisation control time slots received from ecoEMS. The time slots for 1 Day + 24 Hours are published daily at by the ecoEMS tool and will be utilized for displaying timeslots in the ecoCommunity tool. The consumer users can accept or reject the control during these time slots. The acceptance summary for 24 Hours will be published by ecoCommunity at midnight.

5.7.2 Purpose of Deploying This Tool

The purpose of the ecoCommunity tool in the Bornholm demo site is to facilitate community engagement in the microgrid operation by providing access to real-time as well as historical heating consumption data, enabling participation of domestic heating system in the centralized co-optimization algorithms etc.

The problem reporting and, help and support module is intended for the support of the energy community. The forum provides a common space for energy users to share their experiences and suggestions on the multi-energy system.

5.7.3 Deployment Timeline

5.7.3.1 Current Status

The cloud database for the storage of data is hosted using Google Firebase service with the server location in the Netherlands to confirm the GDPR requirements. The user interface text of the tool translated into Danish has been reviewed by the demo site leader. The demosite specific version of the mobile application APK has been developed and is currently being tested for communication and data exchange with ecoEMS and Neogrid device via ecoPlatform through MQTT topic relevant to various modules. The details of consumers participating in the demonstration as well as details on the energy meters and loads are gathered through demo site leaders and are updated in the database and APK. Successful testing and validation of the data exchange with ecoEMS and the Neogrid device has been completed. The application is being deployed on the mobile phones of the community members participating in the demonstration.

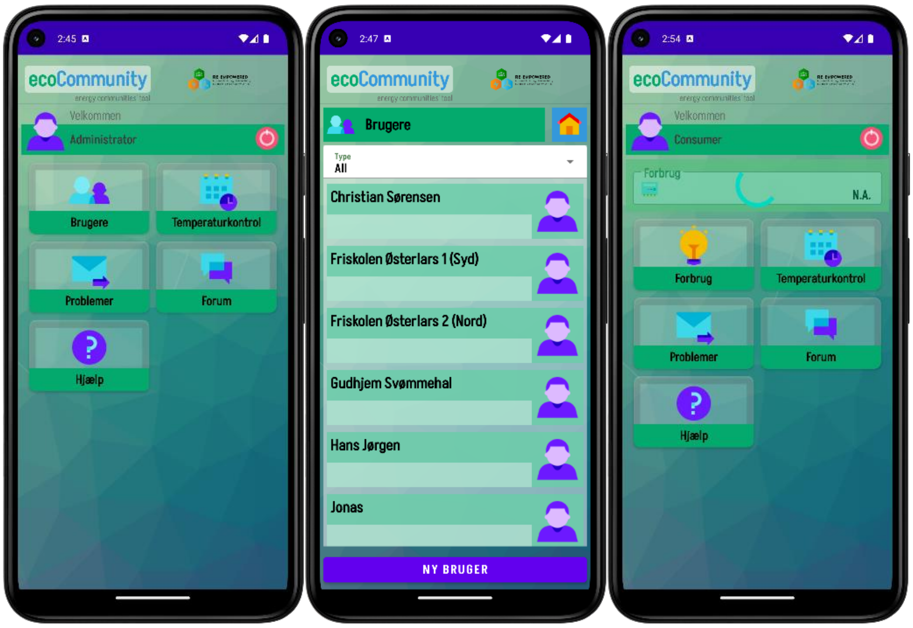


Figure 69: Screenshots of ecoCommunity tool deployed in Bornholm demosite (a) administrator (b) users (c) consumer

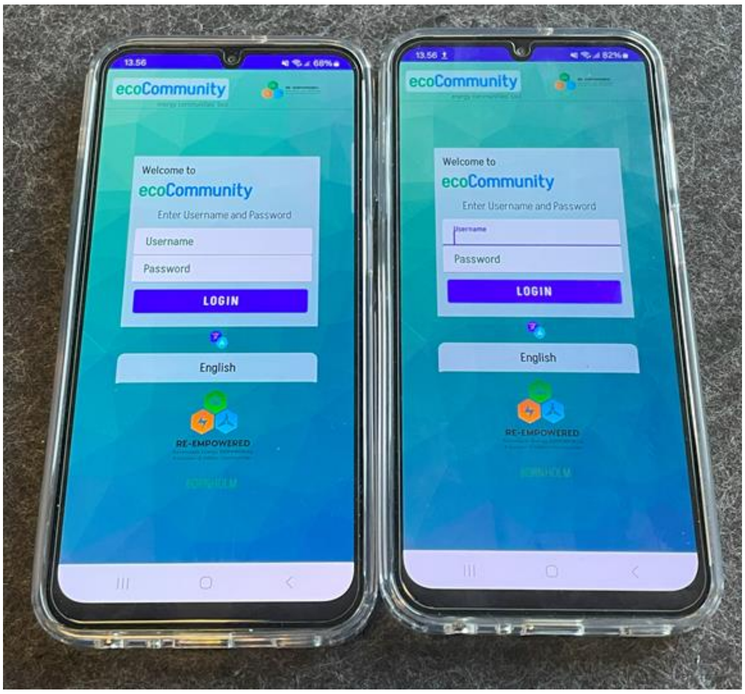


Figure 70: A pair of BEOF phones with ecoCommunity - Ready for testing (Bornholm)

5.7.3.2 Future Plan

The final parameterization and updating of the application are expected to be completed in October 2024 to start the final demonstration of the tool.

Table 18: Deployment Status of ecoCommunity tool in Bornholm Demosite

Sl. No.	Task	Status	Expected Completion
1	Creation of a cloud database for the storage of data. Server Location: Netherlands	Completed	-
2	Review and finalize the tool UI text translation - English to Danish.	Completed	-
3	Integration of domo site specific modules and development of APK for testing.	Completed	-
4	Deployment and testing of APK with demo site leaders and administrators.	Completed	-
5	Testing and verifying communication and data exchange with ecoTools	In-progress	November 10th 2024
6	Gather details on tool users, MQTT payloads, meters, loads etc.	Completed	-
7	Tool parameterization and configuration of the database for demonstration	In-progress	November 10th 2024
8	Installation of application on the mobile phones of consumers from demo site.	Completed	-

5.8 Main Achievements

- Finalized installation of equipment for DSM
- Solve signal strength issues using alternative LoRa sensors and gateway
- Successful deployment of site specific ecoTools: ecoEMS, ecoPlatform
- Deployment of ecoDR and ecoMonitor

5.9 Contribution Per Partner

Table 19: Contribution Chart per Partners for Bornholm Demosite

Involved partners	Contributions (Bornholm Demo-site)
BV	Bornholm demo-site leader. Installation and configuration of necessary commercial equipment along with installation of ecoTools. Data integration between equipment and ecoTools. Onboarding and communication with project participants

DTU	Development of ecoPlatform and establishing connection from local hardware for ecoDR and ecoMonitor to ecoPlatform
CSIR-CMERI	Development of ecoMonitor Development of ecoDR
ICCS-NTUA	ecoEMS leader and responsible for its deployment. Overall project management and alignment of procedures between partners when needed.
ICL	Developed and deployed the ecoCommunity tool and tested the interoperability with other ecoTools. Tested the data exchange with other ecoTools through ecoPlatform. Contributed in the algorithms of the ecoEMS

5.10 Conclusions

During the project duration, various obstacles related to installation, shipping delays, software compatibility and others have arisen that needed the partners effort in order to be overcome. The tools that were planned to be demonstrated in Bornholm demo site, have been developed, tested, deployed and the demo site is moving towards the demonstration phase. Timewise some uncertainties persist but a functional demonstration is expected to be possible no later than early November 2024.

6 Additional Developments

This section details the development of ecoMicrogrid functionalities that occurred following the completion of tasks T3.1 and T4.1. A significant challenge arose due to the absence of data regarding the State of Charge (SOC) of the battery systems at the Ghoramara and Keonjhar sites, which is critical for the effective operation of the ecoMicrogrid tool. The subsequent section provides a brief overview of the SOC algorithm implemented to address this challenge.

6.1 State of Charge estimation

The algorithm uses the Coulomb counting method to calculate the current State of Charge of the battery. The formula of this method is presented below:

$$SoC = 100 \cdot \left(1 - \frac{1}{Qmax} \cdot \int_0^t i(t)dt\right) \quad \text{(Eq.1)}$$

By integrating the current over time, the energy (in Ampere-hours) that is transferred to or from the battery is calculated, and its division over the maximum capacity gives the percentage of the energy of the battery that has been transferred to or from the battery. Subtraction with 1 gives the estimated energy left as a percentage. Therefore, the current flow in and out of the battery is continuously monitored, thus integration of this current over time, if it was a fixed current, boils down to multiplying current and time and gives the net amount of Ah charged or discharged. For example, a discharge current of 10A for 2 hours will withdraw 10 x 2 = 20Ah from the battery.

To make the estimation more accurate, two more parameters have been implemented: the Peukert exponent and the Efficiency Factor:
The Peukert exponent is a factor that takes into account the rate of discharge of a battery. As the discharge rate gets higher, the available energy of the battery is lowered. More specifically, the rate at which a battery is being discharged is expressed as the C rating. The C rating indicates how many hours a battery with a given capacity will last. 1C is the 1h rate and means that the discharge current will discharge the entire battery in 1 hour. For a battery with a capacity of 100Ah, this equates to a discharge current of 100A. A 5C rate for this battery would be 500A for 12 minutes (1/5 hours), and a C5 rate would be 20A for 5 hours. Obviously, the capacity of a battery depends on the rate of discharge, and the faster the rate of discharge, the less capacity will be available. Peukert’ s law calculates the relation between slow or fast discharge and it is expressed by the Peukert exponent. Various types of battery chemistries are more affected from this phenomenon than others. For example, lead-acid batteries are more affected by this than lithium batteries are. The Peukert exponent can be adjusted from 1.00 to 1.50, and the higher the Peukert exponent the faster the effective capacity lessens with increasing discharge rate. An ideal (theoretical) battery has a Peukert exponent of 1.00 and has a fixed capacity regardless of the size of the discharge current. An acceptable average value for most lead acid batteries is to set the Peukert exponent to 1.25. Peukert’ s equation is stated below:

$$C_p = I^n \bullet t \quad \text{(Eq.2)}$$

Where Peukert' s exponent n is:

$$n = \frac{\log t_2 - \log t_1}{\log I_1 - \log I_2} \quad \text{(Eq.3)}$$

To calculate the Peukert exponent you will need two rated battery capacities. This is usually the 20h discharge rate and the 5h rate, but can also be the 10h and 5h, or the 20h and the 10h rate. Ideally use a low discharge rating together with a substantially higher rating. Battery capacity ratings can be found in the battery datasheet.

The Efficiency Factor accounts for capacity losses during battery charging. This factor depends on battery age, usage and type. For example, a charge efficiency of 95% (or 0.95) means that 10Ah must be transferred to the battery to get 9.5Ah actually stored in the battery. The charge efficiency of a lead acid battery is almost 100% as long as no gas generation takes place. Gassing means that part of the charge current is not transformed into chemical energy, stored in the battery plates but used to decompose water into oxygen and hydrogen gas, which is highly explosive. The energy stored in the plates can be retrieved during the next discharge, but the energy used to decompose water is lost. Note that the 'oxygen only' end of the charge phase of sealed (VRLA) gel and AGM batteries also results in a reduced charge efficiency.

The Coulomb counting method is then adapted as follows:

$$\mathrm{SoC} = 100 \cdot \left(1 - \frac{\mathrm{EF}}{\mathrm{Qmax}} \cdot \int_0^t i^n(t)dt\right) \quad \text{(Eq.4)}$$

where EF is the Efficiency Factor and 'n' the Peukert Exponent.

To keep estimations more accurate, the algorithm executes a Synchronization of the battery when the battery is full. This occurs when the battery voltage is above the threshold (VFULL) and the battery current is below the threshold (IFULL) for a given amount of time (FULL_CHARGE_TIMER). Once these two conditions are met, the State of Charge automatically gets set to 100%. This process allows you to correctly calculate and display a fully charged status as the state of the battery deteriorates over time.

Regarding the validation of the SOC algorithm, it was performed by comparing with the results obtained by a Battery Storage Model that exists in the MATLAB/SIMULINK library during a discharge and charge cycle. The developed SOC algorithm was configured with the same parameters as that of the model. The total voltage bank was 60Volt nominal power, 280Ah capacity and lead-acid technology. The SOC algorithm was imported inside a programmable logic controller (PLC) while the voltage and current for the calculations were obtained by the charge – discharge cycles of the MATLAB/SIMULINK scenario. The following figures present information regarding the validation process.

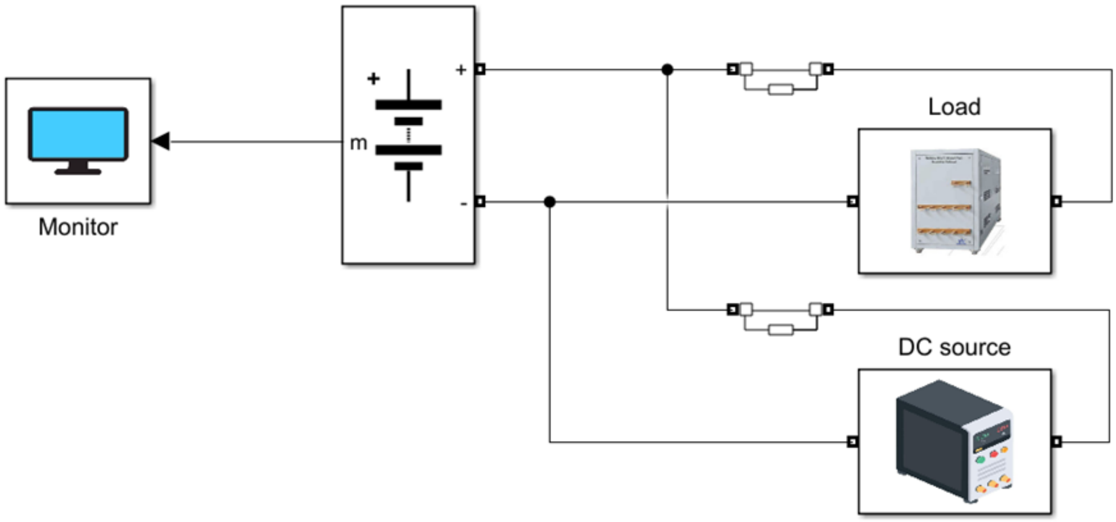


Figure 71: Charge – Discharge topology in MATLAB/SIMULINK.

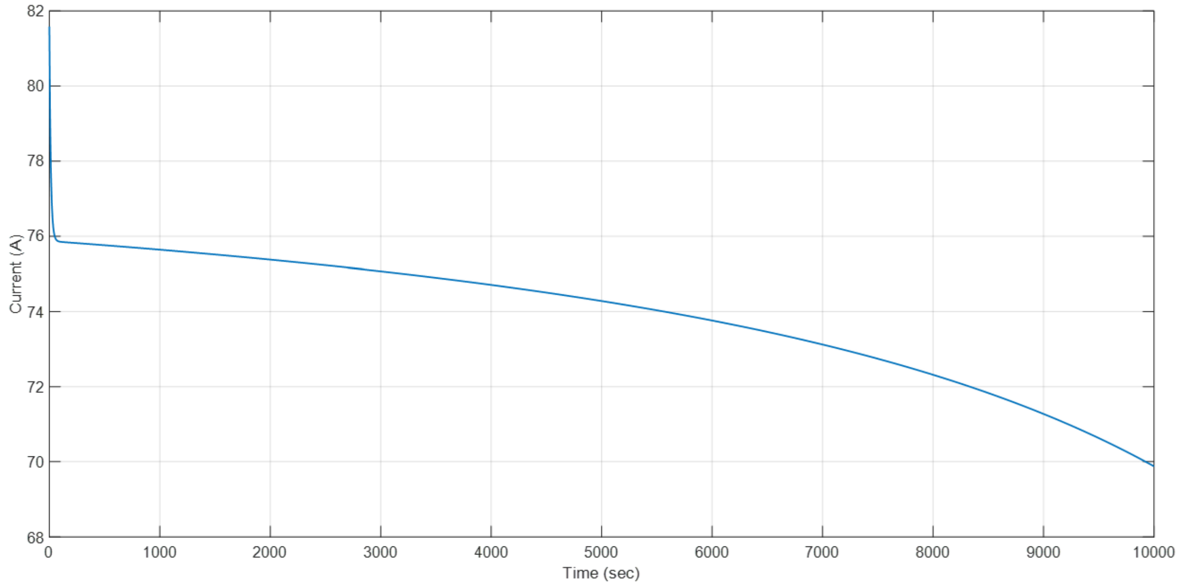


Figure 72: Discharged current from MATLAB/SIMULINK simulation also used as an input to the SOC algorithm.

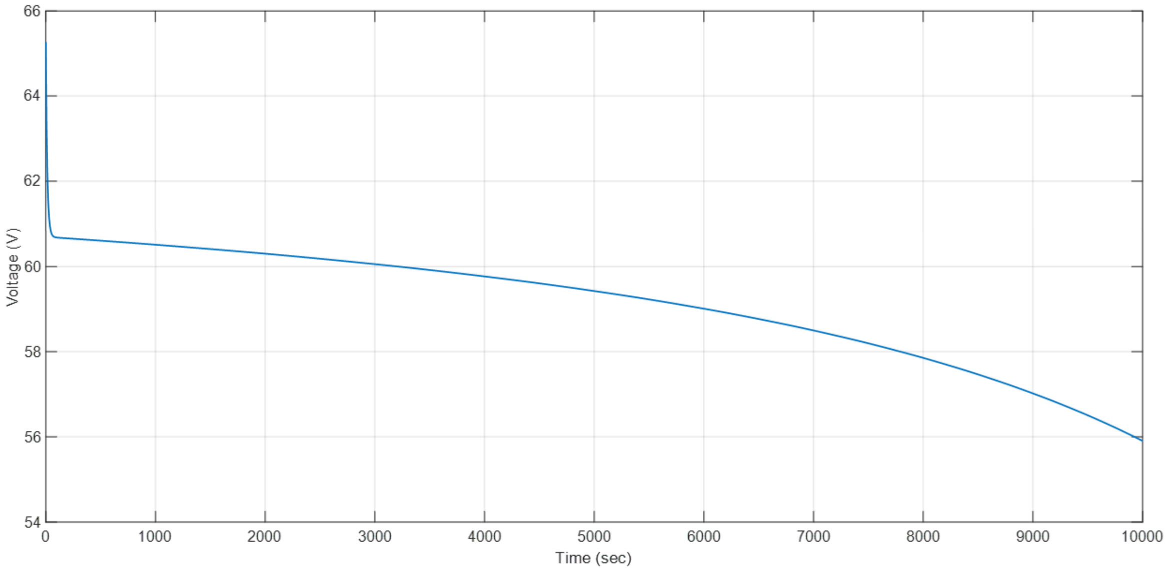


Figure 73: Battery voltage from MATLAB/SIMULINK simulation also used as an input to the SOC algorithm.

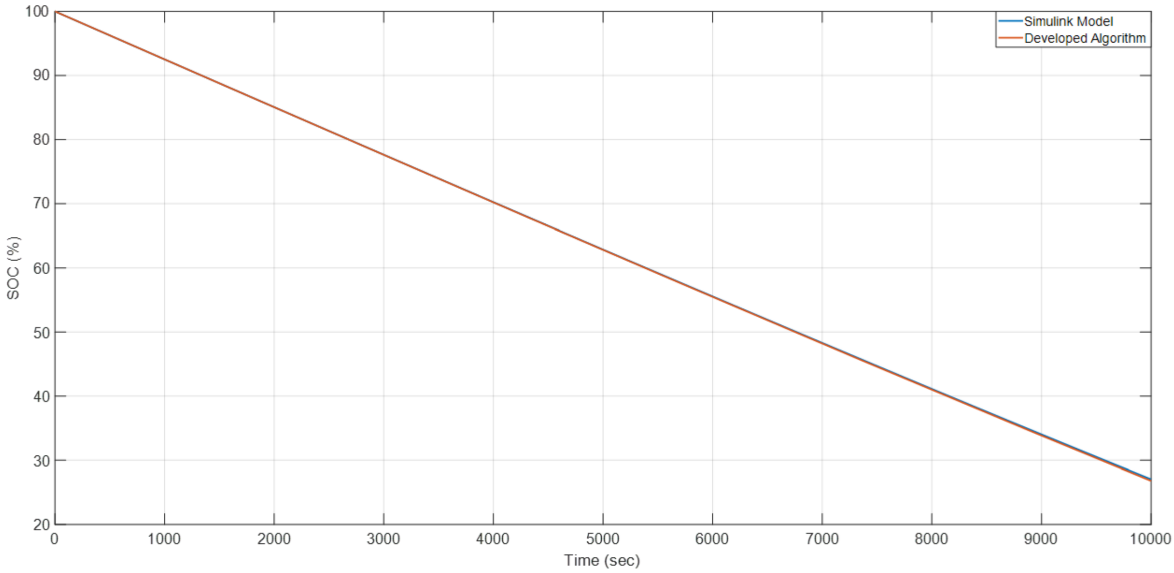


Figure 74: Comparison of the MATLAB/SIMULINK – developed SOC algorithm.

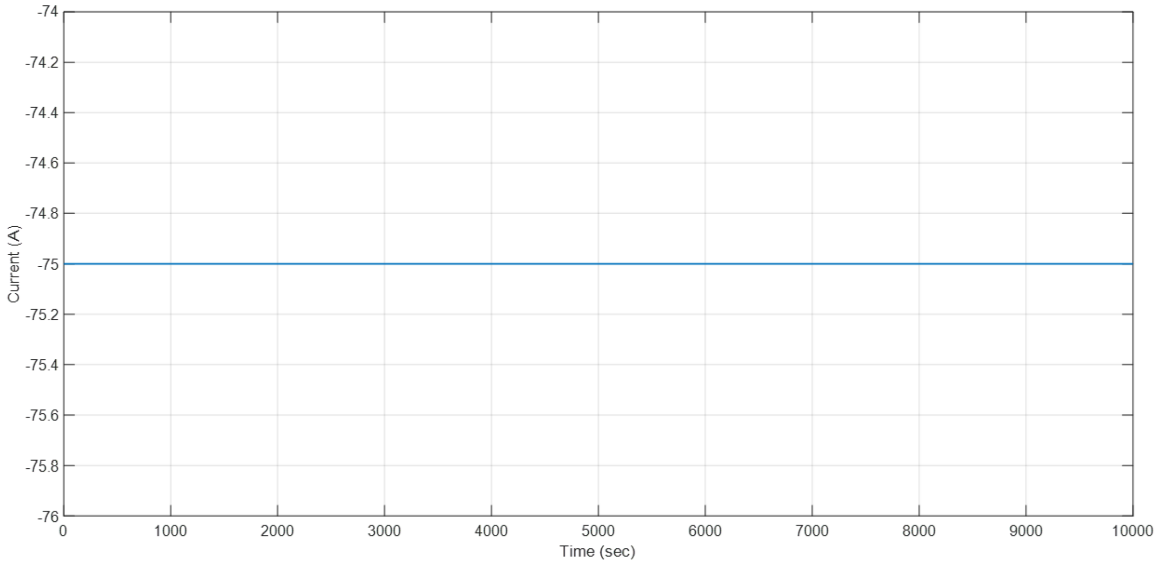


Figure 75: Charged current from MATLAB/SIMULINK simulation also used as an input to the SOC algorithm.

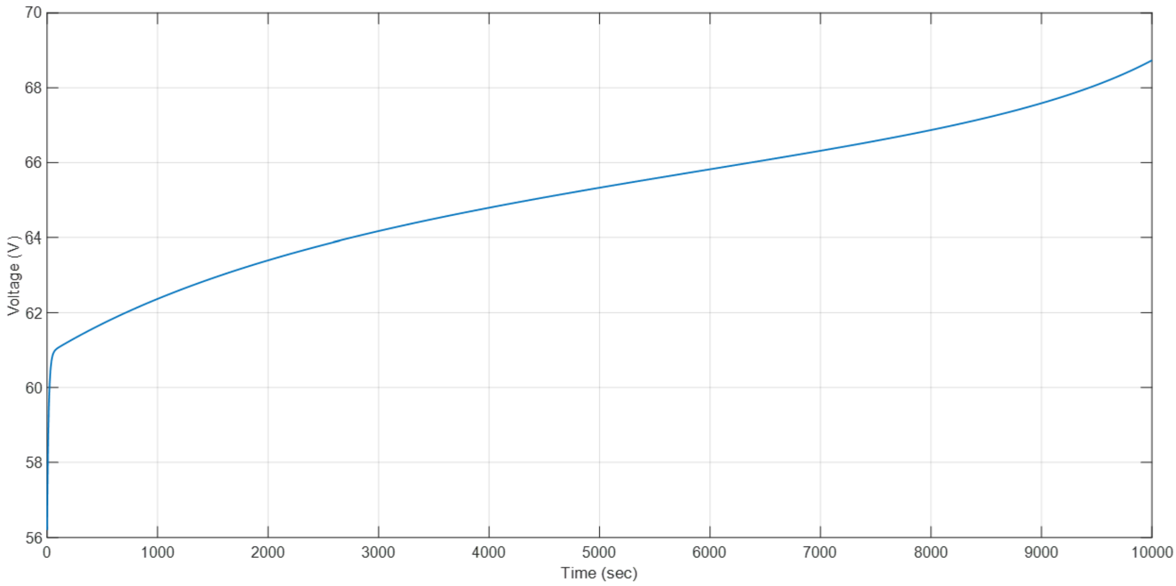


Figure 76: Battery voltage from MATLAB/SIMULINK simulation also used as an input to the SOC algorithm.

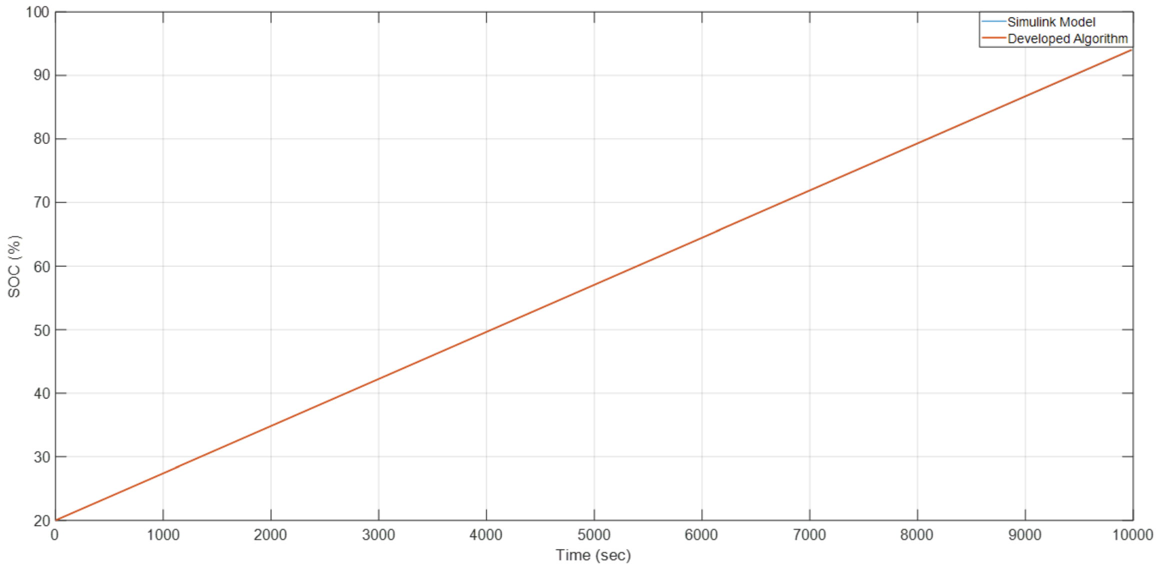


Figure 77: Comparison of the MATLAB/SIMULINK – developed SOC algorithm.

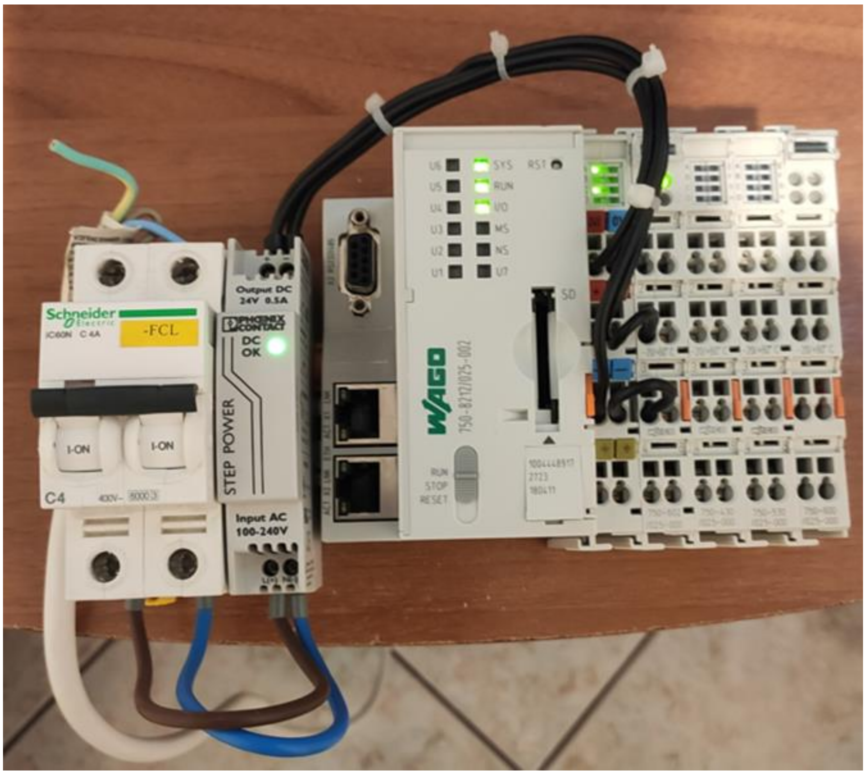


Figure 78: PLC Device that was used to test the execution of the SOC algorithm.

The same algorithm was applied in the demo site of Ghoramara and Keonjhar adapted for each site respected parameters.

7 Conclusions

This deliverable describes the deployment of RE-EMPOWERED solutions at the four demo sites: Bornholm (Denmark), Kythnos (Greece), Ghoramara (India) and Keonjhar (India). In each demo site, different RE-EMPOWERED developed ecoTools have been installed, based on the particularities of each case.

The installation of commercial equipment at the Indian demo sites of Ghoramara and Keonjhar has faced numerous challenges, including land allocation, local authority approvals, and difficult installations. Despite the difficulties, all obstacles have been effectively overcome and microgrids of 160 kW (Ghoramara) and 50 kW (Keonjhar) have been successfully installed, providing power to local communities.

Regarding the deployment of ecoTools, in Ghoramara most of the ecoTools (ecoMicrogrid, ecoConverter, ecoDR, ecoMonitor, ecoVehicle and ecoPlatform) are already deployed. Full deployment of ecoResilience and of ecoCommunity is still in progress but a complete deployment is expected to be possible by November 2024.

In Keonjhar demo-site, most ecoTools have been deployed (ecoMicrogrid, ecoPlanning, ecoDR, ecoPlatform, ecoVehicle) with the only one remaining to be the ecoCommunity, whose deployment was subject to internet availability. The 4G antenna works were finalized by 29 October 2024, providing access to the internet, therefore this activity will be completed very soon.

It should be noted that a physical visit of ICCS-NTUA and PROTASIS in Keonjhar and Ghoramara (middle of September until early October 2024) was instrumental for the deployment of the ecoMicrogrid, ecoPlatfrom and ecoCommunity in India, with the support of the Indian partners. Moreover, a physical visit of ICCS-NTUA to CMERI, India, enabled the successful manufacturing of the wind turbine (part of ecoResilience) together with CMERI that will be soon installed in Ghoramara.

In Kythnos demo-site, communication issues and equipment-related problems were resolved, leading to the initiation of the demonstration phase for several tools as the deployment phase has been completed since several months. ecoEMS, ecoMicrogrid, ecoPlanning, ecoDR, ecoMonitor, ecoCommunity and ecoResilience are in demonstration phase.

Similarly, on Bornholm, despite installation troubles, shipping delays, and software issues, all ecoTools have been developed and tested, and the demo site is progressing toward the demonstration phase. Specifically, ecoEMS, ecoPlatform, and ecoCommunity are ready to initiate their demonstrations. Concerning ecoDR and ecoMonitor, they are both deployed, but integration with ecoPlatform is pending, and their demonstrations are scheduled to begin in early November 2024.

This deliverable thus provides a detailed and concrete report on the deployment of the ecoTools per demo site summarizing the work in the Sub task 7.2.2 of T7.2. Thus, this is an important step towards the overall objectives of RE-EMPOWERED. Demonstration is now ongoing which will be reported in deliverables D7.4 and D7.5.

8 References

[1] RE-EMPOWERED, "Deliverable D7.1: Deployment and demonstration plan," 2023.

[2] RE-EMPOWERED, "Deliverable D3.1: Report on Co-optimisation Tool and DSM Scheme," 2022.

[3] RE-EMPOWERED, "Deliverable D4.1: Development of the ecoEMS, ecoMicrogrid and ecoDR," 2023..