Ref. Ares(2024)8886651 - 12/12/2024

RE-EMPOWERED

Renewable Energy EMPOWERing European & InDian Communities

Deliverable D7.4 / D7.2c: Report demonstration round 1 (testing)

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Horizon 2020 Grant Agreement № 101018420.

This project has received funding from the Department of Science and Technology (DST), India under Grant Agreement № DST /TMD/INDIA/EU/ILES/2020/50(c)

December 2024

Title			Document Version
Report demonstration round 1 (testing)			2.0

Project number	Project acronym	Project Title
EU: 101018420 India: DST/TMD/INDIA/EU/ILES/ 2020/50(c)	RE-EMPOWERED	Renewable Energy EMPOWERing European and InDian communities

Contractual Delivery Date	Actual Delivery Date	Type*/Dissemination Level*
31st May 2024	11th December 2024	R/PU

Responsible Organisation	Contributing WP
ICCS-NTUA	WP7

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

Document information

Current version: V2.0

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Revision History

Revision	Date	Description	Author (partner)
V1.0	10/11/2024	Draft version prepared	ICCS-NTUA, all
V1.1	22/11/2024	Final draft for Review	ICCS-NTUA
V1.2	09/12/2024	Revision according to reviewer's feedback	ICCS-NTUA
V2.0	11/12/2024	Submitted version	ICCS-NTUA

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Executive Summary

The overarching goal of RE-EMPOWERED is to foster efficient, de-carbonized and RES-intensive multi-energy local energy systems and provide local communities with tools for economic and social development. To achieve these goals, the project has delivers a suite of “ecoTools,” namely ecoEMS, ecoMicrogrid, ecoPlanning, ecoDR, ecoPlatform, ecoConverter, ecoMonitor, ecoCommunity, ecoVehicle and ecoResilience, deployed at four demo sites across the EU and India, and thereby demonstrates their value in energy systems at different scales and levels of maturity. Two demonstration runs are being performed at each demo site, one for testing and one operational demonstration. This deliverable reports on the activities of the first round of demonstration which involves the testing of ecoTools laying the foundation for the second demonstration phase and later the project assessment.

This document starts with an overview of the high-level aims of the demonstration activities at each demo site, aligning them with the corresponding functionalities and ecoTools to be showcased during the first round of demonstrations. For Bornholm demo site, the primary goals include successfully collecting and publishing data to the ecoTools and demonstrating the effective implementation of demand-side management functionalities. For Kythnos power system, the main objectives focus on the enhanced system observability & data management, and optimal energy system management. At the Gaidouromandra and the two Indian demo sites – Ghoramara and Keonjhar – the high-level aims include improved observability & data management, optimized energy system operation, efficient implementation of the demand-side management scheme, improved system resilience & reliability, and assessment of the social acceptance and community engagement. The demonstration activities are being carried out at the four demo sites according to the plan set in D7.1 [1] considering the defined Use Cases (UCs) with some adjustments. Tables summarizing the successfully achieved UCs at each demo site are included, providing insights into the level of completion of the demonstration and the progress history. Furthermore, for each successfully achieved Use Case across the ecoTool and demo sites, a detailed description is provided. This includes the methodology followed, the outcome obtained from each activity including visualized results and subsequent preparatory actions planned for the second and final demonstration phase. The primary goal of this demonstration round is to collect essential data, validate, and assess the designed use cases for each tool, ensuring a comprehensive evaluation of its functionality. In certain instances, necessary system adaptations were implemented following insights gained during the initial testing demonstration round. These adaptations are also reported.

Throughout the first demonstration round of RE-EMPOWERED solutions we conclude that the testing phase was mostly successful with slight exceptions, where the relevant activities have been shifted to the next demonstration round.

Keywords:

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

Table of contents

List of figures

List of tables

Acronyms

Acronym	Description
AC	Alternating Current
AFPMG	Axial Flux Permanent Magnet Generator
AMI	Advanced Metering Infrastructure
AoA	Angle of Attack
API	Application Programming Interface
APK	Android Application Package
AQI	Air Quality Index
BESS	Battery Energy Storage System
BLDC	Brush Less Direct Current
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
CHP	Combined Heat and Power
CO	Carbon Monoxide
CO2	Carbon Dioxide
CSV	Comma-Separated Values
DA	Day-ahead
DC	Direct Current
DG	Diesel Generator
DR	Demand Response
DSM	Demand Side Management
DSO	Distribution System Operator
EMS	Energy Management System
EU	European Union
EV	Electric Vehicle
FEA	Finite element analysis
FEMM	Finite Element Method Magnetics
HC	Hosting Capacity
HTTP	Hypertext Transfer Protocol
HVAC	Heating Ventilation and Air Conditioning
IoT	Internet of Things
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LMSWT	Locally Manufactured Small Wind Turbine
MBAP	MODBUS Application Protocol
MPPT	Maximum Power Point Tracking
MQTT	Message Queuing Telemetry Transport

NII	Non-Interconnected Island
NO2	Nitrogen Dioxide
OPC	Open Platform Communications
P&O	Perturb and Observe
P2X	Power to X
PC	Personal Computer
PCC	Plain Cement Concrete
PM2.5/ PM10	Particulate Matter of 2,5/10 microns
PPC	Partial Power Converter
PSO	Particle Swarm Optimization
PV	Photovoltaic
RCC	Reinforced cement concrete
RE	Renewable Energy
RES	Renewable Energy Source
RT	Real Time
SCADA-HMI	Supervisory Control and Data Acquisition – Human Machine Interface
SO2	Sulphur Dioxide
SOC	State of Charge
SQL	Structured Query Language
SWT	Small Wind Turbine
TCP	Transmission Control Protocol
TMT	Thermo-Mechanically Treated
UC	Use Case
UI	User Interface
WF	Wind Farms
WT	Wind Turbine

1 Introduction

1.1 Purpose and scope of the document

The RE-EMPOWERED project has delivered a suite of "ecoTools," tailored to the specific needs of the pilot cases and deployed them at four demo sites across the EU and India. Currently the project is demonstrating their value in energy systems at different scales and levels of maturity. Building on the previously defined Use-Cases (UCs) in D2.1 [1] and D7.1 [2], two demonstration rounds are planned at the four demo sites. This deliverable reports the first-round demonstration activities per demo and ecoTool. The first round is dedicated to testing, aiming to validate the ecoTools and their functionalities in field and real-world conditions. The successful testing is substantiated by test results for the completed activities defined by the use-cases. It should be noted that the UCs of D7.1 and D2.1 have been refined when needed. Following the completion of the first demonstration round, necessary adaptations to the ecoTools have been identified and implemented in preparation for the final demonstration round.

Finally, after incorporating the necessary corrections and fine-tuning the system based on the observations from the testing round, the final operational demonstration will be conducted, in which the complete set of functionalities will be showcased. During the demonstration activities, data from the operation of the Local Energy Systems are being collected and will be evaluated as part of the assessment phase in WP8.

1.2 Structure of the document

This document is structured as follows:

Chapter 2 is divided into two sections. First, an overview of the high-level demonstration objectives of the first demonstration round (testing) focusing on the ecoTools related to each demo site, is provided. Then, the alignment between these objectives and the functionalities that have to be tested in pursuit of the demonstration goals are presented. This chapter provides a link to deliverable D7.1 [1] in which the demonstration plan was defined. The second part of Chapter 2 provides an overview of the demonstration activities that took place at the four demo sites, considering the defined Use Cases (UCs) through check list tables of the successfully achieved Use Cases per demo site with reference on their progress history.

Chapter 3 provides a detailed description of all demonstration activities performed based on the successfully achieved Use Cases for each tool on each demo site, reported in Chapter 2. The steps followed for the demonstration activities are presented along with the obtained results supported with visualizations where applicable. Furthermore, the preparatory actions followed for the second and final demonstration phase are mentioned, while in several cases the required adaptations that appeared to be needed after the first demonstration round are also reported.

Chapter 4 concludes the document.

2 Demonstration activities overview

This section provides an overview of the first-round demonstration activities conducted to test the RE-EMPOWERED solutions at each demo site. First, the purpose and overall goals of the demonstration for each pilot are outlined, and then linked to the functionalities defined in D7.1 [2] and the relevant ecoTools. Then, the list of the achieved UCs, including their priority classification and the duration of the demonstration period associated with each UC, are presented. Some of the use cases will be demonstrated only on the second round as indicated in the following sections.

2.1 Purpose of the demonstration per demo site

2.1.1 Bornholm Island

This section presents the testing demonstration plan for the initial round of demonstrations (earlier referenced as round A) on Bornholm Island, focusing on the five ecoTools related to the demo site. The plan sets out high-level objectives and their alignment with both core and advanced functionalities to be tested, as detailed in D7.1 [2].

The high-level targets to be achieved in Bornholm demo site are the following:

Demonstration Aim 1: Confirm data sources and their integration to ecoTools

Goal: Validate that various data sources are able to publish to ecoPlatform through MQTT. Data sources are required for all calculations. Ensure that necessary data streams are available.

Demonstration Aim 2: Validate data integration for ecoTools.

Goal: Confirm stable connection and demonstrate availability to subscribe from the ecoPlatform. All five tools should be validated.

Demonstration Aim 3: Demand side management.

Goal: Complete implementation of demand side management. Verify integration from ecoEMS, through ecoPlatform to the demand side management IoT devices. Test if control is functional.

Goal: Verify compliance between ecoCommunity (accepted timeslots) and actual control.

Goal: Evaluate how control of the demand is received by consumers. Initial consumer satisfaction survey to be conducted.

Table 1 below presents the mapping between demonstration aims and their corresponding functionalities to be tested during the first demonstration round.

Demonstration Aim	Relevant Functionalities	Relevant tools

Demonstration Aim 1	Electric boiler power consumption monitoring	ecoPlatform ecoEMS ecoCommunity ecoDR ecoMonitor
Demonstration Aim 1 Demonstration Aim 2	Electric boiler setpoint change	ecoPlatform ecoEMS
Demonstration Aim 3	Monitoring and operability of Neogrid controller from ecoPlatform	ecoPlatform ecoEMS ecoCommunity
Demonstration Aim 1 Demonstration Aim 3	Heating load monitoring	ecoPlatform ecoEMS
Demonstration Aim 2	Heating load control	ecoPlatform ecoEMS

Table 1 Mapping between demonstration aims and their corresponding functionalities in Bornholm demo site

2.1.2 Kythnos Island

2.1.2.1 Kythnos power system

This section presents the testing demonstration plan for the initial round of demonstrations at the Kythnos demo site. The plan sets out high-level objectives and their alignment with both core and advanced functionalities to be tested, as detailed in D7.1 [2].

The Kythnos demo site testing demonstration includes several primary objectives, each crafted to validate specific components of each tool by testing their respective functionalities.

Demonstration Aim 1: Validate Data Collection Stability

Goal: Confirm the ecoTools' capability to reliably collect and store all necessary data.

Goal: Validate stable communication between ecoTools and integrated assets, ensuring uninterrupted data flow and operational commands.

Goal: Assess system performance across various operational conditions.

Demonstration Aim 2: Enhance System Observability

Goal: Improve system monitoring and data visualization.

Goal: Demonstrate seamless integration of ecoTools with system assets to enable continuous system monitoring.

Goal: Gather feedback to enhance the visual data provided to users.

Demonstration Aim 3: Optimize System Energy Management

Goal: Achieve cost-effective resource allocation and efficient energy management.

Goal: Apply cost-effective resource allocation strategies within the microgrid.

Goal: Coordinate multiple energy vectors (electric, heating, demand response) effectively.

Goal: Implement advanced control algorithms to optimize system operation.

Demonstration Aim 4: Ensure Interoperability and Data Management

Goal: Validate seamless integration of various ecoTools through the ecoPlatform and verify data storage and retrieval using cloud technology.

Demonstration Aim 5: Validate Demand-Side Management

Goal: Implement and assess advanced monitoring and control strategies on the demand side.

Table 2 below presents the mapping between demonstration aims and their corresponding functionalities to be tested during the first demonstration round in Kythnos power system.

Demonstration Aim	Relevant Functionalities	Relevant tools
Demonstration Aim 1, Demonstration Aim 2, Demonstration Aim 4, Demonstration Aim 5	Generation data collection and storage	ecoEMS, ecoPlanning, ecoPlatform
Demonstration Aim 2, Demonstration Aim 4, Demonstration Aim 5	Interoperability within ecoTools	ecoEMS, ecoPlanning, ecoPlatform
Demonstration Aim 1, Demonstration Aim 2, Demonstration Aim 3, Demonstration Aim 4, Demonstration Aim 5	Unit Commitment scenario setup and scenario run	ecoEMS, ecoPlanning, ecoPlatform
Demonstration Aim 1, Demonstration Aim 3	Energy carriers' identification and quantification at total electricity load	ecoEMS, ecoPlanning
Demonstration Aim 1	Power stations and thermal units' identification	ecoEMS, ecoPlanning
Demonstration Aim 1	Data collection, inspection and storage	ecoEMS, ecoPlanning
Demonstration Aim 1	RES units list identification and data collection	ecoEMS, ecoPlanning
Demonstration Aim 1, Demonstration Aim 3	Electrical models & demand peak models design	ecoPlanning
Demonstration Aim 1, Demonstration Aim 2, Demonstration Aim 3, Demonstration Aim 5	Four types of studies implementation	ecoPlanning
Demonstration Aim 1, Demonstration Aim 2	Instance deployment	ecoEMS, ecoPlanning

Table 2 Mapping between demonstration aims and their corresponding functionalities in Kythnos demo site

2.1.2.2 Gaidouromandra Microgrid

This section outlines the testing demonstration plan for the Gaidouromandra Microgrid site during the first demonstration round. The plan defines high-level targets and their correlation with the basic and advanced functionalities to be tested, as detailed in D7.1 [2].

The testing demonstration at the Gaidouromandra site encompasses eight key objectives, each designed to validate specific aspects of the microgrid implementation through the testing of related functionalities.

Demonstration Aim 1: Validate Operational Stability of ecoMicrogrid: The primary objective is to demonstrate the ecoMicrogrid tool's capability to integrate with the existing power system infrastructure while maintaining operational stability.

Goal: Ensuring that ecoMicrogrid can integrate seamlessly with system assets such as battery storage, photovoltaic (PV) inverters, and diesel generator (DG) units without compromising system stability.

Goal: Validating the stability and reliability of communication between ecoMicrogrid and the various integrated assets, ensuring data flow and operational commands are executed without disruption.

Goal: Verification of system performance under various operational conditions.

Demonstration Aim 2: Improve observability of the system: This aim focuses on enhancing system monitoring and data visualization capabilities.

Goal: Showcase the seamless integration of ecoMicrogrid with system assets, enabling continuous monitoring, logging, and storing of system data.

Goal: Highlight the visualization capabilities provided by the ecoTools.

Goal: Collecting feedback for improving the visual information provided to users and administrators by the ecoTools.

Demonstration Aim 3: Optimize Energy Management of the System: Energy management optimization encompasses.

Goal: Cost-effective resource allocation strategies within the microgrid

Goal: Integration and coordination of multiple energy vectors (electrical, cooling)

Goal: Implementation of advanced control algorithms for optimal system operation

Demonstration Aim 4: Validate Interoperability and Data Management:

Goal: Demonstrate the seamless integration of various ecoTools through the ecoPlatform, and verify efficient data storage and retrieval mechanisms using cloud server technology.

Demonstration Aim 5: Validate Demand-Side Management:

Goal: Implement and evaluate advanced energy monitoring and control strategies on the demand side, including the ecoDR system, to improve overall energy efficiency and reduce peak loads.

Demonstration Aim 6: Demonstrate Resilience and Reliability:

Goal: Test the ecoResilience functionality to ensure uninterrupted operation of critical systems, especially communication infrastructure, during vario

Goal: us simulated disruption scenarios.

Demonstration Aim 7: Implement Dynamic Pricing Mechanisms:

Goal: Evaluate the effectiveness of dynamic electricity pricing in influencing consumer behavior and optimizing overall system efficiency.

Demonstration Aim 8: Assess Social Acceptance and Community Engagement:

Goal: Utilize DAFNI's expertise to gauge social acceptance of the microgrid technology, implement community outreach programs, and provide guidance and training to local stakeholders.

Table 3 presents the mapping between demonstration aims and their corresponding functionalities to be tested during the first demonstration round at Gaidouromandra demo site.

Demonstration Aim	Relevant Functionalities	Relevant tools
Demonstration Aim 1	Continuous supply to all end customers (security of supply)	ecoMicrogrid
Demonstration Aim 1	Frequency / Voltage stability	ecoMicrogrid
Demonstration Aim 1	Battery System charge / discharge	ecoMicrogrid
Demonstration Aim 1	Start / supply / stop of the diesel generator	ecoMicrogrid
Demonstration Aim 1	Active/reactive power control of PV generators	ecoMicrogrid
Demonstration Aim 1 Demonstration Aim 2 Demonstration Aim 4	Uninterruptable operation of the communication systems	ecoMicrogrid, ecoPlatform
Demonstration Aim 1	Connection / disconnection of loads	ecoMicrogrid, ecoDR
Demonstration Aim 1 Demonstration Aim 2 Demonstration Aim 4	Consumption data collection and storage	ecoMicrogrid, ecoDR, ecoPlatform
Demonstration Aim 3 Demonstration Aim 7	Microgrid optimal management of operation	ecoMicrogrid
Demonstration Aim 2 Demonstration Aim 5	Increased energy monitoring at demand side	ecoMicrogrid, ecoDR, ecoCommunity
Demonstration Aim 4	Platform as a service for dependent tools integration	ecoPlatform
Demonstration Aim 4	Data storage and cloud server	ecoMicrogrid, ecoPlatform ecoCommunity

Demonstration Aim 6	Interoperability between Wind Turbine (inverter) and ecoMicrogrid	ecoResilience, ecoMicrogrid

Table 3 Mapping between demonstration aims and their corresponding functionalities in Gaidouromandra

2.1.3 Ghoramara

This section presents the testing demonstration plan for the Ghoramara demo site during the initial demonstration phase. The plan outlines high-level objectives and their alignment with the basic and advanced functionalities to be tested, as described in D7.1 [2].

The testing demonstration at the Ghoramara site focuses on seven key objectives, each designed to validate specific aspects of the micro grid implementation through the testing of related functionalities.

Demonstration Aim 1: Validate Operational Stability of ecoMicrogrid

The primary objective is to validate the ecoMicrogrid tool's ability to integrate with the power system infrastructure while maintaining operational stability:

Goal: Ensure seamless integration of ecoMicrogrid with system assets such as battery storage, photovoltaic (PV) inverters without compromising stability.

Goal: Validate the stability and reliability of communication between ecoMicrogrid and the integrated assets, ensuring uninterrupted data flow and execution of operational commands.

Goal: Verify system performance under various operational scenarios.

Demonstration Aim 2: Enhance System Observability

This aim focuses on improving monitoring and data visualization capabilities:

Goal: Demonstrate seamless integration of ecoMicrogrid with system assets to enable continuous data monitoring, logging, and storage.

Goal: Highlight ecoTools' advanced visualization capabilities.

Goal: Gather user and administrator feedback to enhance the visual information provided by the ecoTools.

Demonstration Aim 3: Optimize Energy Management

Energy management optimization involves:

Goal: Implementing cost-effective resource allocation strategies within the microgrid.

Goal: Coordinating and integrating multiple energy vectors, such as solar PV, battery storage Utilizing advanced control algorithms for achieving optimal system performance.

Demonstration Aim 4: Validate Interoperability and Data Management

Goal: Showcase the seamless integration of various ecoTools through the ecoPlatform.

Goal: Verify the efficiency of data storage and retrieval mechanisms using cloud server technology.

Demonstration Aim 5: Validate Demand-Side Management

Goal: Implement and evaluate advanced demand-side energy monitoring and control strategies, including the ecoDR system, to enhance energy efficiency and reduce peak loads.

Demonstration Aim 6: Ensure Resilience and Reliability

Goal: Test the ecoResilience functionality to guarantee uninterrupted operation of critical systems, particularly communication infrastructure, under various simulated disruption scenarios.

Demonstration Aim 7: Assess Social Acceptance and Community Engagement

Goal: Conduct community outreach programs to build awareness and provide training for local stakeholders.

Table 4 presents the mapping between demonstration aims and their corresponding functionalities to be tested during the first demonstration round in Ghoramara island.

Demonstration Aim	Relevant Functionalities	Relevant tools
Demonstration Aim 1 Demonstration Aim 4 Demonstration Aim 5 Demonstration Aim 6 Demonstration Aim 7	The local energy system is running properly, and continuous power supply is ensured to all the houses.	ecoMicrogrid, ecoDR, ecoConverter, ecoPlatform, ecoCommunity
Demonstration Aim 1 Demonstration Aim 2 Demonstration Aim 4 Demonstration Aim 5 Demonstration Aim 6	SCADA or equivalent communication system is working properly. All the electrical parameters are visible on the display unit of the control room. The command can be changed by the users and the operation of the microgrid should be changed accordingly.	ecoMicrogrid
Demonstration Aim 1 Demonstration Aim 4 Demonstration Aim 5	The overload arrangement is working properly, and auto-disconnection and auto-reconnection takes place depending on the loading condition to each house.	ecoDR
Demonstration Aim 1 Demonstration Aim 4	Frequency / Voltage stability is ensured at the far end of the distribution system.	ecoConverter
Demonstration Aim 3 Demonstration Aim 4	Battery System charge / discharge is working properly.	ecoConverter
Demonstration Aim 1 Demonstration Aim 4	Remote data exchange is happening properly.	ecoMicrogrid
Demonstration Aim 3 Demonstration Aim 4 Demonstration Aim 5 Demonstration Aim 6	5 smart meters have been deployed, and they are working satisfactorily.	ecoDR, ecoCommunity
	35 streetlights have been deployed, and they are working satisfactorily.	

Demonstration Aim 3	Two e-three-wheelers have been deployed, and they are working satisfactorily.	ecoVehicle
Demonstration Aim 3	One e-boat has been deployed, and it is working satisfactorily.	ecoVehicle
Demonstration Aim 3	10 kW EV charging station has been deployed and it is working satisfactorily.	ecoVehicle
Demonstration Aim 1 Demonstration Aim 2 Demonstration Aim 4 Demonstration Aim 5 Demonstration Aim 6	A remote monitoring system has been deployed.	ecoMicrogrid

Table 4 Mapping between demonstration aims and their corresponding functionalities in Ghoramara

2.1.4 Keonjhar

This section presents the testing demonstration plan for the Keonjhar Microgrid site during the initial demonstration phase. The plan outlines high-level objectives and their alignment with the basic and advanced functionalities to be tested, as described in D7.1 [2].

The testing demonstration at the Keonjhar site focuses on seven key objectives, each designed to validate specific aspects of the micro grid implementation through the testing of related functionalities.

Demonstration Aim 1: Validate Operational Stability of ecoMicrogrid

The primary objective is to validate the ecoMicrogrid tool's ability to integrate with the existing power system infrastructure while maintaining operational stability:

Goal: Ensure seamless integration of ecoMicrogrid with system assets such as battery storage, photovoltaic (PV) inverters, biomass and biogas generators units without compromising stability.

Goal: Validate the stability and reliability of communication between ecoMicrogrid and the integrated assets, ensuring uninterrupted data flow and execution of operational commands.

Goal: Verify system performance under various operational scenarios.

Demonstration Aim 2: Enhance System Observability

This aim focuses on improving monitoring and data visualization capabilities:

Goal: Demonstrate seamless integration of ecoMicrogrid with system assets to enable continuous data monitoring, logging, and storage.

Goal: Highlight ecoTools' advanced visualization capabilities.

Goal: Gather user and administrator feedback to enhance the visual information provided by the ecoTools.

Demonstration Aim 3: Optimize Energy Management

Energy management optimization involves:

Goal: Implementing cost-effective resource allocation strategies within the microgrid.

Goal: Coordinating and integrating multiple energy vectors, such as solar PV, biogas, and biomass energy.

Goal: Utilizing advanced control algorithms for achieving optimal system performance.

Demonstration Aim 4: Validate Interoperability and Data Management

Goal: Showcase the seamless integration of various ecoTools through the ecoPlatform.

Goal: Verify the efficiency of data storage and retrieval mechanisms using cloud server technology.

Demonstration Aim 5: Validate Demand-Side Management

Goal: Implement and evaluate advanced demand-side energy monitoring and control strategies, including the ecoDR system, to enhance energy efficiency and reduce peak loads.

Demonstration Aim 6: Ensure Resilience and Reliability

Goal: Test the ecoResilience functionality to guarantee uninterrupted operation of critical systems, particularly communication infrastructure, under various simulated disruption scenarios.

Demonstration Aim 7: Assess Social Acceptance and Community Engagement

Goal: Conduct community outreach programs to build awareness and provide training for local stakeholders.

Table 5 presents the mapping between demonstration aims and their corresponding functionalities tested during the first demonstration round in Keonjhar demo site.

Demonstration Aim	Relevant Functionalities	Relevant tools
Demonstration Aim 1, Demonstration Aim 2, Demonstration Aim 4, Demonstration Aim 5, Demonstration Aim 6	Continuous supply to all end customers (security of supply)	ecoMicrogrid, ecoPlanning, ecoPlatform, ecoCommunity, ecoDR
Demonstration Aim 1	Frequency/ Voltage stability	ecoMicrogrid, ecoDR
Demonstration Aim 1, Demonstration Aim 3, Demonstration Aim 5	Battery system charge/discharge	ecoMicrogrid, ecoDR, ecoCommunity
Demonstration Aim 1, Demonstration Aim 3, Demonstration Aim 5	Start/ supply/ stop of the various energy vector such as Biomass, Biogas and existing system	ecoMicrogrid, ecoDR, ecoCommunity
Demonstration Aim 6	Uninterruptable function of the communication systems	ecoMicrogrid, ecoDR, ecoCommunity
Demonstration Aim 1, Demonstration Aim 2, Demonstration Aim 4, Demonstration Aim 5, Demonstration Aim 6, Demonstration Aim 7	Consumption data collection and storage	ecoMicrogrid, ecoPlanning, ecoPlatform, ecoCommunity, ecoDR

Table 5 Mapping between demonstration aims and their corresponding functionalities in Keonjhar

2.2 Execution completion and met objectives based on the defined UCs

This subchapter contains a comprehensive overview in the form of a table for the status and timeline of each secondary Use Case in the demo sites. The secondary use cases are used in the analysis as they are more detailed and specific than the primary Use Cases, leading to more efficient testing and presentation.

2.2.1 Bornholm Island

A checklist of the successfully achieved UCs demonstrated in Bornholm pilot site is presented below.

Use Cases Inventory - Pilot Site Demonstration: Bornholm Island	UC priority	Status	Timeline
ecoEMS			
EMS_1UC1: Real time monitoring and system data visualization			
EMS_2UC1.1: Real time system monitoring and data acquisition and visualization	Medium	Y	Sept - Oct 24
EMS_2UC1.2: Module manager: intercommunications and data exchange	High	Y	Aug - Sept 24
EMS_1UC2: Forecasts, Unit Commitment, Economic Dispatch, Multi-energy optimization			
EMS_ 2UC2.1: Mid-term and short-term RES and load forecasting. Training of the Forecasting model	High	Y	Sept - Oct 24
EMS_ 2UC2.2: Unit Commitment and Economic Dispatch algorithms	High	Y	Aug - Sept 24
EMS_ 2UC2.3: Multi-energy vector management of operation	High	Y	Dec 24
ecoDR			
DR_1UC1: Increased energy monitoring at demand side			
DR_2UC1.1: Real time monitoring of energy consumption	Medium	Y	Nov 24
DR_1UC2: Integration Interfaces for Load Management			
DR_2UC2.1: Scheduling of loads	Low	2nd demonstration round	
ecoPlatform			
PT_1UC1: Microgrid data acquisition			
PT_2UC1.1: Connect to sensors and acquire data through designated communication network and protocols	High	Y	June 24
PT_2UC1.2: Data cleansing to ensure consistency and human machine interface	Medium	Y	June 24
PT_1UC2: Platform as a service for dependent tools integration			
PT_2UC2.1: Facilitate data exchange between dependent tools	High	Y	July - Aug 24

PT_2UC2.2: Facilitate access to controllable assets for dependent tools	Medium	Y	Oct 24
PT_1UC3: Data storage and cloud server			
PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database	Medium	Y	Sept - Oct 24
PT_2UC3.2: Facilitate archived data access for dependent tools using API	High	Y	Oct - Nov 24
ecoMonitor			
MN_1UC1: Ambient air quality surveillance			
MN_2UC1.1: Acquisition and transmission of air quality parameters data	Low	Partly	Sept - Oct 24
MN_2UC1.2: Data processing and evaluation	Low	2nd demonstration round	
ecoCommunity			
CM_1UC3: Outreach forum			
CM_2UC3.1: Feedback and suggestions from users about the tools	Medium	2nd demonstration round	
CM_2UC3.2: Reporting of problem	High	2nd demonstration round	
CM_2UC3.3: Forum to share experiences	High	2nd demonstration round	
CM_1UC4: Guidance and Training			
CM_2UC4.1: Training material (troubleshooting)	Medium	2nd demonstration round	
CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)	High	2nd demonstration round	
CM_1UC5: Consumption Monitoring			
CM_2UC5.1: Monitoring of heating system at load centers	High	2nd demonstration round	

Table 6 Use cases status and timeline for Bornholm demo site

2.2.2 Kythnos Island

2.2.2.1 Kythnos Power System

Below is a checklist of the successfully achieved Uce Cases (UCs) demonstrated in Kythnos power system is presented.

Use Cases Inventory - Pilot Site Demonstration: Kythnos Power System	UC priority	Status	Duration
ecoEMS			
EMS_1UC1: Real time monitoring and system data visualization			
EMS_2UC1.1: Real time system monitoring and data acquisition and visualization	Medium	Y	Aug - Sept 24
EMS_ 2UC1.2: Module manager: intercommunications and data exchange	High	Y	Aug - Sept 24
EMS_1UC2: Forecasts, Unit Commitment, Economic Dispatch, Multi-energy optimization			

EMS_ 2UC2.1: Mid-term and short-term RES and load forecasting	Low	Y	Aug - Sept 24
EMS_ 2UC2.3: Unit Commitment and Economic Dispatch algorithms	High	Y	Aug - Sept 24
ecoPlanning			
PN_1UC1: 7-Year Energy Planning			
PN_2UC1.1: Data collection and storage	Medium	Y	Jan - Dec 23
PN_2UC1.2: Electrical models & demand peak models design, RES & Load estimation	High	Y	Jan - Dec 23
PN_2UC1.3: Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation	High	Y	Jan - Dec 23
PN_1UC2: RES Hosting Capacity			
PN_2UC2.1: Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds	High	Y	Jan - Dec 23
PN_2UC2.2: Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment	High	Y	Jan - Dec 23
PN_1UC3: Interconnections			
PN_2UC3.1: Electrical models, demand peak models & interconnections design, RES & Load estimation	High	2nd demonstration round	
PN_2UC3.2: Hourly Unit Commitment, through optimization algorithm for mid to long term horizon	High	2nd demonstration round	
PN_1UC4: Multi-energy vectors			
PN_2UC4.1: Energy carriers' identification, data collection and quantification of impact on total load (hourly)	Low	Y	Jan - Dec 23
PN_2UC4.2: Electrical models & demand peak design, RES & Load estimation, energy carriers' scenarios integration	High	Y	Jan - Dec 23
PN_2UC4.3: Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers	High	Y	Jan - Dec 23
ecoMonitor			
MN_1UC1: Ambient air quality surveillance			
MN_2UC1.1: Acquisition and transmission of air quality parameters data	High	Partly	Sept - Dec 24
MN_2UC1.2: Data processing and evaluation	Medium	2nd demonstration round	

Table 7 Use cases status and timeline for Kythnos power system demo site

2.2.2.2 Gaidouromandra Microgrid

A checklist of the successfully achieved Uce Cases (UCs) demonstrated in Gaidouromandra microgrid is presented below.

Use Cases Inventory - Pilot Site Demonstration: Gaidroumandra Microgrid	**UC priority**	**Status**	**Duration**
ecoMicrogrid			
MG_1UC1: Microgrid monitoring			
MG_2UC1.1: Real time microgrid monitoring and data acquisition	High	Y	Dec 23 - Sept 24
MG_2UC1.2: RES production estimation	Low	2nd demonstration round	
MG_2UC1.3: Data concentration, storage, and management	High	Y	Jun - Sept 24
MG_1UC2: Microgrid optimal management of operation			
MG_2UC2.1: Effective communication with controllable assets	High	Y	Jun - Dec 24
MG_2UC2.3: Multi-energy vector microgrid management of operation	High	2nd demonstration round	
ecoDR			
DR_1UC1: Increased energy monitoring at demand side			
DR_2UC1.1: Real time monitoring of energy consumption	Medium	Partly	Sept - Oct 24
ecoPlatform			
PT_1UC2: Platform as a service for dependent tools integration			
PT_2UC2.1: Facilitate data exchange between dependent tools	High	Y	May - Sept 24
PT_1UC3: Data storage and cloud server			
PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database	Medium	Y	May - Sept 24
PT_2UC3.2: Facilitate archived data access for dependent tools using API	Low	Y	May - Sept 24
ecoCommunity			
CM_1UC1: Dynamic pricing of electricity			
CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile	High	Y	Oct 24
CM_2UC1.3: Data security and privacy	Medium	Y	Oct 24
CM_1UC2: Scheduling and Coordination			
CM_2UC2.1: Facilitating (display) of the scheduling and shifting of non-critical and flexible loads	High	Y	Oct 24
CM_1UC3: Outreach forum			
CM_2UC3.1: Feedback and suggestions from users about the tools	Medium	2nd demonstration round	
CM_2UC3.2: Reporting of problem	High	2nd demonstration round	
CM_2UC3.3: Forum to share experiences	High	2nd demonstration round	

CM_1UC4: Guidance and Training			
CM_2UC4.1: Training material (troubleshooting)	Medium	2nd demonstration round	
CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)	High	Y	Oct 24
CM_1UC5: Display of Energy Consumption			
CM_2UC5.1: Monitoring of electricity consumption of energy consumers	High	Y	Oct 24
ecoResilience			
RS_1UC3: WT Local Manufacturing and Testing			
RS _2UC3.1: Testing of Small Wind Turbines using Standards	High	Y	Oct 24

Table 8 Use cases status and timeline for Gaidouromandra demo site

2.2.3 Ghoramara

A checklist of the successfully achieved Uce Cases (UCs) demonstrated in Ghoramara pilot site is presented below.

Use Cases Inventory - Pilot Site Demonstration: Gaidroumandra Microgrid	UC priority	Status	Timeline
ecoMicrogrid			
MG_1UC1: Microgrid monitoring			
MG_2UC1.1: Real time microgrid monitoring and data acquisition	High	Y	Nov 24
MG_2UC1.3: Data concentration, storage, and management	Medium	2nd demonstration round	
ecoDR			
DR_1UC1: Increased energy monitoring at demand side			
DR_2UC1.1: Real time monitoring of energy consumption	Medium	Y	Sep - Dec 24
DR_1UC2: Integration Interfaces for Load Management			
DR_2UC2.1: Scheduling of loads	High	Y	Sep - Dec 24
DR_2UC2.2: Programmable Load shedding controller	High	Y	Sep - Dec 24
ecoMonitor			
MN_1UC1: Ambient air quality surveillance			
MN_2UC1.1: Acquisition and transmission of air quality parameters data	Medium	Y	Sep - Dec 24
ecoPlatform			
PT_1UC2: Platform as a service for dependent tools integration			
PT_2UC2.1: Facilitate data exchange between dependent tools	High	Y	Sept - Oct 24
PT_1UC3: Data storage and cloud server			
PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database	Medium	Y	Sept - Oct 24

PT_2UC3.2: Facilitate archived data access for dependent tools using API	Low	Y	Sept - Oct 24
ecoCommunity			
CM_1UC1: Dynamic pricing of electricity			
CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile	High	2nd demonstration round	
CM_2UC1.2: Billing and payments	Medium	2nd demonstration round	
CM_1UC2: Scheduling and Coordination			
CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads	Medium	2nd demonstration round	
CM_2UC2.2: Coordination of communal/shared loads	Medium	2nd demonstration round	
CM_1UC3: Outreach forum			
CM_2UC3.1: Feedback and suggestions from users about the tools	Medium	2nd demonstration round	
CM_2UC3.2: Reporting of problem	High	2nd demonstration round	
CM_2UC3.3: Forum to share experiences	High	2nd demonstration round	
CM_1UC4: Guidance and Training			
CM_2UC4.1: Training material (troubleshooting)	Medium	2nd demonstration round	
CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)	High	2nd demonstration round	
CM_1UC5: Display of Energy Consumption			
CM_2UC5.1: Monitoring of electricity consumption of energy consumers	High	2nd demonstration round	
ecoResilience			
RS_1UC1: Resilient support structure for solar photovoltaic system with passive addon components			
RS_2UC1.1: Optimal selection of parameters	High	Y	Oct - Nov 21
RS_2UC1.2: Computational fluid dynamics and structural analysis of support structures	Low	Y	Nov 21 - Mar 22
RS_2UC1.3: Experimental validation of the designed structure through wind tunnel testing	High	Y	Apr - July 22
RS_2UC1.4: Design of resilient foundation for solar photovoltaic system	Low	Y	Aug - Nov 22
RS_1UC2: Improved resilient tower and passive mechanism for wind turbine blades			
RS_2UC2.1: Preliminary design of a tower truss structure and its optimization	Low	Y	Feb - Apr 23
RS_2UC2.2: Design of a resilient mechanism to reduce wind loads on blades and its optimization	Low	Y	May - Jun 23
RS_2UC2.3: Laboratory and field testing of the mechanism	High	Y	Jun - Sep 23

RS_2UC2.4: Resilient foundation for wind turbine tower structure	Low	Y	Sep - Dec 23
RS_1UC3: Design, Development and Installation of small wind turbine from locally available materials			
RS_2UC3.1: Small Wind Turbine Manufacturing and installation	High	Y	Sep - Nov 24
RS _2UC3.2 Testing of Small Wind Turbines using Standards	Low	2nd demonstration round	
ecoConverter			
C_1UC1: Development and control of power electronic converters			
C_2UC1.1: Development and control of power electronic converters	High	Y	Mar - Sept 24
C_2UC1.2: Testing and on-filed demonstration of the power electronic converters satisfying various standards	High	2nd demonstration round	
ecoVehicle			
VH_1UC2: Selection and customization of rickshaw			
VH_2UC2.2: Customization of the vehicle to the demo site requirements	High	Y	Mar 24
VH_1UC3: Onboard energy management for e-Boat			
VH_2UC3.1: PV Integration with e-Boat	High	Y	Aug 24

Table 9 Use cases status and timeline for Ghoramara island demo site

2.2.4 Keonjhar

A checklist of the successfully achieved Uce Cases (UCs) demonstrated in Keonjhar pilot site is presented below.

Use Cases Inventory - Pilot Site Demonstration: Gaidroumandra Microgrid	UC priority	Status	Timeline
ecoMicrogrid			
MG_1UC1: Microgrid monitoring			
MG_2UC1.1: Real time microgrid monitoring and data acquisition	High	Y	Oct - Dec 24
MG_2UC1.3: Data concentration, storage, and management	High	Y	Oct - Dec 24
MG_1UC2: Microgrid optimal management of operation			
MG_2UC2.2: Multi objective microgrid management - Optimization of Energy Production, Storage and Purchase	High	2nd demonstration round	
ecoPlanning			
PN_1UC1: 7-Year Energy Planning			

PN_2UC1.1: Data collection and storage	Low	Y	Jan - Dec 23
PN_2UC1.2: Electrical models & demand peak models design, RES & Load estimation	High	Y	Jan - Dec 23
PN_2UC1.3: Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation	High	Y	Jan - Dec 23
PN_1UC2: RES Hosting Capacity			
PN_2UC2.1: Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds	High	Y	Jan - Dec 23
PN_2UC2.2: Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment	High	Y	Jan - Dec 23
PN_1UC3: Interconnections			
PN_2UC3.1: Electrical models, demand peak models & interconnections design, RES & Load estimation	High	2nd demonstration round	
PN_2UC3.2: Hourly Unit Commitment, through optimization algorithm for mid to long term horizon	High	2nd demonstration round	
PN_1UC4: Multi-energy vectors			
PN_2UC4.1: Energy carriers' identification, data collection and quantification of impact on total load (hourly)	Low	Y	Jan - Dec 23
PN_2UC4.2: Electrical models & demand peak design, RES & Load estimation, energy carriers' scenarios integration	High	Y	Jan - Dec 23
PN_2UC4.3: Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers	High	Y	Jan - Dec 23
ecoDR			
DR_1UC1: Increased energy monitoring at demand side			
DR_2UC1.1: Real time monitoring of energy consumption	Medium	2nd demonstration round	
DR_1UC2: Integration Interfaces for Load Management			
DR_2UC2.1: Scheduling of loads	High	2nd demonstration round	
DR_2UC2.2: Programmable Load shedding controller	High	2nd demonstration round	
ecoPlatform			
PT_1UC2: Platform as a service for dependent tools integration			
PT_2UC2.1: Facilitate data exchange between dependent tools	High	Y	Sept - Oct 24
PT_1UC3: Data storage and cloud server			
PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database	Medium	Y	Sept - Oct 24
PT_2UC3.2: Facilitate archived data access for dependent tools using API	Low	Y	Sept - Oct 24

ecoCommunity			
CM_1UC1: Dynamic pricing of electricity			
CM_2UC1.2: Billing and payments	Medium	Partly	Dec 24
CM_1UC2: Scheduling and Coordination			
CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads	Medium	Partly	Dec 24
CM_2UC2.2: Coordination of communal/shared loads	Low	2nd demonstration round	
CM_1UC3: Outreach forum			
CM_2UC3.1: Feedback and suggestions from users about the tools	Medium	2nd demonstration round	
CM_2UC3.2: Reporting of problem	High	Y	Oct - Nov 24
CM_2UC3.3: Forum to share experiences	Medium	Y	Oct - Nov 24
CM_1UC4: Guidance and Training			
CM_2UC4.1: Training material (troubleshooting)	Medium	2nd demonstration round	
CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)	High	Y	Oct - Nov 24
ecoVehicle			
VH_1UC2: Selection and customization of rickshaw			
VH_2UC2.2: Customization of the vehicle to the demo site requirements	High	Y	May 24

Table 10 Use cases status and timeline for Keonjhar demo site

3 Demonstration round 1 activities at demo sites

This section provides a detailed description of the round 1 demonstration activities conducted at each demo site, structured around the achieved UCs presented in Chapter 2. The description is based on the secondary use cases, which allows a more detailed presentation.

3.1 Bornholm Island

3.1.1 Report of the demonstration round 1 activities

This section presents the status of the use cases for the Bornholm demo-site.

3.1.1.1 ecoEMS

EMS_2UC1.1: Real time system monitoring and data acquisition and visualization

For real time system monitoring and visualization, data acquisition is the first step. In Bornholm, data from the SCADA system at the heat plant and consumer data is gathered and published to the ecoPlatform.

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Figure 1 Illustrated messages from the SCADA system being published to the ecoPlatform using MQTT

This use case ‘s targets were to visualize the data in the ecoEMS framework, produced by algorithms as well as received from ecoPlatform referring to the forecasts, the Neogrid devices and the community engagement. Since the ecoEMS architecture is designed to monitor and schedule the system operation as close to the real time as possible, as well as scheduling and dispatching orders earlier than the real time, the granularity has been divided into two horizons: a) daily and b) hourly updates, in a rolling window of 24 hours horizon. So, the data acquisition and visualization followed this architecture, and the data are collected and projected in the following format. At the first two graphs, forecasts data are shown.

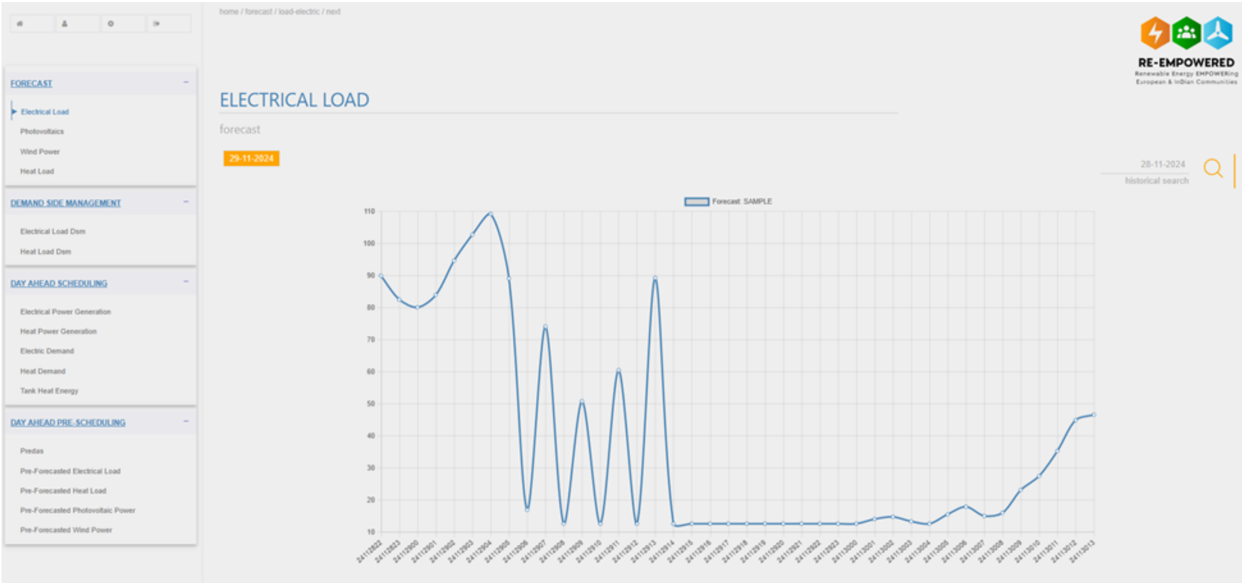


Figure 2 Hourly electrical load forecast of Bornholm for hourly updates

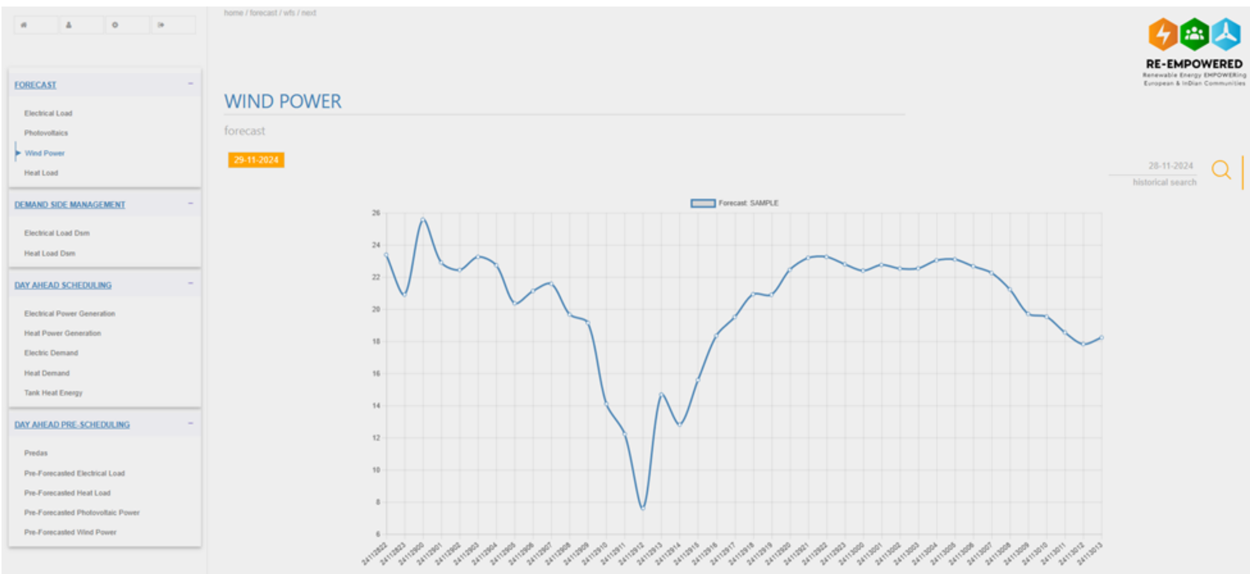


Figure 3 Hourly wind farms forecast of Bornholm for hourly updates

In the next figure, data referring to community engagement after the pre-DAS is depicted.

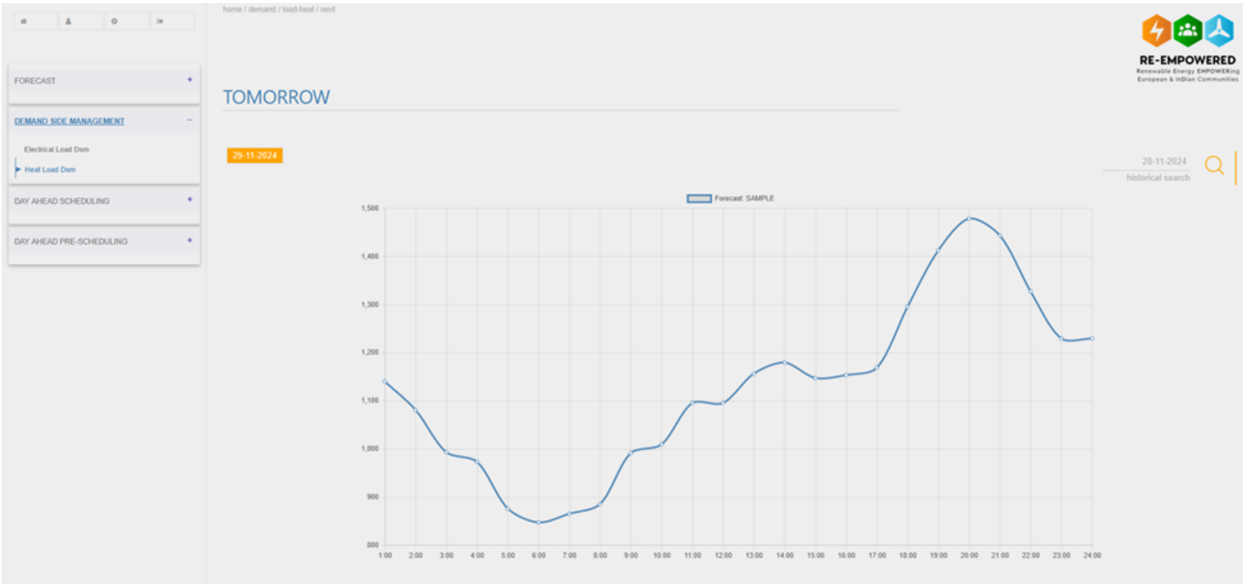


Figure 4 Hourly electrical load engagement from community in Bornholm demo site

EMS_ 2UC1.2: Module manager: intercommunications and data exchange

The primary objectives of this use case were to assess and test data integrity, the data exchange process, and identify potential issues with data corruption or connection failures. A secondary goal was to evaluate the operational efficiency of the ecoEMS integrated database architecture and the speed of data transfers.

The integrated database is designed to receive data from the ecoPlatform, preparing it for visualization (as detailed in the previous use case) and for the Unit Commitment functionality described in subsequent use cases.

Once data are pulled and transformed in the application's back end, the schema of the integrated database, where the data are stored, is illustrated in the following two figures. The database includes both static tables, which rarely change (e.g., data like the cost of each generation unit or renewable curtailments), and dynamic tables that update every hour, such as forecasts, data from Neogrid devices, and Unit Commitment updates.

The integrated database architecture ensures immediate tool responses, minimizing data delays, and facilitates debugging by allowing identification of failures related to database connections, raw data from source systems, algorithms, or the ecoEMS framework itself.

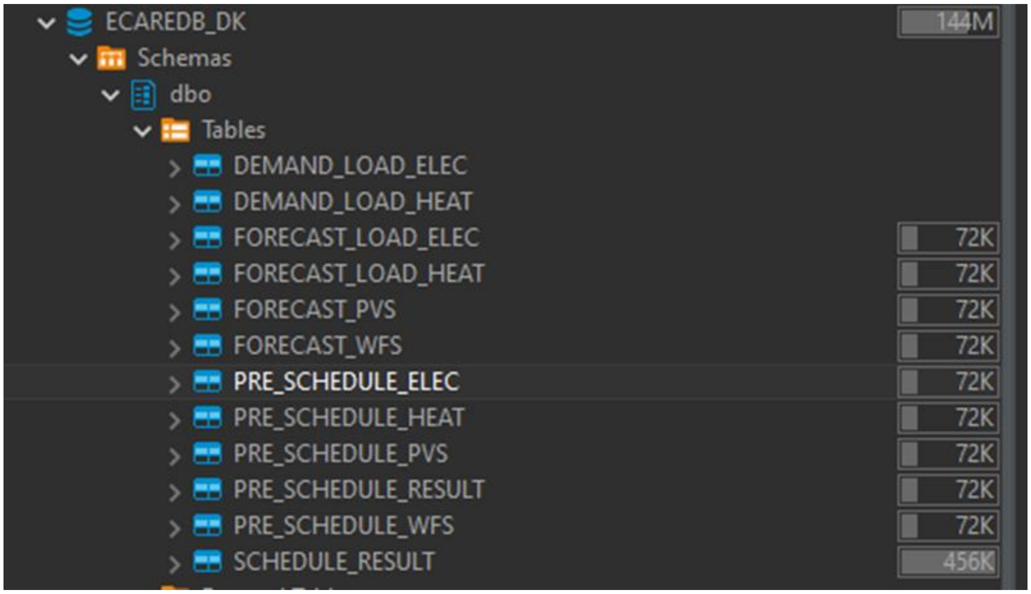


Figure 5 Database architecture from integrated in ecoEMS framework database

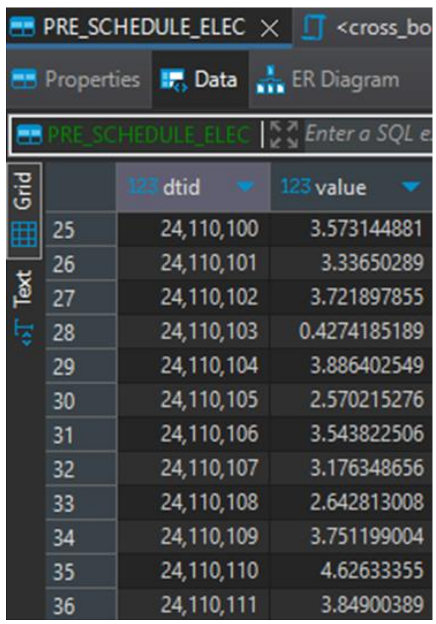
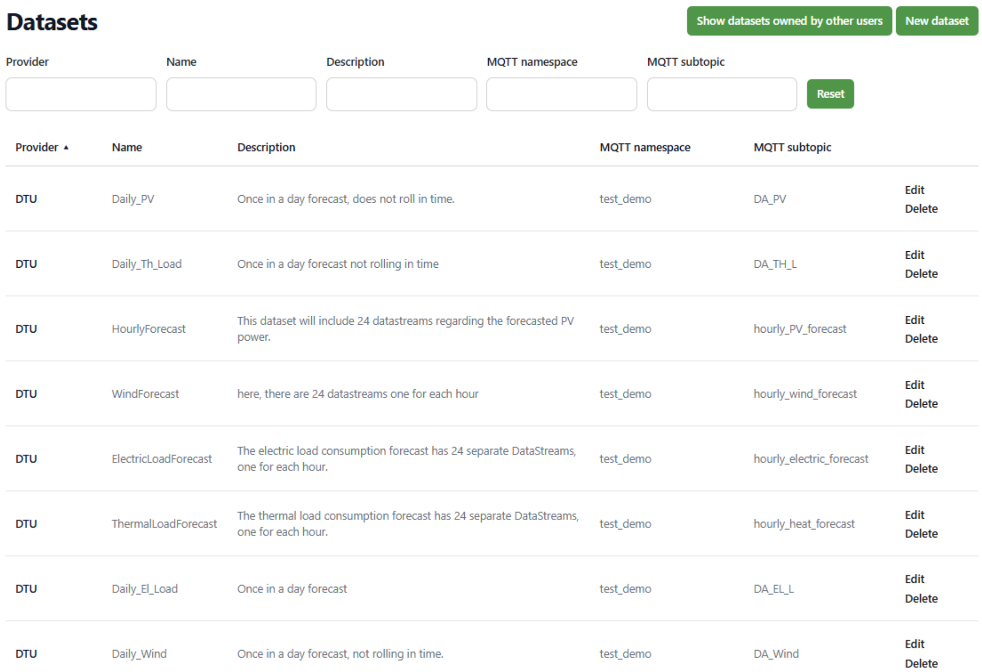


Figure 6 Database table from integrated in ecoEMS framework database showing the pre Day Ahead Scheduling output for ecoCommunity

EMS_ 2UC2.1: Mid-term and short-term RES and load forecasting. Training of the Forecasting model

The ecoEMS requires daily forecasts of renewable energy generation and consumption to provide a day-ahead (DA) scheduling solution. These forecasts, which span 24 hours, are generated once per day. Using these daily forecasts, ecoEMS creates a DA schedule and subsequently performs co-optimization, transitioning to a closer-to-real-time (RT) scheduling approach. For this second step, ecoEMS relies on hourly updated forecasts, which provide updated 24-hour projections every hour.

To meet these requirements, the forecasting models are divided into daily and hourly forecasts, which are developed for PV power and wind power generation as well as electric and heat load consumption. These models are pre-trained and deployed to continuously generate the necessary forecasts. As outlined in Work Package 3, the forecasts are tailored to fulfill the specific needs of ecoEMS. Eight distinct datasets have been created to accommodate both daily and hourly updated forecasts for RES and load consumption as shown in Figure 7.


Datasets

Show datasets owned by other users | New dataset

Provider | Name | Description | MQTT namespace | MQTT subtopic | Reset

Provider ▲	Name	Description	MQTT namespace	MQTT subtopic	
DTU	Daily_PV	Once in a day forecast, does not roll in time.	test_demo	DA_PV	Edit Delete
DTU	Daily_Th_Load	Once in a day forecast not rolling in time	test_demo	DA_TH_L	Edit Delete
DTU	HourlyForecast	This dataset will include 24 datastreams regarding the forecasted PV power.	test_demo	hourly_PV_forecast	Edit Delete
DTU	WindForecast	here, there are 24 datastreams one for each hour	test_demo	hourly_wind_forecast	Edit Delete
DTU	ElectricLoadForecast	The electric load consumption forecast has 24 separate DataStreams, one for each hour.	test_demo	hourly_electric_forecast	Edit Delete
DTU	ThermalLoadForecast	The thermal load consumption forecast has 24 separate DataStreams, one for each hour.	test_demo	hourly_heat_forecast	Edit Delete
DTU	Daily_El_Load	Once in a day forecast	test_demo	DA_EL_L	Edit Delete
DTU	Daily_Wind	Once in a day forecast, not rolling in time.	test_demo	DA_Wind	Edit Delete

Figure 7 Structure of eight datasets for daily and hourly updated RES and load forecasts.

For the use case, data were collected from the Bornholm demo site for each forecast type, analyzed, and prepared for training a deep learning model described in Work Package 5. These generated forecasts are sent to the ecoPlatform under a separate dataset. It is worth noting that while some datasets were gathered directly from Bornholm, they did not entirely align with the exact ecoEMS field. To address this, realistic adjustments were made to ensure the data represents the operational field accurately.

EMS_ 2UC2.2: Unit Commitment and Economic Dispatch algorithms

The goals of the final Use Case for the ecoEMS were to a) prepare daily the UC simulation with input of forecasts, community engagement and Neogrid devices, b) run the pre Day Ahead Scheduling, send the orders and visualize the output and c) run the Day Ahead Scheduling on hourly step with 24 hours horizon, to optimize the dispatch orders according to the updated input and maximize the flexibility.

For all the parts, ecoEMS can run autonomously, as the data are being fetched from ecoPlatform on specified times, after they have been uploaded from other sources, and followingly, simulations are run and the orders are being published to ecoPlatform to be available for the rest ecoTools.

To define feasibility, if an ecoTool fails to publish data on time, ecoEMS uses the last fetched data that had been published.
Firstly, according to the forecasts, renewable surplus is calculated, and available flexible demand slots are being published to ecoPlatform, waiting for community engagement.

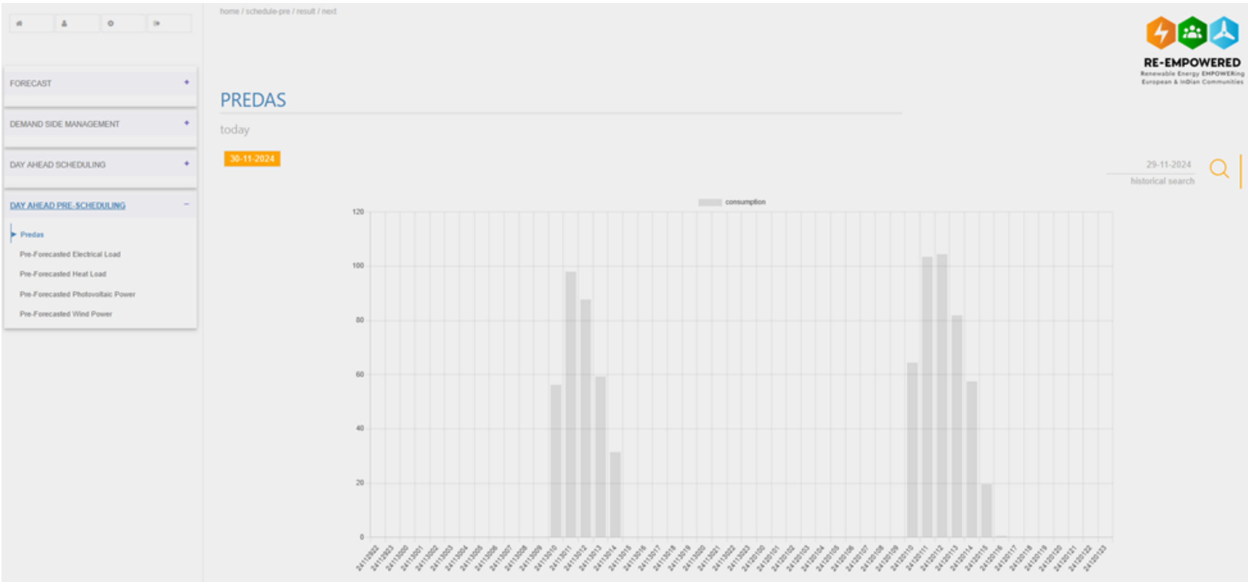


Figure 8 Available slots for flexible consumption according to ecoEMS pre-DAS calculations

Following that, together with the forecasts updates and the engagement community, data from Neogrid devises are subscribed from ecoPlatform, getting the return temperature of the heating water as well as the volume flow. All these data are being updated on hourly basis, and the Economic Dispatch runs on a rolling window of 24 hours horizon, publishing optimal dispatch orders for the imports/exports, CHP, wind farms, PVs, as well as the temperature adjustment for the Neogrid devices, according to the acceptable levels.

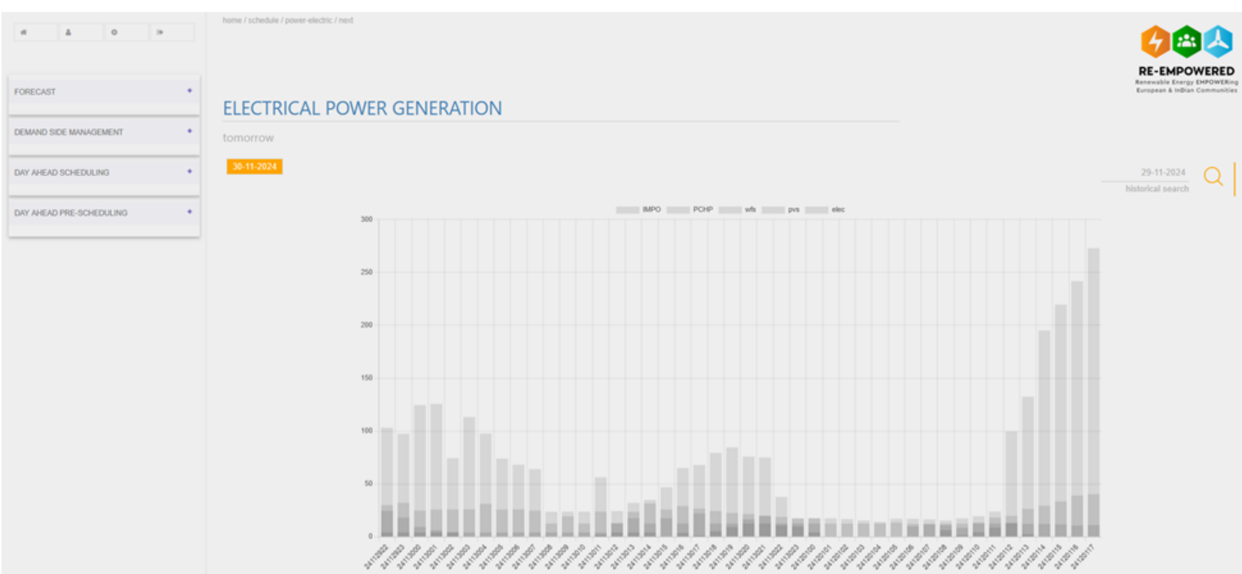


Figure 9 ecoEMS displaying the suggested setpoints to the units

EMS_ 2UC2.3: Multi-energy vector management of operation

This UC focuses on the development and demonstration of the ecoEMS as a tailored solution for rural electrification, utilizing various energy vectors to ensure a 24/7 power supply at a low cost. The system integrates electrical energy resources with district heating systems, co-optimizing their operation to determine the most effective actions for achieving optimal performance.

As part of the ecoEMS, advanced optimization techniques are employed for integrated energy planning. To accomplish this, a multi-service co-optimization model is implemented, which considers diverse energy vectors and conversion technologies, including electric power and heating. The optimization framework aims to achieve efficient multi-energy utilization across the entire spectrum of energy vectors, targeting the most economical operation while meeting a wide array of operational, security, and availability constraints.

A key mechanism for achieving these objectives is the scheduling of different energy vectors by leveraging their flexibility. In the pilot cases, this flexibility is realized through the use of electric boilers for hot water production, hot water tanks, and electric heaters. These flexible energy sources are strategically managed to optimize performance, contributing to the overall efficiency and cost-effectiveness of the system.

3.1.1.2 ecoDR

As stated in D7.3 [3], 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 currently being connected through the internet with ecoPlatform and the Bornholm demo-site, minimizing the impact of this relocation on the project activities.

DR_2UC1.1: Real time monitoring of energy consumption

Following the deployment of ecoDR in the DTU laboratory, the router connection has been successfully established, enabling data transfer via the router.

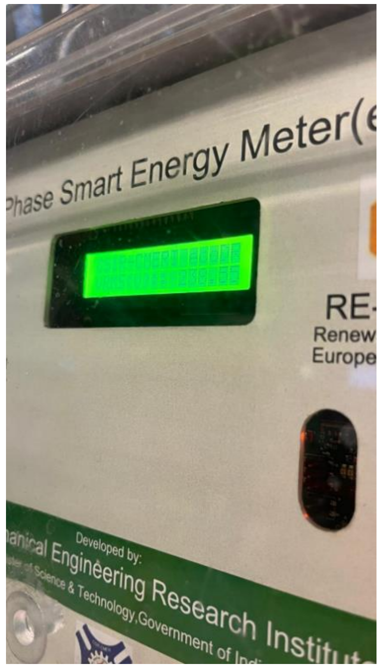


Figure 10 ecoDR deployed in DTU

The ecoDR device can measure sixteen different parameters and transfer them via the router, in addition to capturing discrete data readings. The table below provides a complete list of the data readings supported by ecoDR.

	Start address	Quantity	Purpose
Coils	0x00	2	**Coil 0 :** set status for critical output port **Coil 1 :** set status for non-critical output port
Discrete Inputs	0x00	2	**Coil 0 :** read status for critical output port **Coil 1 :** read status for non-critical output port
Input Registers	0x00	24	**Register 0 & 1 :** holds higher order and lower order words respectively of 4 byte floating point data for **Vrms in V** **Register 2 & 3 :** holds higher order and lower order words respectively of 4 byte floating point data for **Irms in A** **Register 4 & 5 :** holds higher order and lower order words respectively of 4 byte floating point data for **Active Power in W** **Register 6 & 7 :** holds higher order and lower order words respectively of 4 byte floating point data for Apparent power in VA **Register 8 & 9 :** holds higher order and lower order words respectively of 4 byte floating point data for Reactive Power in VAR **Register 10 & 11 :** holds higher order and lower order words respectively of 4 byte floating point data for power factor **Register 12 & 13 :** holds higher order and lower order words respectively of 4 byte floating point data for **Active Energy in kWh** **Register 14 & 15 :** holds higher order and lower order words respectively of 4 byte floating point data for **Total Active Energy in kWh** **Register 16 - 21 :** holds **DD, MM, YYYY, hh, mm, ss** respectively of **timestamp data**. **Register 22 & 23 :** holds higher order and lower order words respectively of 4 byte long data for Meter ID **Register 24 & 25 :** holds higher order and lower order words respectively of 4 byte floating point data for **threshold limit for energy in kWh** **Register 26 & 27 :** holds higher order and lower order words respectively of 4 byte floating point data for threshold limit for load in W **Register 28 & 29 :** holds higher order and lower order words respectively of 4 byte floating point data for Vpeak in V **Register 30 & 31 :** holds higher order and lower order words respectively of 4 byte floating point data for Ipeak in A
Holding Register	0x00	4	**Register 0 & 1 :** holds higher order and lower order words respectively of 4 byte floating point data for **new threshold limit for energy** **Register 2 & 3 :** holds higher order and lower order words respectively of 4 byte floating point data for **new threshold limit for load**

Table 11 Complete list of ecoDR readings

The router has been successfully connected to the ecoDR, and the configurations showed in Figure 11 and Figure 12 have been completed to facilitate the transfer of ecoDR data readings to the Teltonika (router) interface.

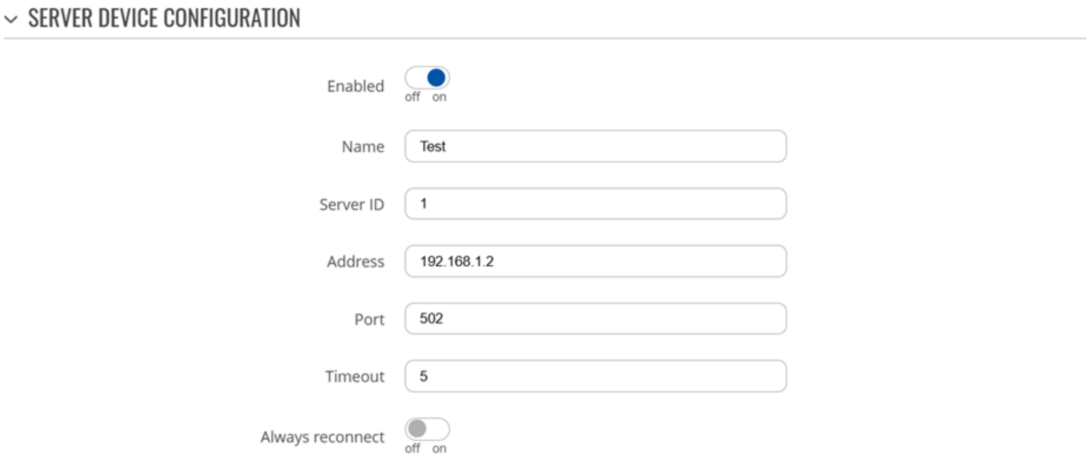


Figure 11 Configuration of router that communicates with ecoDR (1)

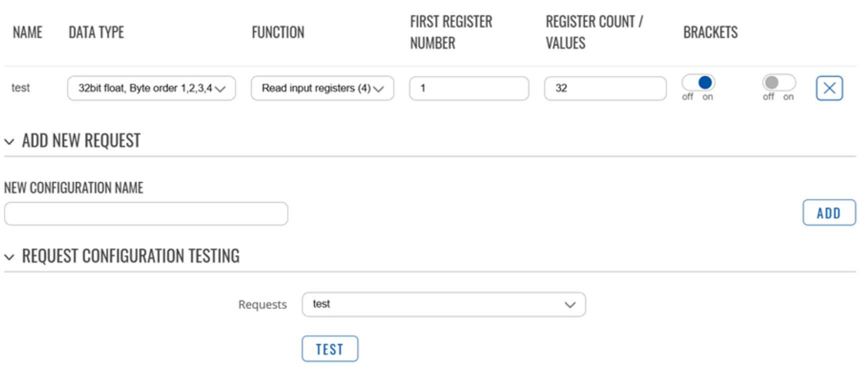


Figure 12 Configuration of router that communicates with ecoDR (2)

With the configurations completed, the test case demonstrates the measurements of ecoDR. To understand the representation of these measurements shown in Figure 13, Table 11 serves as a reference guide.

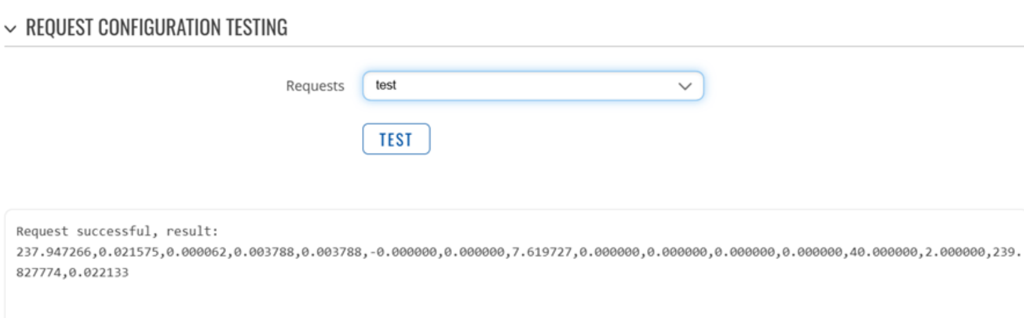


Figure 13 Test connection where data are read successfully from ecoDR

The next step involves transmitting these measurements from the router interface to the ecoPlatform during the second demonstration round.

DR_2UC2.1: Scheduling of loads

This use case will be fully demonstrated in the 2nd demonstration round as it is not completed during the first demonstration round.

3.1.1.3 ecoPlatform

The ecoPlatform is an open, cloud-based platform designed to facilitate the secure and stable exchange of information among key tools, including ecoEMS, ecoCommunity, ecoDR, ecoMonitor, and other assets such as forecasting services and edge device data. It features critical functionalities like MQTT communication, data exchange in JSON and CSV formats, reliable data storage, and data visualization tools.

For the first round of the demonstration phase, following the successful completion of the deployment phase, the primary objective is to ensure stable and seamless data exchange across all tools and assets. This involves conducting multiple full-cycle data exchanges to thoroughly assess the platform's functionality, identify any technical issues, and implement necessary fixes. These steps will prepare the ecoPlatform for the final demonstration phase (Round 2) and ensure its readiness for real-world applications.

PT_2UC1.1: Connect to sensors and acquire data through designated communication network and protocols

Sensors originate from two primary sources. One, the biomass fueled heat plant in Østerlars. Two, the project participants and their related consumptions and temperatures from each smart meter.

Data from heat plant

Inside the heat plant a SCADA system is used to control operation. A data integration from the SCADA system to the ecoTools have been established. A continuous export to a SQL database is landing inside the company data platform using Azure Data Factory. From Data Factory the data is wrangled to a curated dataset using Azure Databricks. From Databricks a number of pipelines are created to run the related to notebooks to finally publish data to the ecoPlatform using MQTT protocol.

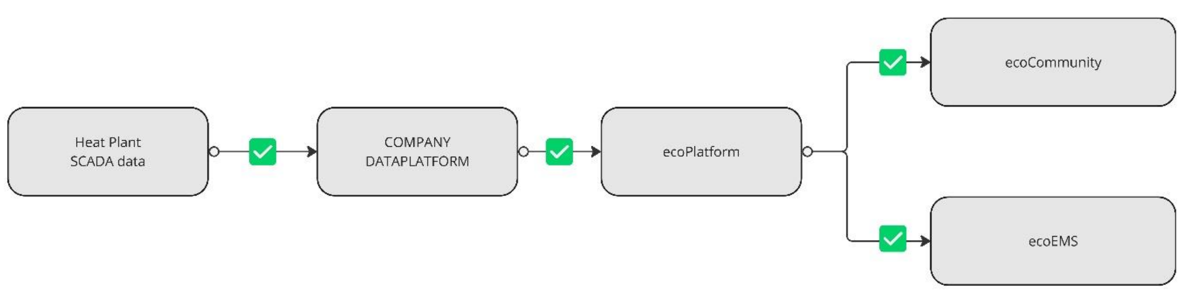


Figure 14 Process diagram illustrating the dataflow from SCADA to ecoTools

Figure 15 Pipeline wrangling the raw SCADA data to the specific needs of RE-EMPOWERED

PT_2UC1.2: Data cleansing to ensure consistency and human machine interface

The ecoPlatform is designed to manage and process time series data, which consists of time-value pairs. In this system, a time series is referred to as a data stream, and its individual elements, the time-value pairs, are called datapoints. Each datapoint must be a floating-point number. Related data streams are grouped into a dataset, which forms the fundamental hierarchy for organizing and providing context to the time series data stored within the ecoPlatform.

To submit data into the ecoPlatform, users must utilize the platform's MQTT or HTTP APIs. These APIs facilitate interaction between data providers and consumers and ensure secure data transactions. Every dataset is owned by a *provider*, who is exclusively authorized to submit data for their datasets. Providers may represent an organization, a team, or an individual. They are responsible for building and maintaining the tools interfacing with the ecoPlatform APIs. While providers can submit data only to their own datasets, they have read-only access to datasets belonging to other providers. Figure 16 illustrates a temperature plot of the outlet electric boiler as displayed on the ecoPlatform, which is an efficient way of visualizing the data in the data stream.

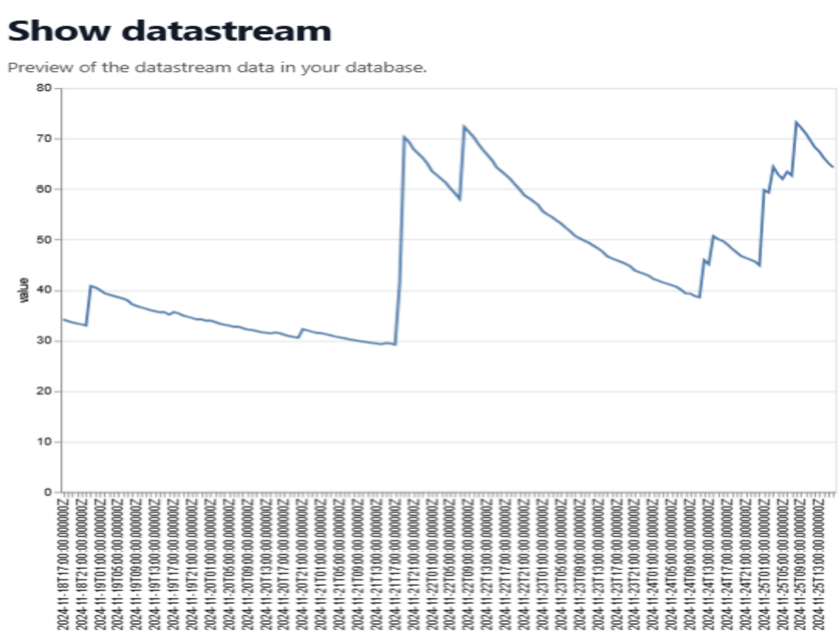


Figure 16 Temperature of the outlet electric boiler on ecoPlatform.

Before submitting time series data, datasets and data streams must first be created via the ecoPlatform web UI. Any user with access to the web UI can create datasets, becoming their respective owners. Dataset owners can manage data streams, assign additional dataset owners, and define critical attributes such as data bounds and silence periods. The MQTT topic in each message identifies the dataset to which the data belongs. Each message contains a single timestamp and its corresponding datapoint value. For daily data uploads, separate data streams are created for each hour within the same dataset, ensuring granular and consistent time series data management. Figure 17 shows a sample view of the ecoPlatform dataset configuration.

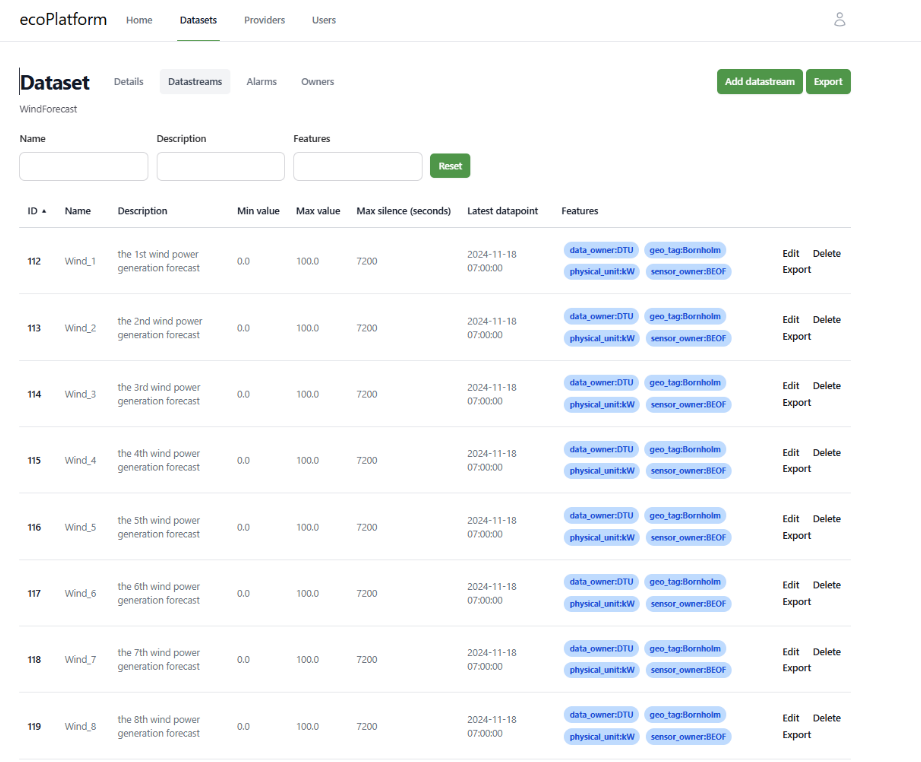
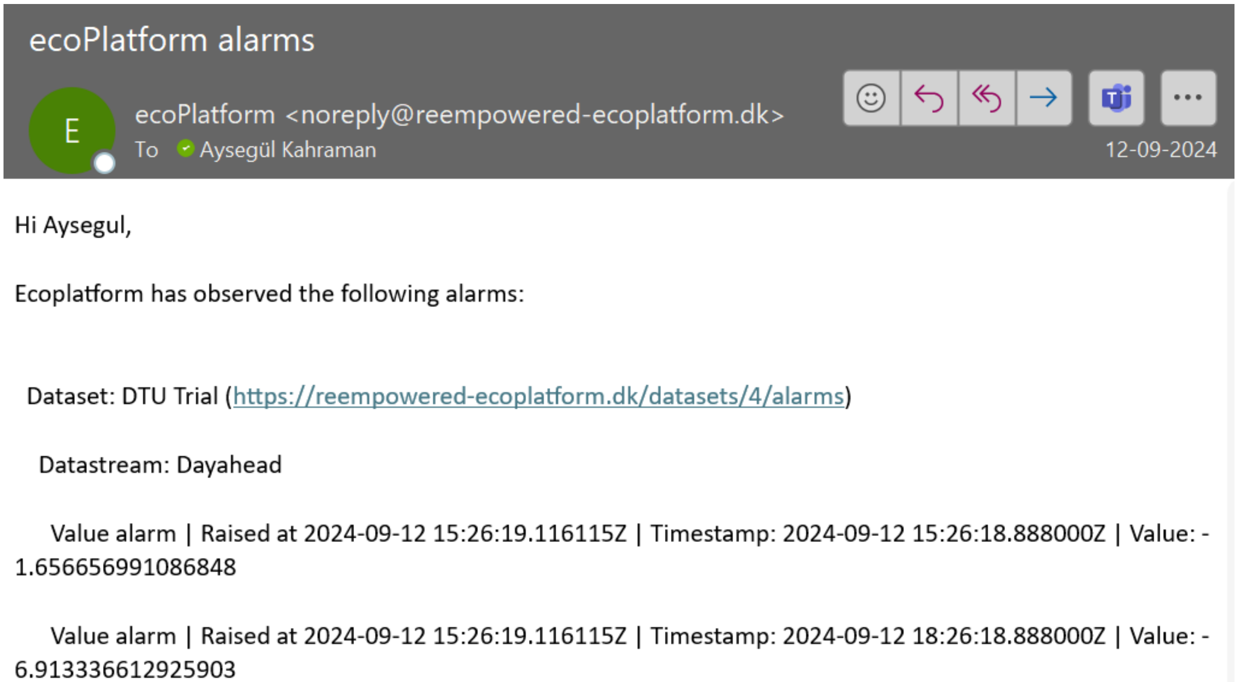


Figure 17 Screenshot of ecoPlatform dataset configuration showing minimum and maximum value bounds and maximum silence settings.

Once data is submitted, the ecoPlatform's data pipeline processes the incoming data. Its primary tasks include:

Sanitizing: Validating and cleaning incoming data to ensure quality.
Filtering: Discarding invalid data that does not meet the specified criteria.
Storage: Saving valid data into a time series database for long-term access and analysis.

Dataset owners can define minimum and maximum bounds for their data streams. Datapoints falling outside these limits are marked as invalid and discarded, triggering a *value alarm*. Additionally, owners can specify a maximum silence period for data streams. If no valid datapoints are received within this period, a *silence alarm* is generated. Owners can subscribe to receive email notifications for these alarms, with a limit of one notification per hour to avoid spam. Figure 18 shows how the ecoPlatform notifies dataset owners of observed alarms, such as value alarms or silence alarms. The email contains details including the dataset name, the data stream name, the type of alarm, the timestamp, and the corresponding value of the datapoint that triggered the alarm. This feature ensures that dataset owners can promptly address data irregularities, maintaining the integrity of time series data.


ecoPlatform alarms

ecoPlatform <noreply@reempowered-ecoplatform.dk>
To Aysegül Kahraman
12-09-2024

Hi Aysegul,

Ecoplatform has observed the following alarms:

Dataset: DTU Trial (https://reempowered-ecoplatform.dk/datasets/4/alarms)

Datastream: Dayahead

Value alarm | Raised at 2024-09-12 15:26:19.116115Z | Timestamp: 2024-09-12 15:26:18.888000Z | Value: -1.656656991086848

Value alarm | Raised at 2024-09-12 15:26:19.116115Z | Timestamp: 2024-09-12 18:26:18.888000Z | Value: -6.913336612925903

Figure 18 Example of an email notification from the ecoPlatform alarm system.

By implementing these robust data cleansing and management protocols, the ecoPlatform ensures high-quality data storage and seamless communication between various ecoTools, including ecoEMS, ecoCommunity, ecoDR, ecoMonitor, forecasting services, and edge devices. This approach establishes a reliable foundation for further analytical processing and system-wide interoperability.

PT_2UC2.1: Facilitate data exchange between dependent tools

The ecoPlatform provides two API interfaces, MQTT and HTTP, tailored for different use cases:

- The **MQTT API** allows providers to publish and subscribe to data. It is particularly suitable for scenarios where subscribers must receive immediate notifications when new data is published.
- The **HTTP API** supports the bulk transfer of data, offering a reliable option for uploading larger datasets.

In Figure 19, the trained PV forecasting model generates hourly forecasts and sends them to the ecoPlatform using the MQTT API on an hourly basis.

```
Connected with result code 0
1/1 [==============================] - 1s 819ms/step
Publishing message: {"ts": 1732754553950, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 0.0, "PV_4": 0.0, "PV_5": 0.0, "PV_6": 0.0, "PV_7":
0.0, "PV_8": 0.0, "PV_9": 0.0, "PV_10": 17.01, "PV_11": 48.98, "PV_12": 76.99, "PV_13": 90.16, "PV_14": 119.79, "PV_15": 124.73, "PV_16":
110.5, "PV_17": 104.63, "PV_18": 82.04, "PV_19": 64.19, "PV_20": 38.43, "PV_21": 17.78, "PV_22": 7.06, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Message published successfully
Sleeping for 1046 seconds until the next hour starts at 2024-11-28 02:00:00
1/1 [==============================] - 0s 46ms/step
Publishing message: {"ts": 1732755600596, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 0.0, "PV_4": 0.0, "PV_5": 0.0, "PV_6": 0.0, "PV_7":
0.0, "PV_8": 0.0, "PV_9": 5.94, "PV_10": 44.21, "PV_11": 72.99, "PV_12": 101.53, "PV_13": 112.91, "PV_14": 128.98, "PV_15": 118.5, "PV_1
6": 95.22, "PV_17": 78.91, "PV_18": 54.13, "PV_19": 36.27, "PV_20": 20.54, "PV_21": 11.23, "PV_22": 3.54, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Sleeping for 3599 seconds until the next hour starts at 2024-11-28 03:00:00
Message published successfully
1/1 [==============================] - 0s 35ms/step
Publishing message: {"ts": 1732759200232, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 0.0, "PV_4": 0.0, "PV_5": 0.0, "PV_6": 0.0, "PV_7":
0.0, "PV_8": 13.86, "PV_9": 32.84, "PV_10": 72.08, "PV_11": 94.2, "PV_12": 118.73, "PV_13": 118.06, "PV_14": 115.56, "PV_15": 92.15, "PV_1
6": 75.43, "PV_17": 52.04, "PV_18": 38.1, "PV_19": 13.05, "PV_20": 4.17, "PV_21": 6.77, "PV_22": 1.71, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Message published successfully
Sleeping for 3600 seconds until the next hour starts at 2024-11-28 04:00:00
1/1 [==============================] - 0s 17ms/step
Publishing message: {"ts": 1732762800245, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 0.0, "PV_4": 0.0, "PV_5": 0.0, "PV_6": 15.05, "PV_
7": 10.8, "PV_8": 32.56, "PV_9": 73.16, "PV_10": 107.62, "PV_11": 123.06, "PV_12": 126.34, "PV_13": 106.41, "PV_14": 86.38, "PV_15": 66.7,
"PV_16": 49.95, "PV_17": 28.84, "PV_18": 32.79, "PV_19": 7.35, "PV_20": 0.0, "PV_21": 0.0, "PV_22": 0.0, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Sleeping for 3600 seconds until the next hour starts at 2024-11-28 05:00:00
Message published successfully
1/1 [==============================] - 0s 34ms/step
Publishing message: {"ts": 1732766400240, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 0.0, "PV_4": 0.0, "PV_5": 9.84, "PV_6": 34.57, "PV_
7": 27.61, "PV_8": 53.22, "PV_9": 102.3, "PV_10": 119.16, "PV_11": 129.98, "PV_12": 115.23, "PV_13": 81.64, "PV_14": 64.4, "PV_15": 48.37,
"PV_16": 26.87, "PV_17": 15.98, "PV_18": 18.23, "PV_19": 8.42, "PV_20": 0.0, "PV_21": 0.0, "PV_22": 0.0, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Sleeping for 3600 seconds until the next hour starts at 2024-11-28 06:00:00
Message published successfully
1/1 [==============================] - 0s 29ms/step
Publishing message: {"ts": 1732770000217, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 0.0, "PV_4": 0.0, "PV_5": 24.54, "PV_6": 52.4, "PV_
7": 54.74, "PV_8": 85.18, "PV_9": 124.75, "PV_10": 131.03, "PV_11": 122.61, "PV_12": 92.59, "PV_13": 56.46, "PV_14": 50.33, "PV_15": 32.5
4, "PV_16": 15.95, "PV_17": 8.0, "PV_18": 2.95, "PV_19": 6.09, "PV_20": 0.0, "PV_21": 0.0, "PV_22": 0.0, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Sleeping for 3600 seconds until the next hour starts at 2024-11-28 07:00:00
Message published successfully
1/1 [==============================] - 0s 32ms/step
Publishing message: {"ts": 1732773600260, "values": {"PV_1": 0.0, "PV_2": 0.0, "PV_3": 10.97, "PV_4": 2.18, "PV_5": 38.54, "PV_6": 61.89,
"PV_7": 80.64, "PV_8": 110.79, "PV_9": 128.52, "PV_10": 128.01, "PV_11": 95.4, "PV_12": 65.83, "PV_13": 37.28, "PV_14": 38.3, "PV_15": 22.
74, "PV_16": 4.31, "PV_17": 4.82, "PV_18": 0.0, "PV_19": 5.1, "PV_20": 0.0, "PV_21": 0.0, "PV_22": 0.0, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Sleeping for 3600 seconds until the next hour starts at 2024-11-28 08:00:00
Message published successfully
1/1 [==============================] - 0s 24ms/step
Publishing message: {"ts": 1732777200234, "values": {"PV_1": 0.0, "PV_2": 3.08, "PV_3": 22.53, "PV_4": 22.31, "PV_5": 64.75, "PV_6": 84.0
2, "PV_7": 108.85, "PV_8": 124.67, "PV_9": 113.63, "PV_10": 113.66, "PV_11": 72.93, "PV_12": 41.21, "PV_13": 24.15, "PV_14": 22.31, "PV_1
5": 7.69, "PV_16": 0.0, "PV_17": 0.66, "PV_18": 0.0, "PV_19": 0.0, "PV_20": 0.0, "PV_21": 0.0, "PV_22": 0.0, "PV_23": 0.0, "PV_24": 0.0}}
Message sent
Sleeping for 3600 seconds until the next hour starts at 2024-11-28 09:00:00
```

Figure 19 Hourly PV power forecast generation and sending them to the ecoPlatform using MQTT API.

The relevant tool leaders and partners at Bornholm site including ecoEMS, ecoCommunity, ecoDR, ecoMonitor, forecasting services, and edge devices mainly use MQTT API to communicate with each other through the ecoPlatform.

PT_2UC2.2: Facilitate access to controllable assets for dependent tools

As mentioned in PT_2UC2.1 the ecoPlatform facilitates data exchange between various assets and tools through either MQTT API or HTTP API. This functionality is used to connect controllable assets like electric boilers, district heating units and an electric heater.

<u>Asset: Electric boiler</u>

The task for ecoPlatform is to facilitate data being published by ecoEMS and stored in the platform. Afterwards the utility company subscribes to the platform using one of the mentioned API functionalities. In the case of the electric boilers the MQTT API is used. The messages received through MQTT are then captured by an internal data lake (Company Data Platform) and distributed to a program (OPC Router) which enables the final integration to the electric boilers.

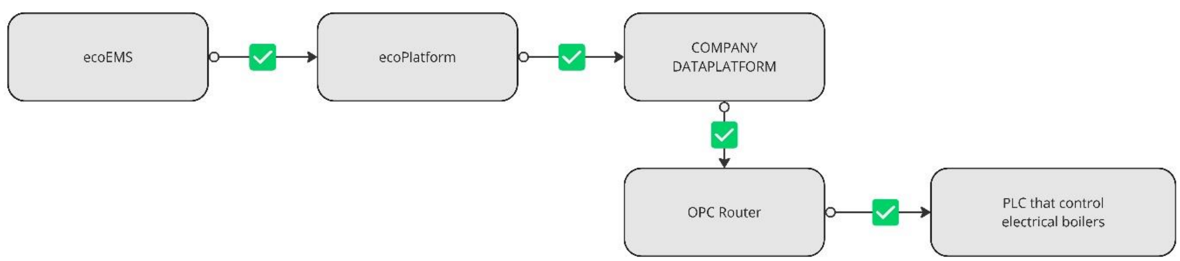


Figure 20 Diagram illustrating the pathway from ecoEMS to control of the electric boilers at the heat plant

<u>Asset: District heating units</u>

As with the electrical boilers the task for ecoPlatform is to facilitate data flow between other sources and connection nodes. In the case of control of the district heating units a temperature adjustment is calculated in ecoEMS and provided for the given timestamp given through ecoCommunity application. The IoT device from Neogrid can attach MQTT data sources and a connection to ecoPlatform is thereby possible.

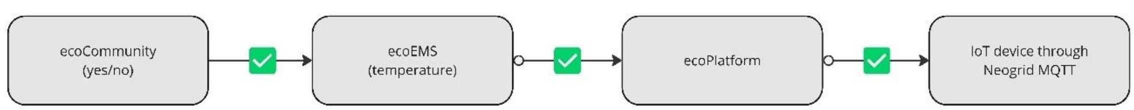


Figure 21 Diagram illustration the pathway from ecoCommunity to the IoT device for control of the district heating unit supply temperature (on the secondary side)

PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database

As already documented in PT_2UC2.1 and PT_2UC2.2, data from various assets/tools have successfully either subscribed or published data to and from the ecoPlatform and its database.

PT_2UC3.2: Facilitate archived data access for dependent tools using API

The ecoPlatform exposes an HTTP API that facilitates batch import and export of data points. This capability is particularly beneficial for tools that generate data periodically or require scheduled data retrieval to perform specific calculations. By leveraging this API, users can seamlessly integrate their applications with the ecoPlatform, ensuring efficient and reliable data exchange.

The relevant script for implementing this functionality is provided below:

```
BASE_URL = 'https://reempowered-ecoplatform.dk'
API_KEY = 'P004-xxx'
API_SECRET = '7yyy'

DATASTREAM_IDS = ','.join(str(i) for i in range(88, 112))
headers = {
    'x-api-key': API_KEY,
    'x-api-secret': API_SECRET
}

params = {
    'start_ts': 1732754553950,
    'end_ts': 1733232385003,
    'datastream_ids': DATASTREAM_IDS
}
```

Figure 22 Script for implementing the functionality of facilitating archived data access for dependent tools using API

3.1.1.4 ecoMonitor

As stated in D7.3 [3], the ecoMonitor device could not be installed directly at the Bornholm Energy and Utilities (BEOF), as it did not meet mandatory EU requirements. 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 currently being connected through the internet with ecoPlatform, minimizing the impact of this relocation on the project activities.

MN_2UC1.1: Acquisition and transmission of air quality parameters data

The laboratory setup at DTU replicates a similar climate to the intended operational conditions, ensuring both reliable testing and safe operations. The deployed measurement device has been functioning without any issues, confirming the stability and reliability of the system.

Figure 23 ecoMonitor readings for air quality metrics.

Concerning transmission of data, the connection between ecoMonitor and the router is managed after the configurations and only one reading could be read. Efforts are taking place to remotely receive all the readings.

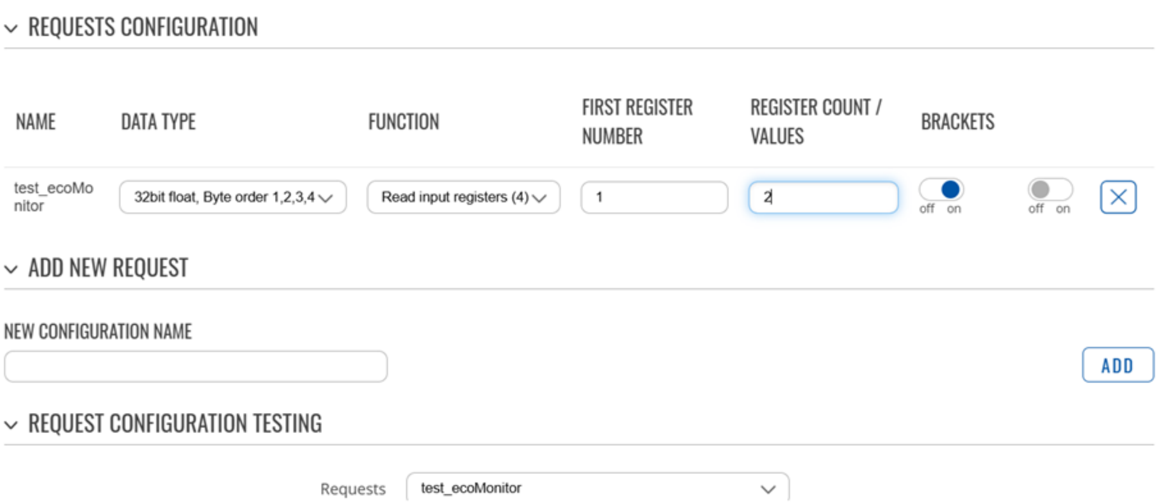


Figure 24 Configuration of router that communicates with ecoMonitor (1)

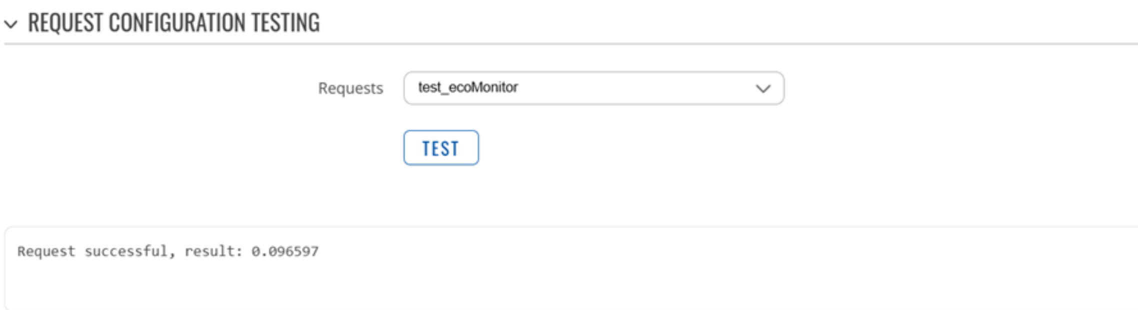


Figure 25 Configuration of router that communicates with ecoMonitor (2)

MN_2UC1.2: Data processing and evaluation

After deployment, the ecoMonitor was connected to the router for data reading. While the connection attempt was successful with a single reading, the system failed to retrieve data when multiple readings were attempted. The issue resulted in a failure message indicating a request error as shown in Figure 26. The root cause of this problem is yet to be identified but it is expected to be resolved during the second demonstration round.

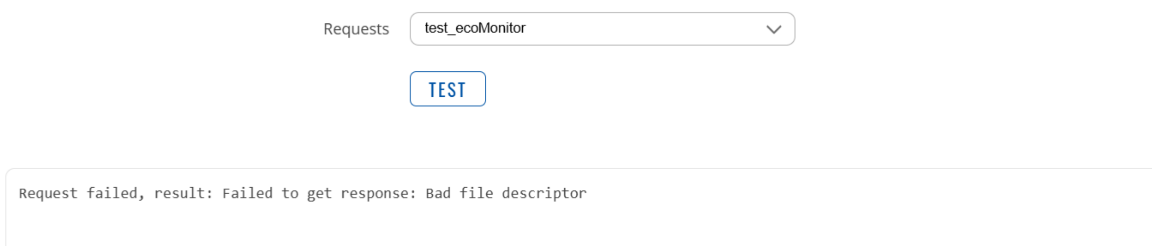


Figure 26 ecoMonitor's attempted connection to the router for multiple data collection

3.1.1.5 ecoCommunity

The deployment of the tool is completed as described in D7.3. Its demonstration will be presented in D7.5.

CM_2UC3.1: Feedback and suggestions from users about the tools

This Use Case will be demonstrated in the 2nd demonstration round.

CM_2UC3.2: Reporting of problem

This Use Case will be demonstrated in the 2nd demonstration round.

CM_2UC3.3: Forum to share experiences

This Use Case will be demonstrated in the 2nd demonstration round.

CM_2UC4.1: Training material (troubleshooting)

This Use Case will be demonstrated in the 2nd demonstration round.

CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)

This Use Case will be demonstrated in the 2nd demonstration round.

CM_2UC5.1: Monitoring of heating system at load centers

This Use Case will be demonstrated in the 2nd demonstration round.

3.1.2 List of adaptations for demonstration round 2

Regarding ecoEMS and concerning the flexibility usage provided by the electric boilers, during demonstration round 1, a fixed temperature adjustment of 5 degrees Celsius was provided to all Neogrid devices. In demonstration round 2, the goal is to target and achieve dispatching orders about the temperature adjustment that are tailored to each device, according to each water return temperature. The ecoCommunity tool will be demonstrated in the 2nd round, while no adaptations are needed for ecoPlatform. For ecoMonitor, the receiving of all the data readings and transfer to the ecoPlatform will be addressed in the second demonstration round. The ecoDR is connected to the router and sending its readings to the router interface; the next step is sending these measurements from the router interface to the ecoPlatform as well as implementing load scheduling feature during the second demonstration round.

3.2 Kythnos Island

3.2.1 Report of the demonstration round 1 activities

This section presents the status of the use cases for the Kythnos Power System and Gaidouromantra Microgrid.

3.2.1.1 Kythnos Power System

3.2.1.1.1 ecoEMS

ecoEMS is an energy management system (EMS) aiming at optimizing the overall performance of isolated and weakly interconnected energy systems by increasing the share of RES. The goal of ecoEMS is the full exploitation of the RES potential at reasonable costs in isolated electricity systems. For the scope of the first round of the demonstration phase, following the completion of the deployment phase, the target is to make a batch of full runs of the tool, in order to assess its functionality, target any technical issues and proceed to fixes for the finalization and preparation of the final demonstration phase round two.
The first round of demonstration process was to run the ecoEMS for the period of one week, ie 29th of August until 4th of September of 2024, collect all the data (the input of the algorithm as well as the results of the algorithm), validate them and assess the set of use cases that have been designed for the tool.

EMS_2UC1.1: Real time system monitoring and data acquisition and visualization

This use case 's targets were to visualize the data in the ecoEMS framework, produced by algorithms as well as received from SCADA systems referring to the thermal generation. Since the ecoEMS architecture is designed to monitor and schedule the system operation as close to the real time as possible, as well as scheduling and dispatching orders earlier than the real time, the granularity has been divided into two horizons; a) hourly and b) quarter-hourly. So, the data acquisition and visualization followed this architecture and the data are collected and projected in the following format. At the first two graphs, the SCADA data are shown, where the generation per unit as well as the total load of the island is monitored in hourly and quarter hourly analysis.

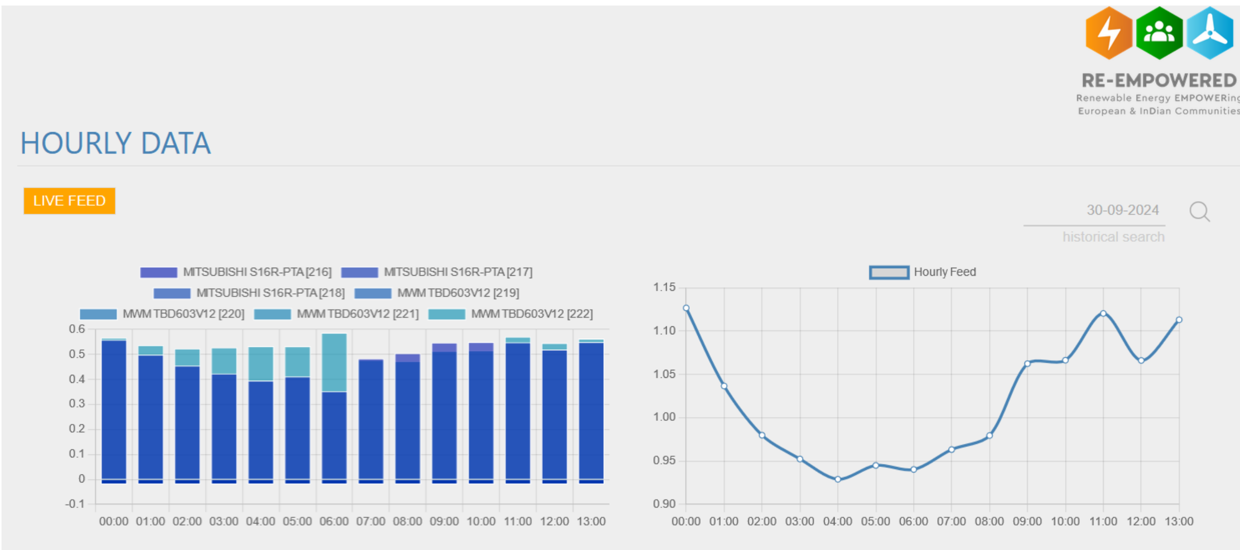


Figure 27 Hourly monitoring of Kythnos's conventional units production and total load

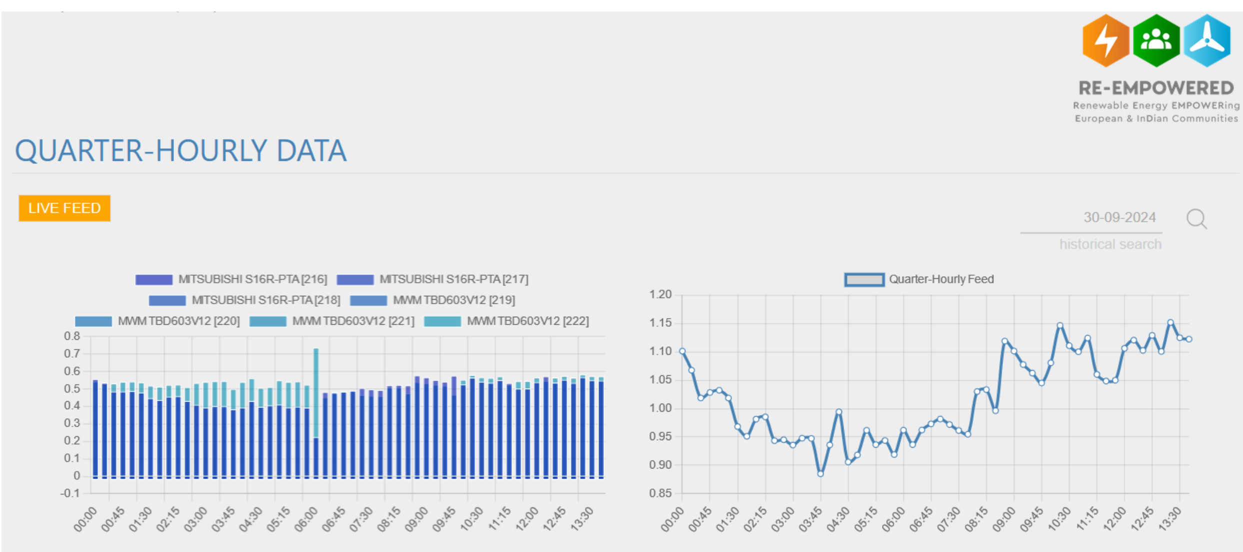


Figure 28 Quarter-hourly monitoring of Kythnos's conventional units production and total load

In the next two graphs, data referring to forecasts are presented; load and photovoltaic forecasts have been retrieved from the database. It needs to be mentioned that ecoEMS has also been designed to integrate wind forecasts, yet since in Kythnos demo site there is no operational active wind turbine, for the scope of this demonstration phase it has been avoided.

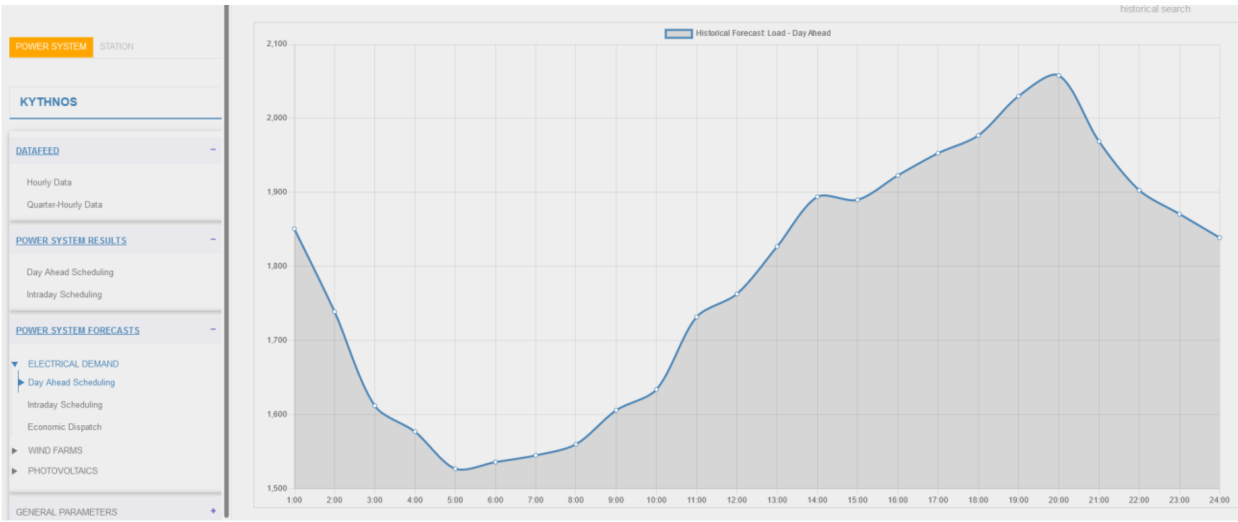


Figure 29 Hourly electrical load forecast for Kythnos demo site

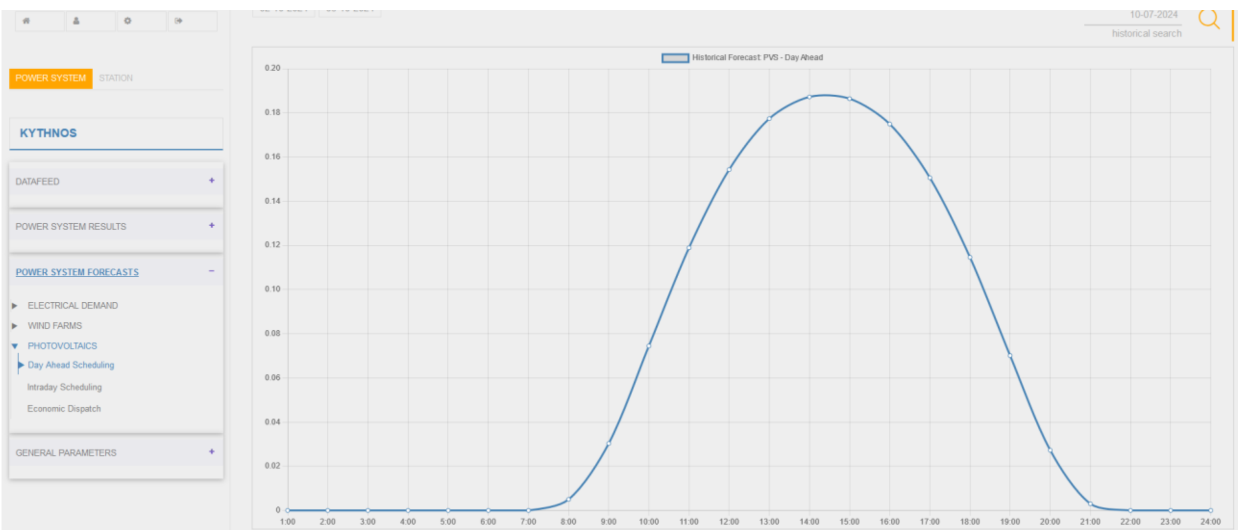
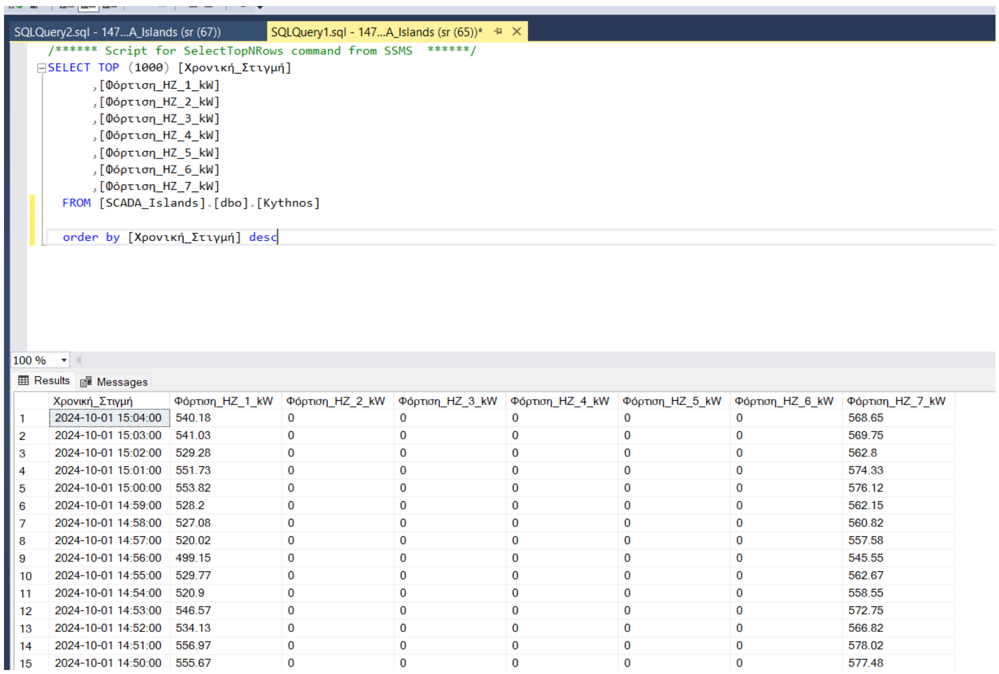


Figure 30 Hourly PV forecast for Kythnos demo site

EMS_ 2UC1.2: Module manager: intercommunications and data exchange

This use case ‘s targets were, primarily, to assess and test the data integrity, as well as of the data exchange process, and search for data corruption or APIs connections failures. Secondarily, within this use case, the goal was to operationally assess the ecoEMS integrated database architecture and speed of data transfers.

The integrated database is scheduled to receive data from the source database that thermal generation data and load data are stored every minute, as shown in the following picture, and manipulate them in order to aggregate these data in hourly and quarter hourly intervals, to prepare them for the visualization of the previous use case, as well as for the Unit Commitment functionality that is described in the next use cases.



SQLQuery2.sql - 147...A_Islands (sr (67))
SQLQuery1.sql - 147...A_Islands (sr (65))*

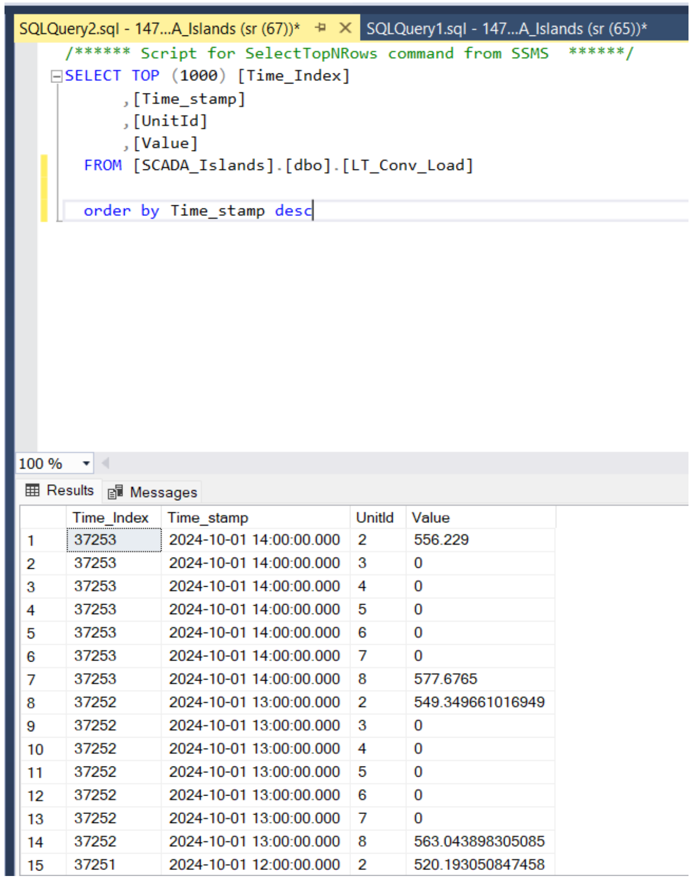
```
/****** Script for SelectTopNRows command from SSMS  ******/
SELECT TOP (1000) [Χρονική_Στιγμή]
      ,[Φόρτιση_HZ_1_kW]
      ,[Φόρτιση_HZ_2_kW]
      ,[Φόρτιση_HZ_3_kW]
      ,[Φόρτιση_HZ_4_kW]
      ,[Φόρτιση_HZ_5_kW]
      ,[Φόρτιση_HZ_6_kW]
      ,[Φόρτιση_HZ_7_kW]
  FROM [SCADA_Islands].[dbo].[Kythnos]

  order by [Χρονική_Στιγμή] desc
```

100 %

Results | Messages

	Χρονική_Στιγμή	Φόρτιση_HZ_1_kW	Φόρτιση_HZ_2_kW	Φόρτιση_HZ_3_kW	Φόρτιση_HZ_4_kW	Φόρτιση_HZ_5_kW	Φόρτιση_HZ_6_kW	Φόρτιση_HZ_7_kW
1	2024-10-01 15:04:00	540.18	0	0	0	0	0	568.65
2	2024-10-01 15:03:00	541.03	0	0	0	0	0	569.75
3	2024-10-01 15:02:00	529.28	0	0	0	0	0	562.8
4	2024-10-01 15:01:00	551.73	0	0	0	0	0	574.33
5	2024-10-01 15:00:00	553.82	0	0	0	0	0	576.12
6	2024-10-01 14:59:00	528.2	0	0	0	0	0	562.15
7	2024-10-01 14:58:00	527.08	0	0	0	0	0	560.82
8	2024-10-01 14:57:00	520.02	0	0	0	0	0	557.58
9	2024-10-01 14:56:00	499.15	0	0	0	0	0	545.55
10	2024-10-01 14:55:00	529.77	0	0	0	0	0	562.67
11	2024-10-01 14:54:00	520.9	0	0	0	0	0	558.55
12	2024-10-01 14:53:00	546.57	0	0	0	0	0	572.75
13	2024-10-01 14:52:00	534.13	0	0	0	0	0	566.82
14	2024-10-01 14:51:00	556.97	0	0	0	0	0	578.02
15	2024-10-01 14:50:00	555.67	0	0	0	0	0	577.48

Figure 31 Database table where Kythnos's actual generation and actual load are stored per minute



SQLQuery2.sql - 147...A_Islands (sr (67))* | SQLQuery1.sql - 147...A_Islands (sr (65))*

```
/****** Script for SelectTopNRows command from SSMS  ******/
SELECT TOP (1000) [Time_Index]
      ,[Time_stamp]
      ,[UnitId]
      ,[Value]
  FROM [SCADA_Islands].[dbo].[LT_Conv_Load]

  order by Time_stamp desc
```

100 %

Results | Messages

	Time_Index	Time_stamp	UnitId	Value
1	37253	2024-10-01 14:00:00.000	2	556.229
2	37253	2024-10-01 14:00:00.000	3	0
3	37253	2024-10-01 14:00:00.000	4	0
4	37253	2024-10-01 14:00:00.000	5	0
5	37253	2024-10-01 14:00:00.000	6	0
6	37253	2024-10-01 14:00:00.000	7	0
7	37253	2024-10-01 14:00:00.000	8	577.6765
8	37252	2024-10-01 13:00:00.000	2	549.349661016949
9	37252	2024-10-01 13:00:00.000	3	0
10	37252	2024-10-01 13:00:00.000	4	0
11	37252	2024-10-01 13:00:00.000	5	0
12	37252	2024-10-01 13:00:00.000	6	0
13	37252	2024-10-01 13:00:00.000	7	0
14	37252	2024-10-01 13:00:00.000	8	563.043898305085
15	37251	2024-10-01 12:00:00.000	2	520.193050847458

Figure 32 Database table where Kythnos's actual generation and actual load are raw data are transformed in hourly granularity

Since the data have been pulled and transformed in the backend of the application, the integrated database schema, where they are stored, is shown in the next two pictures. There are both static tables where the data are rarely being modified, since the contain data that do not get any often alterations, e.g. the technical datasheets of the installed generation units, as well as tables that change every quarter of the hour or every hour, such as the forecasts and SCADA tables. The architecture of the integrated database provided not only instant responses of the tool, minimizing any data delay, but also the availability to debug and find if any failure had to do with the connections to the databases, the raw data from source databases and algorithms, or with the ecoEMS framework itself.

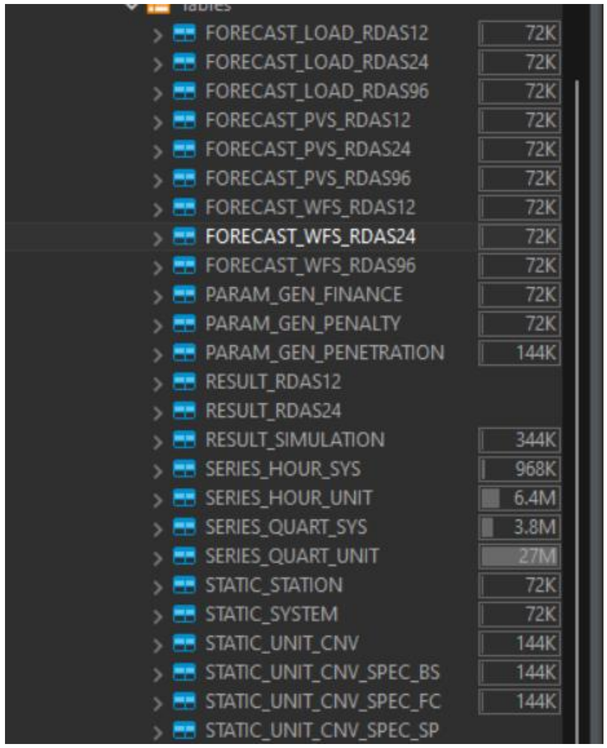


Figure 33 Database architecture from integrated in ecoEMS framework database

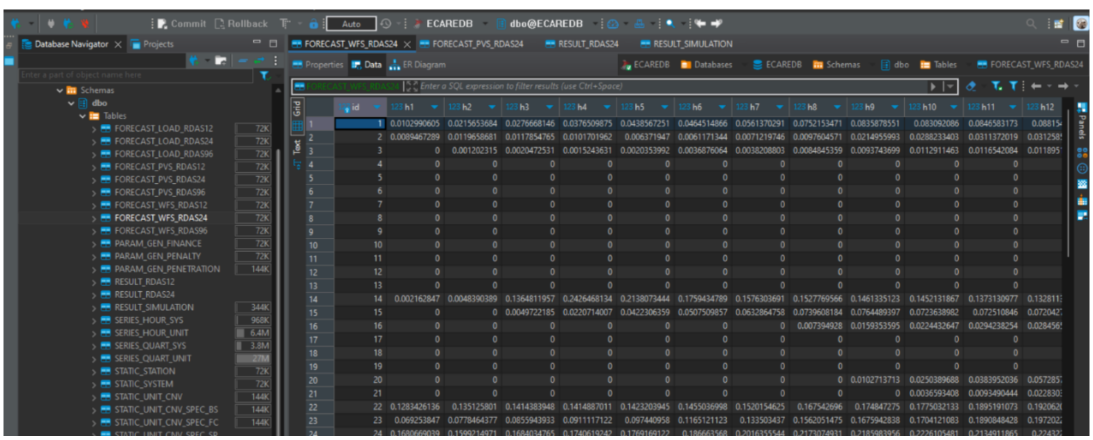
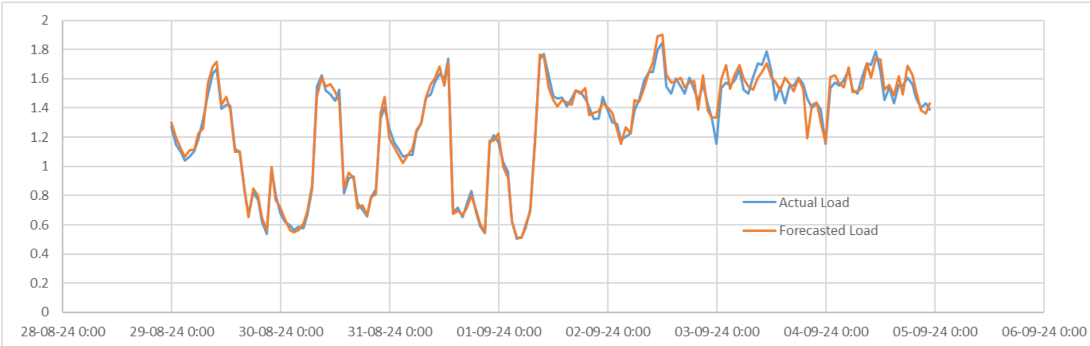


Figure 34 Database table from integrated in ecoEMS framework database showing the forecast of PVs

EMS_ 2UC2.1: Mid-term and short-term RES and load forecasting

As described in D7.1 and D2.1, the goal of this use case is to receive the forecasting algorithm's results, as designed in Work Package 3, and not only use the forecasts but also assess and estimate the uncertainties in order to provide the ecoEMS user some information that he may needs to take into consideration when preparing the UC simulation, as described in the next use case. For the scope of the current use case, data were collected and analyzed from the integrated database, for the aforementioned time interval, and compared the forecasts with the actual values, i.e. load and PV forecasts compared with the actual values, as shown in the next two figures. It is noted that the load forecast is working in a satisfying level, while for the examined period the PV forecasts performed poorly, as the clouds and the unstable weather was not depicted in the forecasts.



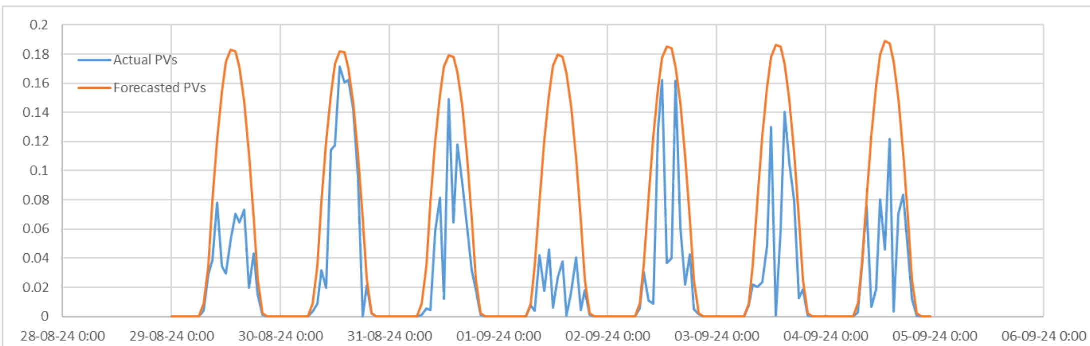


Figure 35 Assessment of electrical load forecast (above) and PV forecast (below)

EMS_ 2UC2.3: Unit Commitment and Economic Dispatch algorithms

The goals of the final Use Case for the ecoEMS were to a) prepare daily the UC simulation with input of forecasts and thermal generators, b) run the simulation, send the orders and visualize the output and c) run the economic dispatch simulation, update the orders and visualize the output.
For the first part, the user of ecoEMS defines and checks the technical datasheet of the thermal units which are depicted in the following pictures, such as the operational conventional unit requirements, which comprise to the minimum and maximum intertemporal constraints, the ramping limits, the fuel consumption and CO_2 emissions factors, fuel costs, CO_2 emissions allowance, etc.

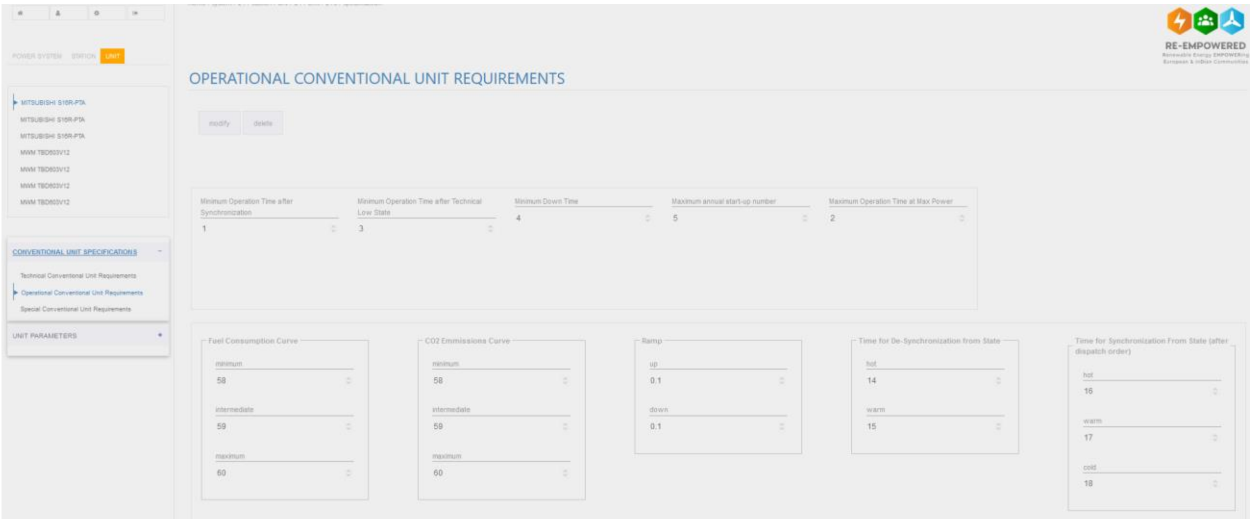


Figure 36 Page from ecoEMS displaying the operational conventional units data input

Figure 37 Page from ecoEMS displaying the cost parameters, such as the price of fossil fuels

Following that, together with the forecasts and the uncertainty as shown in the previous use case, the user may define the reserve requirements as well as the constraint violation merit order, which actually defines what slack variables will be enabled in the algorithm and with what order in order to find a feasible solution.

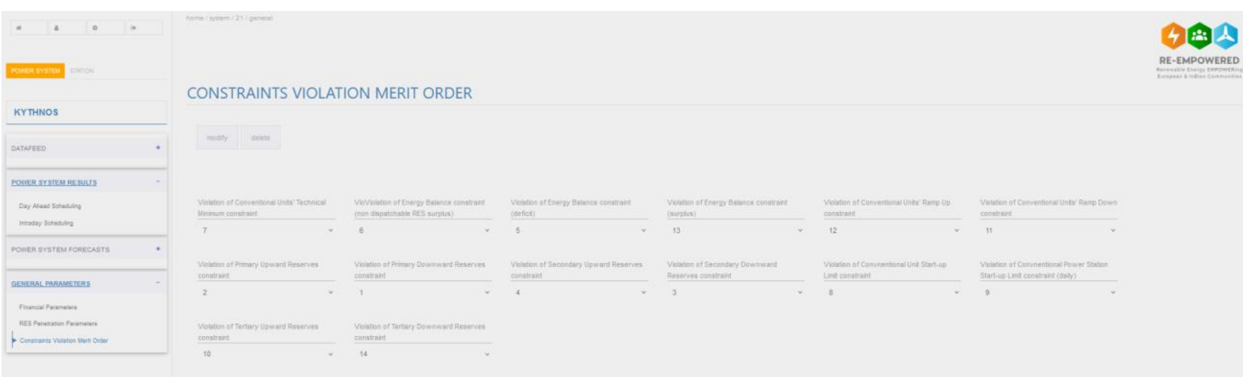


Figure 38 Page from ecoEMS displaying the order that constraints shall be raised in order to find a feasible solution

Finally, the user is ready to run the simulation and investigate the results. The user may make any alterations on the preparation of the Unit Commitment, and run a new simulation. All the simulations results are stored in the database, and can be fetched back. When the final result is accepted by the user, then he can hit the “Finalize” button, upon which the final scheduling is stored in a different table and the scheduling orders are dispatched to the Operator of the demo site.

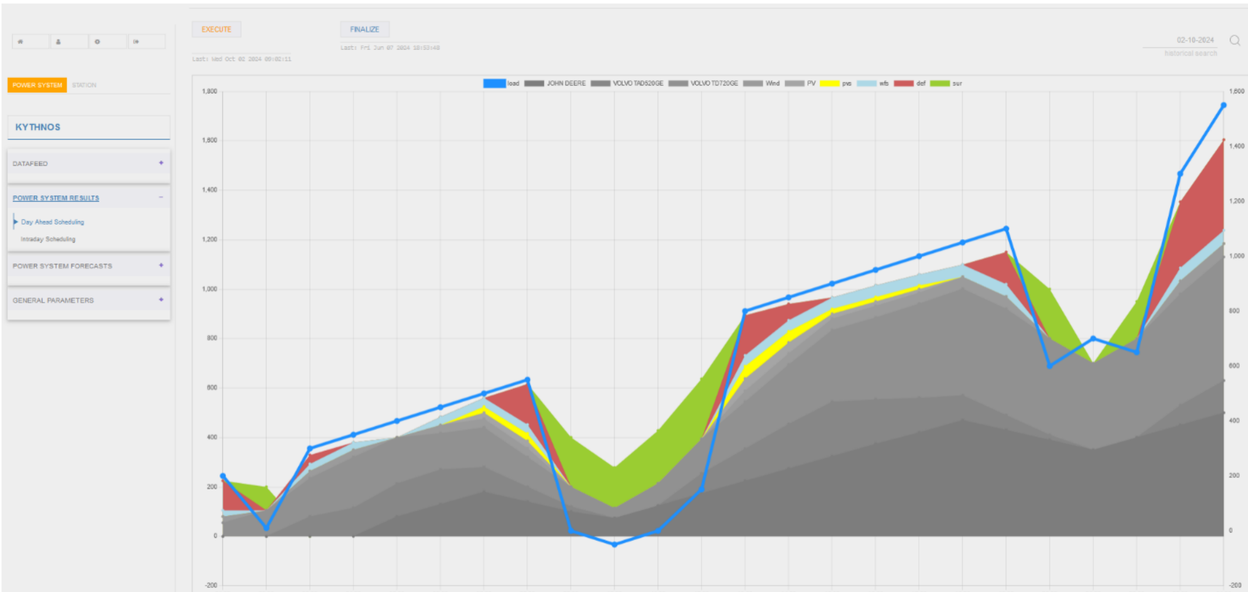


Figure 39 Page from ecoEMS displaying the suggested setpoints to the units

For the scope of this demonstration phase, the economic Dispatch algorithm was not assessed as the photovoltaic data were not found in a quarter hourly granularity, and is left to be examined thoroughly in the second round of the demonstration phase.

3.2.1.1.2 ecoPlanning

ecoPlanning is a tool for supporting the decision-making process for the deployment of new electricity generation units (conventional and renewable) in the electrical systems of non-interconnected islands (NIIs) in a mid-term horizon.

The goal of ecoPlanning is to the following types of studies: 7-Year energy planning for assessing the deployment plan of new conventional production units; RES hosting capacity for analyzing the hosting capacity of RES in the electric system; and interconnection assessment by performing steady state simulations of the electric system to evaluate the interconnection gains. Finally, it produces reports for the operation of the generation units and several results pertaining to the energy production in terms of quantity, fuel consumption and cost, CO_2 emissions, etc.

For the scope of the first round of the demonstration phase, following the completion of the deployment phase, the target is to make a batch of full runs of the tool, in order to assess its

functionalities, target any technical issues and proceed to fixes for the finalization and preparation of the final demonstration phase round two.
The first round of demonstration process was to perform all the ecoPlanning simulations, so firstly collecting all the input data, then design the models and finally run the optimization studies (e.g., Energy Planning 7 years, RES Hosting Capacity, etc)

PN_2UC1.1: Data collection and storage

This use case 's targets were, primarily, to collect and store all the necessary data according to the data mapping of the tool, assess and test the data integrity, as well as of the data exchange process between the integrated database and the backend/frontend of the tool. Secondarily, within this use case, the goal was to operationally assess the ecoPlanning integrated database architecture and speed of data transfers.
The integrated database is scheduled to store data from the front end corresponding the annual RES and load curves, or importing data through the SQL management studio.

Since the data have been collected and transformed, the integrated database schema, where they are stored, is shown in the next two pictures. They all are static tables in the meaning that they do not change dynamically, but only if the user creates or imports data. Also, the data are rarely being modified, since the contain data that do not get any often alterations, eg the technical datasheets of the installed generation units. The architecture of the integrated database provided not only instant responses of the tool, minimizing any data delay, but also the availability to debug and find if any failure had to do with the connections to the database or the raw data, or within the ecoPlanning framework itself.

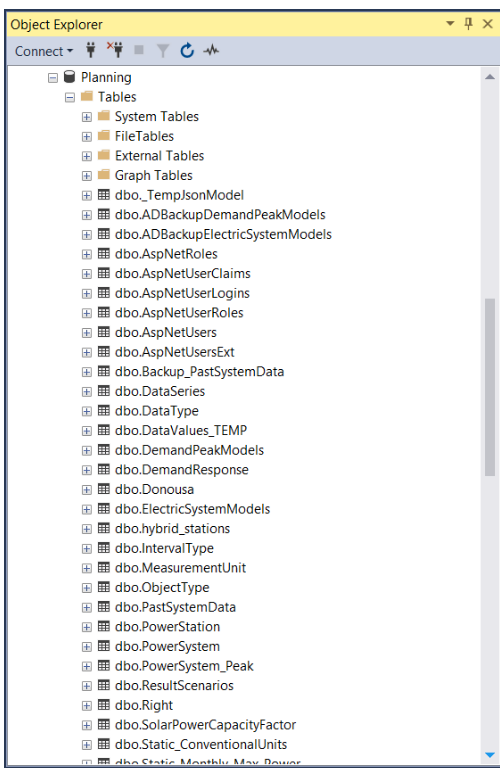


Figure 40 Database architecture from integrated in ecoPlanning framework database

	UnitId	PowerStationId	UnitName	TypeofUnit	InstallationDate	DeInstallationDate	StartDateAsSpare	FuelCoeffA	FuelCoeffB	FuelCoeffC	Fuelid	MinActivePower	MaxActivePower	RatedPower	DisplayCode	Busid
1	256	24	MITSUBISHI S16R-PTA	3	2006-01-01 00:00:00	2035-01-01 00:00:00	2006	266.89	-85.876	37.134	2	0.637	1.1	1.275	G1	256
2	257	24	MITSUBISHI S16R-PTA	3	2006-01-01 00:00:00	2035-01-01 00:00:00	2006	266.89	-85.876	37.134	2	0.637	1.1	1.275	G2	257
3	258	24	MITSUBISHI S16R-PTA	3	2006-01-01 00:00:00	2035-01-01 00:00:00	2006	266.89	-85.876	37.134	2	0.637	1.1	1.275	G7	258
4	259	24	MWM TBD603V12	3	1981-01-01 00:00:00	2035-01-01 00:00:00	1999	237.26	48.362	-103.49	2	0.265	0.4	0.53	G6	259
5	422	24	MWM TBD603V12	3	1981-01-01 00:00:00	2035-01-01 00:00:00	1999	237.26	48.362	-103.49	2	0.265	0.4	0.53	G3	422
6	423	24	MWM TBD603V12	3	1981-01-01 00:00:00	2035-01-01 00:00:00	1999	237.26	48.362	-103.49	2	0.265	0.4	0.53	G4	423
7	424	24	MWM TBD603V12	3	1981-01-01 00:00:00	2035-01-01 00:00:00	1999	237.26	48.362	-103.49	2	0.265	0.4	0.53	G5	424

Figure 41 Database table from integrated in ecoPlanning framework database showing the technical datasheet stored for each conventional unit

	DataSeriesID	DataTypeID	ObjectID	ObjectTypeID	StartDate	IntervalTypeID	MeasUnitID	DataSeriesName	LastModified	ModifiedByUser
1	20	1	21	1	2100-01-01 00:00:00	1	4		1900-01-01 00:00:00.000	0
2	51	2	21	1	2010-01-01 00:00:00	1	1	Καμπύλη Αιολικών 2010 (Κύθνος)	1900-01-01 00:00:00.000	0
3	82	3	21	1	2010-01-01 00:00:00	1	1		1900-01-01 00:00:00.000	0
4	113	4	21	1	2010-01-01 00:00:00	1	1		1900-01-01 00:00:00.000	0
5	144	5	21	1	2010-01-01 00:00:00	1	1		1900-01-01 00:00:00.000	0
6	443	1	21	1	2009-01-01 00:00:00	1	4	Ωριαία Φορτία Συστήματος 2009	1900-01-01 00:00:00.000	0
7	614	1	21	1	1900-01-01 00:00:00	1	4	Test Adonis 20/02	NULL	NULL
8	615	1	21	1	1900-01-01 00:00:00	1	4	Test 2 Adonis 20/02	NULL	NULL
9	616	1	21	1	1900-01-01 00:00:00	1	4	Test 4 Adonis 20/02	NULL	NULL
10	617	1	21	1	1900-01-01 00:00:00	1	4	Test 6 Adonis 20/02	NULL	NULL
11	618	1	21	1	1900-01-01 00:00:00	1	4	gm_test	NULL	NULL
12	619	1	21	1	1900-01-01 00:00:00	1	4	gm_test2	NULL	NULL
13	620	1	21	1	1900-01-01 00:00:00	1	4	Test 7 Adonis 20/02	NULL	NULL
14	621	1	21	1	1900-01-01 00:00:00	1	4	Test 7 Adonis 24/02	NULL	NULL

Query executed successfully. | 147.102.30.15 (15.0 RTM) | sr (67) | Planning | 00:00:00 | 18 rows

Figure 42 Database table from integrated in ecoPlanning framework database showing the timeseries stored for Kythnos demo site

PN_2UC1.2: Electrical models & demand peak models design, RES & Load estimation

This use case's targets were to create both demand-peak and electrical system models, as shown in the next pictures;

- ➢ for the demand peak model, after all methods were tested, the first of them, for the linear extrapolation was chosen to calculate the demand and the peak of the load for a 7 year horizon.
- ➢ For the electric system model all tabs were tested, and at the renewables management tab PVs were modeled, on the conventional units management tab 7 units were modeled with their technical characteristics, and finally at the parameters management tab reserves requirements were defined, among other cost parameters.

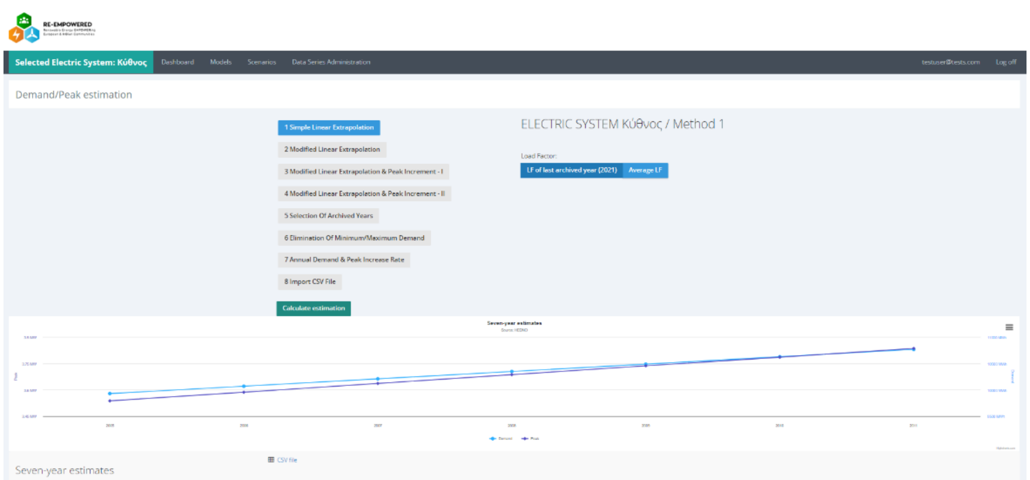


Figure 43 Page from ecoPlanning displaying the methodologies available for the demand/peak model and the estimation using the 1st method

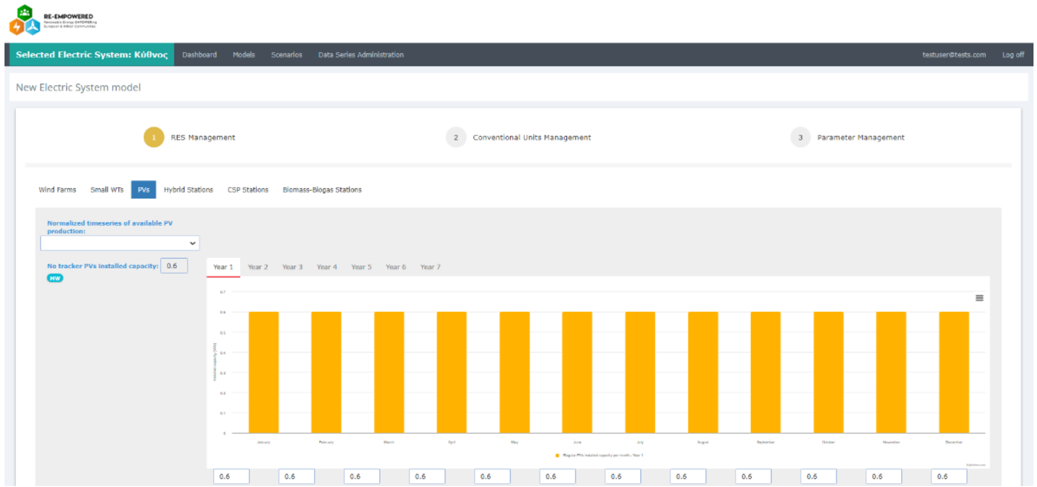


Figure 44 Page from ecoPlanning displaying the installed capacity of PVs in an electrical system model

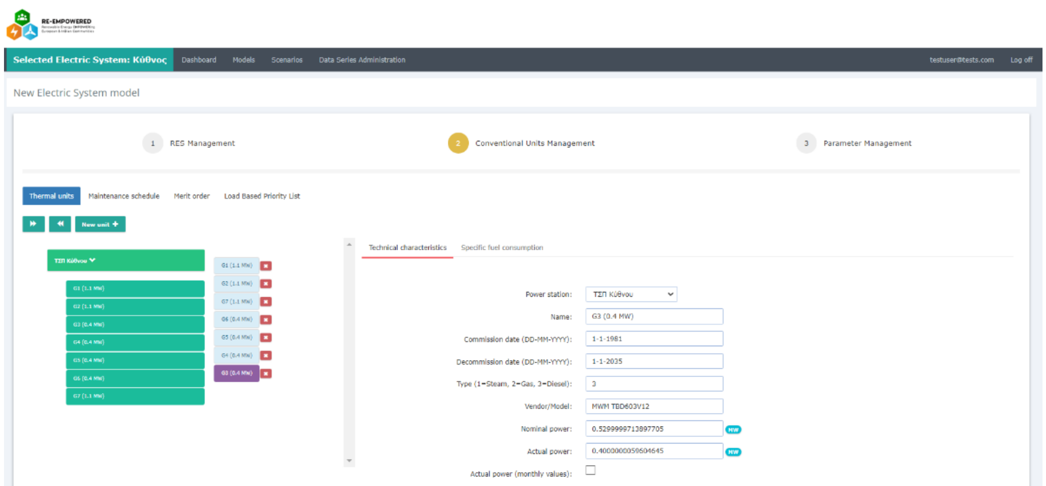


Figure 45 Page from ecoPlanning displaying the units and their technical datasheet

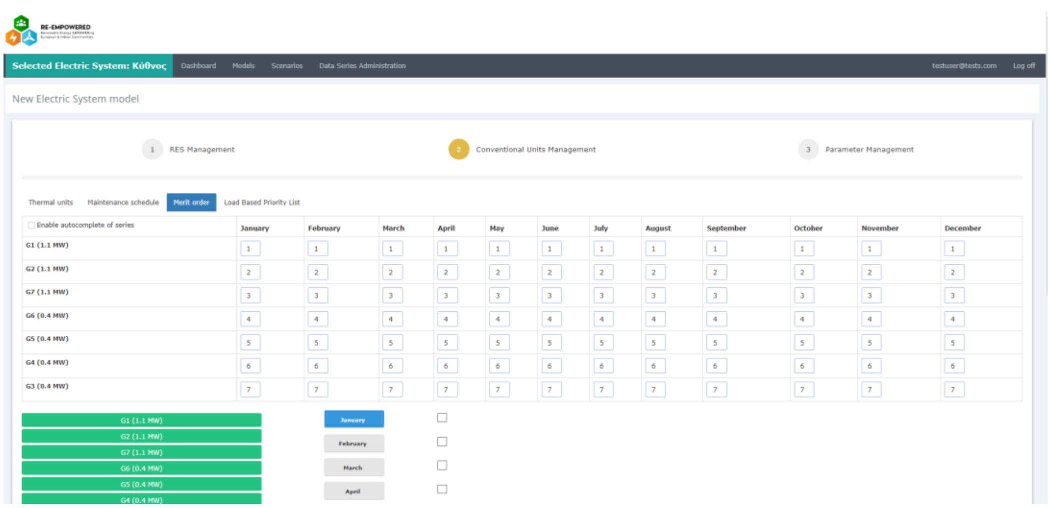


Figure 46 Page from ecoPlanning displaying the units and their merit order

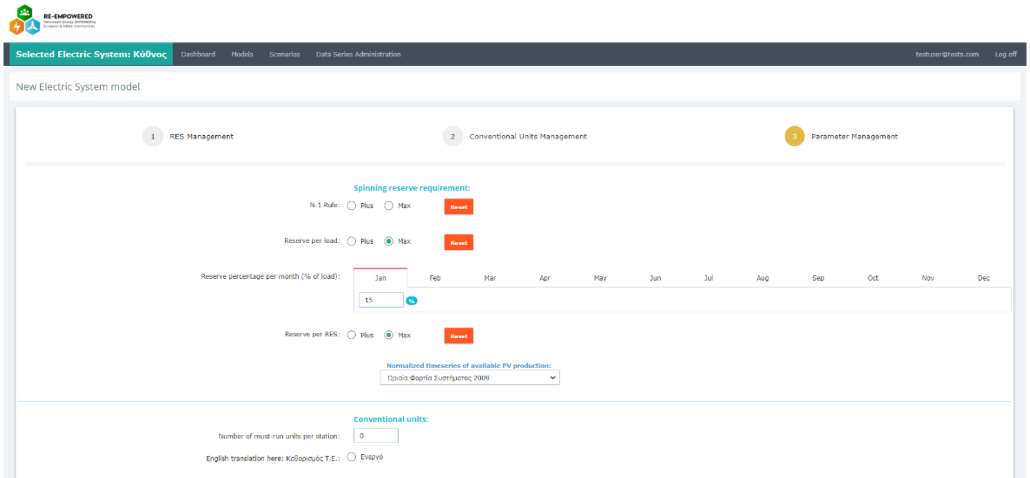


Figure 47 Page from ecoPlanning displaying the reserve requirements from an electrical system model

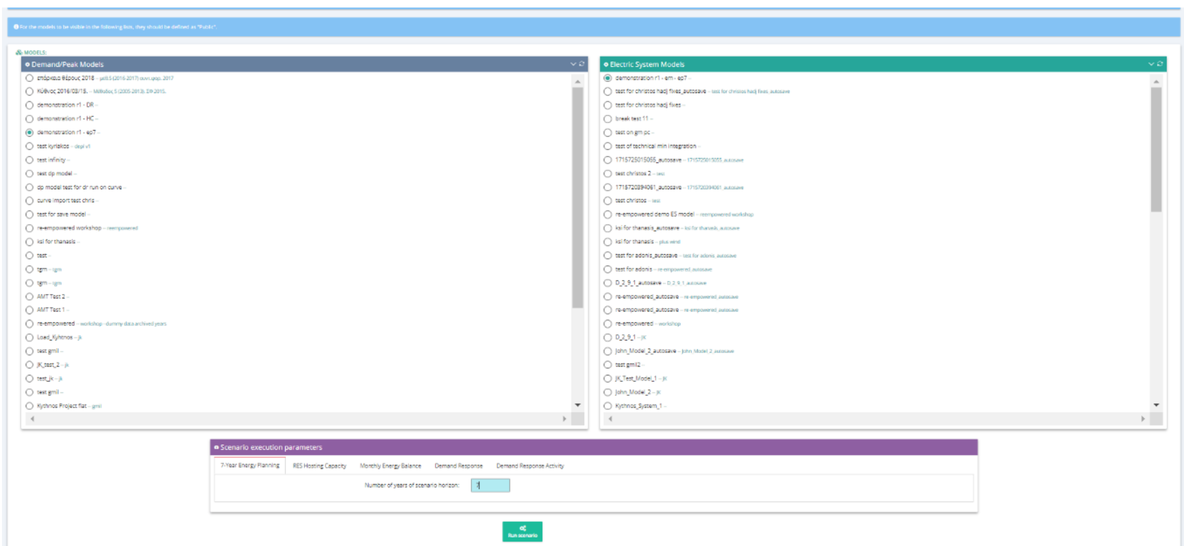


Figure 48 Page from ecoPlanning displaying selection of scenarios and studies to perform - Energy Planning for 7 year is selected

PN_2UC1.3: Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation

In this use case, the goal was to receive the export and navigate through the most important KPIs, as well as match them with the analytical output's CSVs. Specifically, as shown in the next pictures, a graph of the annual energy mix is exported, as well as a list of tables providing information about the aggregated results of annual thermal and RES production, fuel consumption, CO_2 emissions, the input general parameters, the hours of operation of thermal units and various costs.

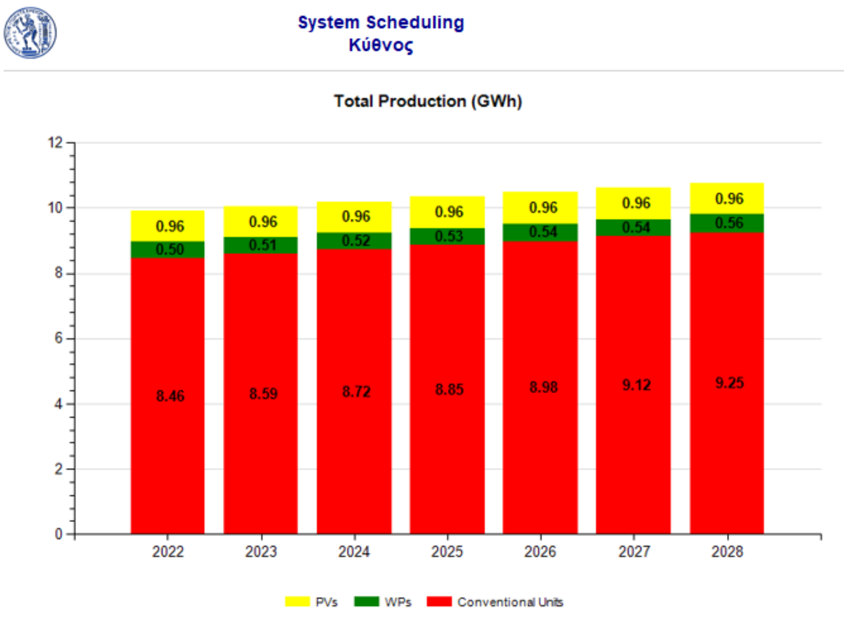


Figure 49 Report output from ecoPlanning displaying the energy mix over the selected horizon simulated

Aggregated results

	2022	2023	2024	2025	2026	2027	2028
Thermal production (MWh)	8,460.00	8,589.88	8,722.20	8,853.20	8,984.96	9,119.60	9,247.88
RES production (MWh)	1,467.50	1,477.32	1,484.70	1,493.30	1,501.24	1,506.30	1,517.72
Demand (MWh)	9,927.50	10,067.20	10,206.90	10,346.50	10,486.20	10,625.90	10,765.60
Annual RES penetration (% of load)	14.78	14.67	14.55	14.43	14.32	14.18	14.10
Maximum instantaneous	55.57	54.85	54.50	53.85	53.21	52.91	52.60
WPs equivalent full load hours (h)	2,397.42	2,436.20	2,480.53	2,546.34	2,597.16	2,647.28	2,718.65
WPs capacity factor (%)	11.53	11.75	11.92	12.12	12.30	12.41	12.67
Diesel consumption (klt)	2,306.04	2,340.94	2,376.27	2,410.30	2,445.39	2,481.30	2,515.00
Mazut consumption (tn)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2 emissions (tn)	6,144.32	6,237.31	6,331.46	6,422.12	6,515.61	6,611.31	6,701.10

General parameters

	2022	2023	2024	2025	2026	2027	2028
Reserves: N-1 Rule	No	No	No	No	No	No	No
Reserves: per Load	Max	Max	Max	Max	Max	Max	Max
Reserves: per RES	Max	Max	Max	Max	Max	Max	Max
Proportional dispatch of conventional units	No	No	No	No	No	No	No
Economic dispatch of conventional units	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit Cost - Heavy Diesel (€/tn)	480.00	480.00	480.00	480.00	480.00	480.00	480.00
Unit Cost - Light Diesel (€/klit)	1,100.00	1,100.00	1,100.00	1,100.00	1,100.00	1,100.00	1,100.00
CO2 emissions price (€/tn)	22.00	22.00	22.00	22.00	22.00	22.00	22.00
RES Penetration (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Instantaneous wind penetration CD (%)	35.00	35.00	35.00	35.00	35.00	35.00	35.00
Wind dynamic margin: CD per Load	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wind dynamic margin: CD per Load (variation)	No	No	No	No	No	No	No
Wind dynamic margin: CD per committed conventional	No	No	No	No	No	No	No
Wind dynamic margin: Sum of conventional and	No	No	No	No	No	No	No

Figure 50 Report output from ecoPlanning displaying the aggregated results and the general parameters over the selected horizon simulated

Annual production per conventional unit (MWh)

	2022	2023	2024	2025	2026	2027	2028
G1 (1.1 MW)	5,345.42	5,350.25	5,371.02	5,440.41	5,480.65	5,539.16	5,591.81
G2 (1.1 MW)	2,295.20	2,392.80	2,461.76	2,514.77	2,609.63	2,664.78	2,743.30
G3 (0.4 MW)	1.32	1.32	1.32	0.00	0.00	1.32	6.82
G4 (0.4 MW)	6.63	6.72	12.39	11.08	11.32	15.25	11.03
G5 (0.4 MW)	22.36	28.45	27.23	25.03	28.43	33.78	36.33
G6 (0.4 MW)	73.78	75.82	83.72	76.12	74.96	75.14	76.74
G7 (1.1 MW)	715.29	734.52	764.76	785.79	779.98	790.18	781.86
Total	***8,460***	***8,590***	***8,722***	***8,853***	***8,985***	***9,120***	***9,248***

Annual production per type of RES (MWh)

Type of RES	Name	2022	2023	2024	2025	2026	2027	2028
PVs	PV	962.56	962.56	962.56	962.56	962.56	962.56	962.56
	Total	*963*	*963*	*963*	*963*	*963*	*963*	*963*
WPs	WT	504.94	514.76	522.13	530.73	538.68	543.73	555.16
	Total	*505*	*515*	*522*	*531*	*539*	*544*	*555*
Total Sum		***1,467.50***	***1,477.32***	***1,484.70***	***1,493.30***	***1,501.24***	***1,506.30***	***1,517.72***

Figure 51 Report output from ecoPlanning displaying the annual conventional and RES production over the selected horizon simulated

Fuel consumption of conventional units (light diesel) (klt)

	2022	2023	2024	2025	2026	2027	2028
G1 (1.1 MW)	1,454.66	1,455.34	1,460.19	1,477.92	1,487.87	1,502.85	1,516.10
G2 (1.1 MW)	625.68	652.32	670.99	685.30	711.21	726.36	747.38
G3 (0.4 MW)	0.39	0.39	0.39	0.00	0.00	0.39	1.99
G4 (0.4 MW)	1.94	1.97	3.62	3.24	3.31	4.46	3.22
G5 (0.4 MW)	6.54	8.32	7.96	7.32	8.31	9.88	10.62
G6 (0.4 MW)	21.57	22.17	24.48	22.26	21.91	21.96	22.44
G7 (1.1 MW)	195.26	200.44	208.63	214.27	212.77	215.41	213.24
Total	***2,306***	***2,341***	***2,376***	***2,410***	***2,445***	***2,481***	***2,515***

CO2 emissions per conventional unit (tn CO2)

	2022	2023	2024	2025	2026	2027	2028
G1 (1.1 MW)	3,875.86	3,877.68	3,890.61	3,937.84	3,964.35	4,004.27	4,039.58
G2 (1.1 MW)	1,667.09	1,738.07	1,787.83	1,825.95	1,894.99	1,935.34	1,991.36
G3 (0.4 MW)	1.03	1.03	1.03	0.00	0.00	1.03	5.31
G4 (0.4 MW)	5.17	5.24	9.66	8.63	8.82	11.88	8.59
G5 (0.4 MW)	17.42	22.17	21.22	19.50	22.14	26.31	28.30
G6 (0.4 MW)	57.48	59.07	65.22	59.30	58.39	58.52	59.78
G7 (1.1 MW)	520.26	534.06	555.89	570.90	566.92	573.96	568.18
Total	***6,144***	***6,237***	***6,331***	***6,422***	***6,516***	***6,611***	***6,701***

Hours of operation per conventional unit

	2022	2023	2024	2025	2026	2027	2028
G1 (1.1 MW)	8,052	8,018	8,000	8,036	8,038	8,071	8,089
G2 (1.1 MW)	3,480	3,630	3,728	3,800	3,946	4,035	4,134
G3 (0.4 MW)	5	5	5	0	0	5	25
G4 (0.4 MW)	25	25	46	41	42	56	40
G5 (0.4 MW)	83	106	101	91	104	124	133
G6 (0.4 MW)	278	282	313	283	276	275	283
G7 (1.1 MW)	1,096	1,122	1,165	1,192	1,188	1,196	1,188

Figure 52 Report output from ecoPlanning displaying the aggregated results for conventional units (fuel, hours, emissions) over the selected horizon simulated

Costs

	2022	2023	2024	2025	2026	2027	2028
Fuel cost (▮)	2,536,638.74	2,575,032.09	2,613,898.74	2,651,329.32	2,689,927.06	2,729,434.88	2,766,501.63
CO2 emissions allowance cost (▮)	135,174.94	137,220.89	139,292.05	141,286.69	143,343.52	145,448.86	147,424.11
Additional variable cost (O&M) (▮)	25,379.99	25,769.64	26,166.61	26,559.61	26,954.87	27,358.81	27,743.63
Variable cost of thermal production (▮)	2,697,193.68	2,738,022.62	2,779,357.40	2,819,175.62	2,860,225.46	2,902,242.55	2,941,669.36
WP production cost (▮)	50,493.94	51,475.56	52,213.41	53,073.26	53,868.13	54,373.23	55,516.18
PV production cost (▮)	96,256.29	96,256.29	96,256.29	96,256.29	96,256.29	96,256.29	96,256.29
RES production cost (▮)	146,750.24	147,731.85	148,469.71	149,329.55	150,124.42	150,629.52	151,772.47
Total production cost (▮)	2,843,943.91	2,885,754.47	2,927,827.10	2,968,505.17	3,010,349.88	3,052,872.07	3,093,441.84
Average thermal production variable cost (▮/MWh)	318.82	318.75	318.65	318.44	318.33	318.24	318.09
Average system cost (▮/MWh)	286.47	286.65	286.85	286.91	287.08	287.30	287.35

Figure 53 Report output from ecoPlanning displaying the various costs over the selected horizon simulated

PN_2UC2.1: Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds

This use case's targets were to create both demand-peak and electrical system models, as shown in the next pictures;

- for the demand peak model, after all methods were tested, then the chosen one was method 7, where user may defines per year the annual increase/decrease of the demand and peak levels for the horizon of the seven years. Yet, since the study of the Hosting Capacity that is examined in this use case only runs for the first year of each combination, this method is the suggested one.
- For the electric system model, the one from the previous use case was used, and scenarios with various Wind Farms and PV parks installed capacity were tested.

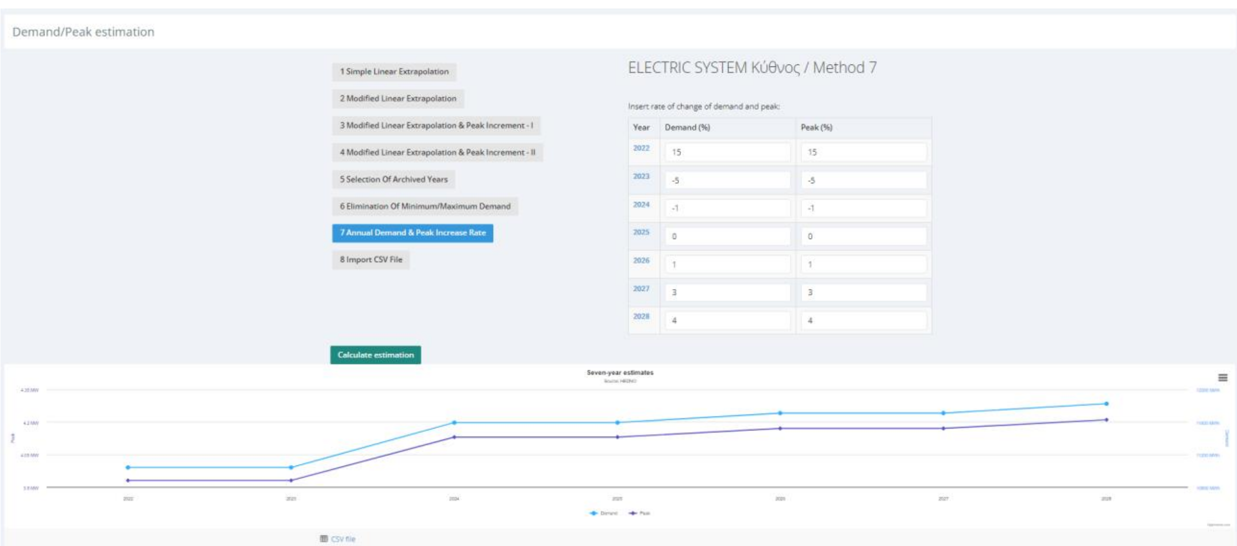


Figure 54 Page from ecoPlanning displaying the methodologies available for the demand/peak model and the estimation using the 7th method

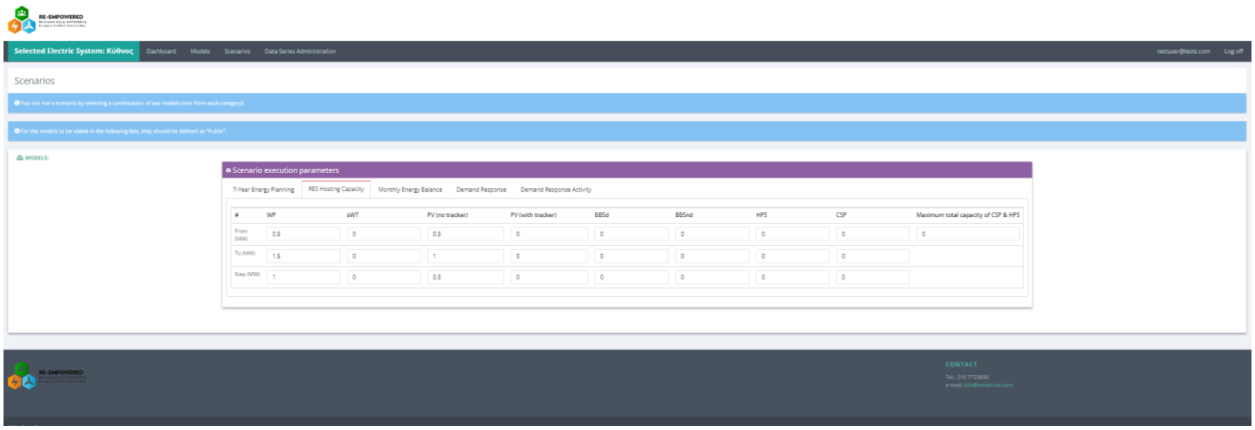


Figure 55 Page from ecoPlanning displaying the input of RES Hosting Capacity study

PN_2UC2.2: Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment

In this use case, the goal was to receive the export and navigate through the most important KPIs for this study, as well as match them with the analytical output's CSVs.
Specifically, in the demonstration of Hosting Capacity study, 4 scenarios were designed and simulated, as shown in the next pictures; the RES installed capacity examined are different levels of PV and Wind Farms installed capacity and the combination of them, while the aggregated results include tables providing information about various costs, the conventional units efficiency, miscellaneous RES results and RES rejections.

RES Hosting Capacity
Κύθνος

System cost

Scenario No	Fuel cost (€)	CO2 emissions allowance cost	Additional variable cost	Variable cost of thermal	RES production cost (€)	Total production cost (€)	Average thermal production	Average system cost (€/MWh)
1	2,884,849.30	153,730.73	28,972.42	3,067,552.45	138,252.77	3,205,805.21	317.64	290.38
2	2,696,507.44	143,694.18	27,002.88	2,867,204.51	203,903.89	3,071,108.40	318.54	278.18
3	2,671,370.84	142,354.68	26,745.29	2,840,470.81	212,630.81	3,053,101.63	318.61	276.55
4	2,508,768.34	133,689.76	25,048.91	2,667,507.01	269,176.98	2,936,683.99	319.48	266.00

RES cost

Scenario No	PV production cost (€)	WP production cost (€)	Total
1	80,213.58	58,039.19	**138,252.77**
2	80,213.58	123,690.32	**203,903.89**
3	160,427.15	52,203.66	**212,630.81**
4	160,427.15	108,749.83	**269,176.98**

Figure 56 Report output from ecoPlanning - Hosting Capacity displaying system and RES costs over the simulated scenarios

Conventional units underload

Scenario No	Hours with underload of conventional units (h)	Average conventional production during underload (MW)	Underload energy (MWh)	Minimum underload (% of nominal capacity)	Minimum underload (% of technical minimum)
1	2,683.00	0.82	292.29	36.14	62.41
2	2,357.00	0.78	238.76	35.94	62.07
3	3,398.00	0.73	522.87	8.63	14.90
4	3,073.00	0.69	469.56	7.78	13.43

Miscellaneous RES results

Scenario No	Annual RES penetration (% of load)	Maximum instantaneous penetration of Non-	WPs capacity factor (%)	WPs equivalent full load hours (h)	Non-dispatched energy of Dispatchable RES	Rejected energy of Dispatchable RES units (% of primarily	Spinning reserve ratio (% of the production of the
1	12.52	44.02	13.25	2,941.86	0.00	0.00	65.29
2	18.47	50.76	9.41	1,293.98	0.00	0.00	61.82
3	19.26	82.86	11.92	2,522.49	0.00	0.00	47.84
4	24.38	82.86	8.28	1,102.91	0.00	0.00	47.48

RES production (MWh)

RES type	PVs	WPs	Total
Scenario No	PV	WT	
1	802.14	580.39	**1,382.53**
2	802.14	1,236.90	**2,039.04**
3	1,604.27	522.04	**2,126.31**
4	1,604.27	1,087.50	**2,691.77**

Figure 57 Report output from ecoPlanning - Hosting Capacity displaying conventional and RES units technical results over the simulated scenarios

Rejected RES energy (% of primarily available)

RES investments Internal Rate of Return (%)

RES type	PVs	WPs
Scenario No	PV	WT
1	8.76	-5.11
2	8.76	-12.54
3	8.76	-7.55
4	8.76	-15.06

RES installed capacity (MW)

RES type	PVs	WPs
Scenario No	PV	WT
1	0.50	0.50
2	0.50	1.50
3	1.00	0.50
4	1.00	1.50

Figure 58 Report output from ecoPlanning - Hosting Capacity displaying various RES units results over the simulated scenarios

PN_2UC3.1: Electrical models, demand peak models & interconnections design, RES & Load estimation

Due to technical bugs of the front end this use case was not thoroughly assessed in the scope of the demonstration round 1 and will be examined analytically at the demonstration round 2.

PN_2UC3.2: Hourly Unit Commitment, through optimization algorithm for mid to long term horizon

Due to technical bugs of the front end this use case was not thoroughly assessed in the scope of the demonstration round 1, and will be examined analytically at the demonstration round 2.

PN_2UC4.1: Energy carriers' identification, data collection and quantification of impact on total load (hourly)

Through the *"Energy carriers' identification, data collection and quantification of impact on total load (hourly)"* use case, which was fulfilled in round 1 (with limited testing), the user may actually implement strategies such as Peak Shaving, RES production reallocation and desalination activities integration. Their corresponding pages are depicted below, yet their thorough examination is left for the second demonstration round, as their algorithm did not converge to an optimal solution.

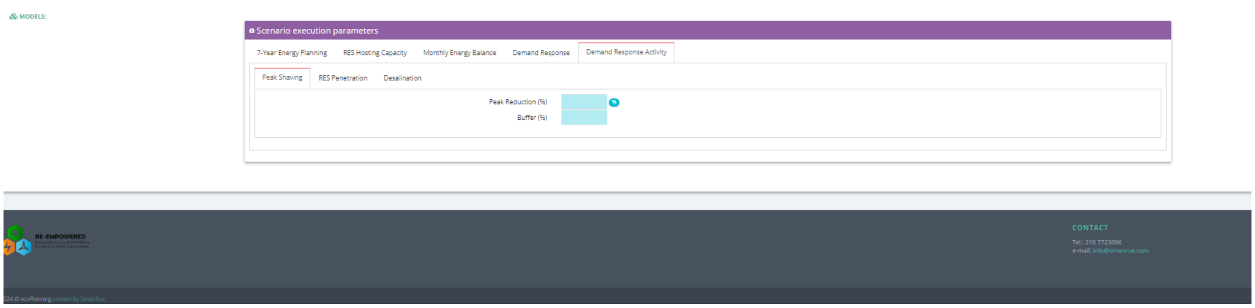


Figure 59 Page from ecoPlanning displaying the input of Demand Response study for peak shaving

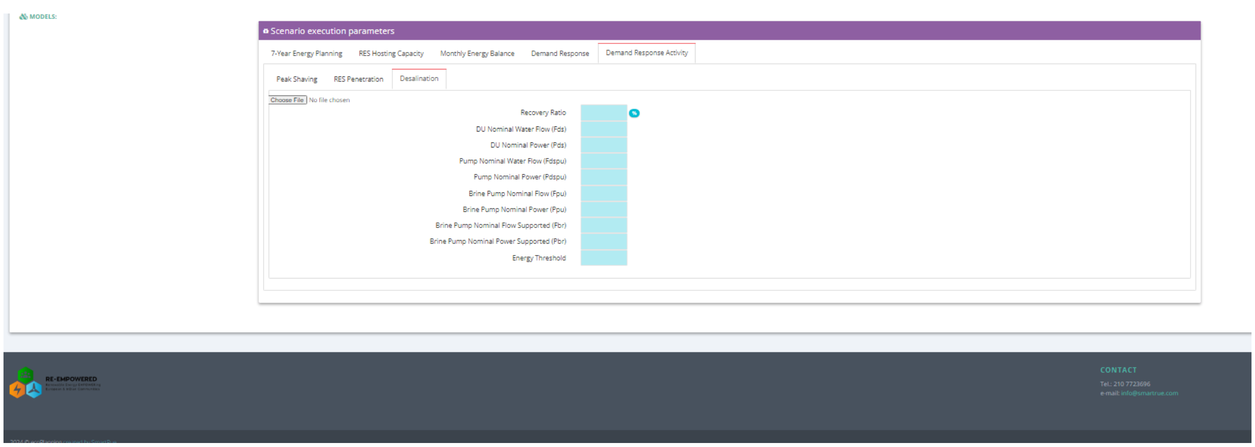


Figure 60 Page from ecoPlanning displaying the input of Demand Response study for desalination

PN_2UC4.2: Electrical models & demand peak design, RES & Load estimation, energy carriers' scenarios integration

This use case's targets were to create both demand-peak and electrical system models, as shown in the next pictures;

- for the demand peak model, after all methods were tested, the one that the user imports the demand curve to be simulated was chosen.
- For the electric system model, the one from the previous use cases was used, as the primary goal here was to check that the imported load is actually used for the simulation.

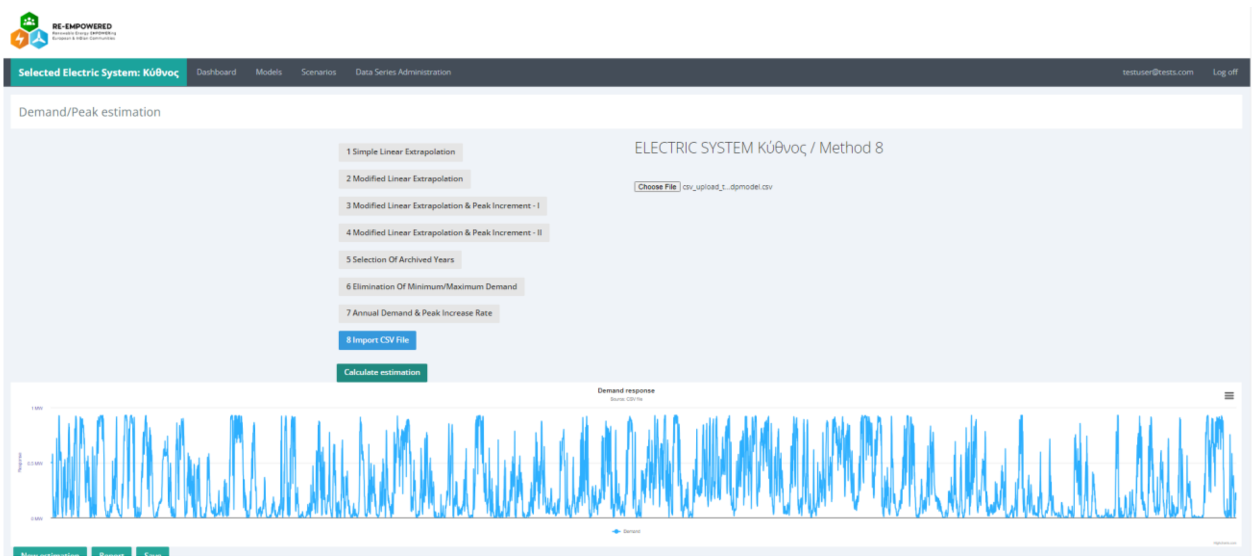


Figure 61 Page from ecoPlanning displaying imported specific load timeseries

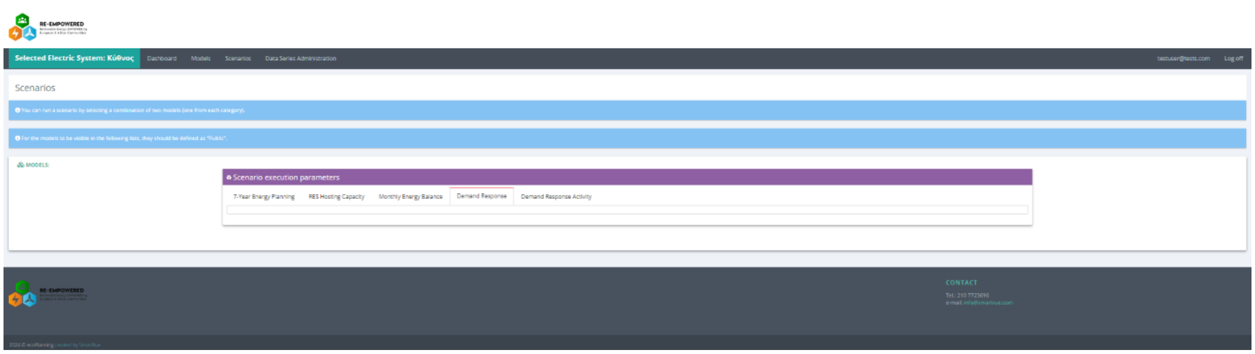
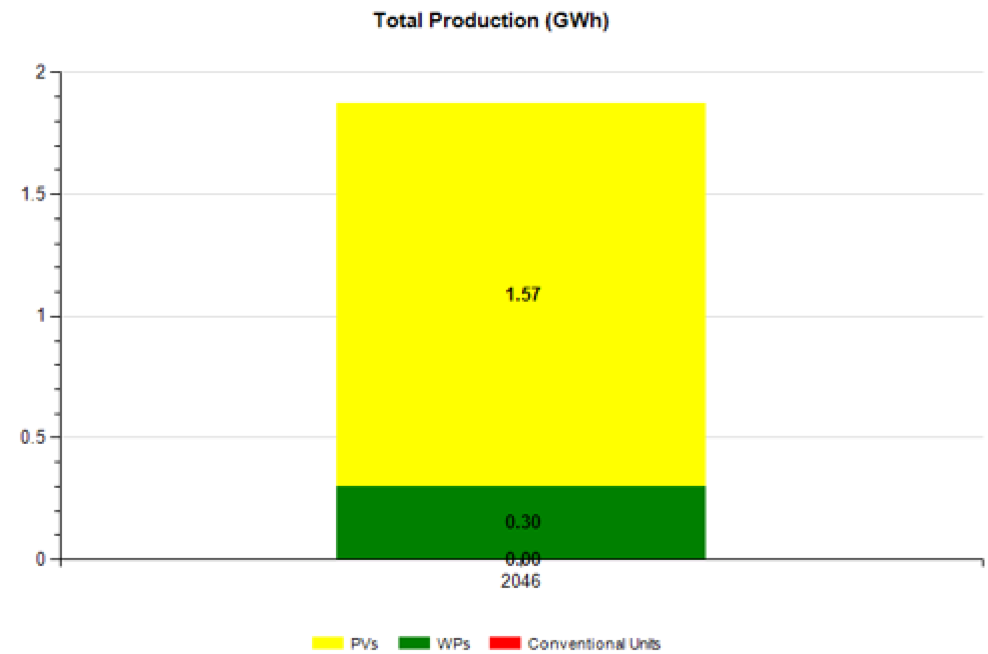


Figure 62 Page from ecoPlanning displaying the input of Demand Response study for dedicated load timeseries

PN_2UC4.3: Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers

In this use case, the goal was to receive the export and navigate through the most important KPIs, as well as match them with the analytical output's CSVs. Specifically, as shown in the next pictures, a graph of the annual energy mix is exported, as well as a list of tables providing information about the aggregated results of annual thermal and RES production, fuel consumption, CO_2 emissions, etc. The target of this study is to compare how the integrated demand response activity that is integrated in the imported load curve, alternates these KPIs in regard with the load curve without the demand response integration.

System Scheduling
Κύθνος



Aggregated results

	2024
Thermal production (MWh)	0.00
RES production (MWh)	1,875.71
Demand (MWh)	2,624.00
Annual RES penetration (% of load)	71.48
Maximum instantaneous	78.67
WPs equivalent full load	979.63
WPs capacity factor (%)	6.88
Diesel consumption (klt)	0.00
Mazut consumption (tn)	0.00
CO2 emissions (tn)	0.00

Figure 63 Report output from ecoPlanning - DR displaying aggregated results over the simulated scenario

Annual production per type of RES (MWh)

Type of RES	Name	2024
PVs	PV	1,574.40
	Total	*1,574*
WPs	WT	301.32
	Total	*301*
Total Sum		*1,875.71*

Non-dispatched RES energy per annum (% of declared)

Rejected RES energy per annum (% of primarily available)

Miscellaneous results

	2024
Hours with non-served load or non-observed reserve (h)	8,717.00
Maximum non-served load or non-	0.51
Total non-served load and non-observed reserve (MWh)	1,308.84
Hours with non-served load (h)	8,707.00
Maximum non-served load (MW)	0.37
Total non-served load (MWh)	748.28
Hours with underload of conventional	0.00

Figure 64 Report output from ecoPlanning - DR displaying various results over the simulated scenario

3.2.1.1.3 ecoMonitor

The ecoMonitor tool has been successfully installed at Merichas Primary School. Merichas, the primary port of Kythnos Island, serves as a significant hub for maritime activities, making it essential to monitor air quality in this area. This installation aims to measure key air quality indicators, providing data to assess pollution levels that could potentially pose health risks to the local community.

MN_2UC1.1: Acquisition and transmission of air quality parameters data

The MN_2UC1.1 use case focuses on validating the monitoring capabilities of the ecoMonitor platform by acquiring and transmitting real-time air quality index (AQI) parameters data for further analysis. The ecoMonitor includes a local display unit with color indications to alert the community when any air quality parameter exceeds the maximum allowable limits. Additionally, the measured air quality data should be transmitted to the ecoPlatform via a MODBUS/MQTT gateway for display and further analysis. In our case this UC is only partly completed, as the communication with the tool via it’s nonstandard Modbus implementation has not yet been established due to complications and is expected to be completed at the demonstration round 2.

Description of Activities

The primary objective of this phase was to ensure the ecoMonitor system could effectively monitor key AQI parameters and reliably transmit the data to the ecoPlatform for further analysis.

Key activities conducted during this phase included:

- **On-Device Monitoring:** Monitored critical AQI parameters, including CO, Ozone, SO_2, NO_2, PM2.5, PM10, temperature, and humidity in real time, to capture environmental conditions and ensure continuous air quality assessment.
- **Data Transmission Validation:** Data transmission validation has been postponed to the second round of validation, as this was not tested during the first demonstration phase.

Results and Observations

The monitoring process was successfully validated. During the first demonstration period, all AQI parameters were found to be within permissible limit. This outcome demonstrated the effective operation of the ecoMonitor platform in monitoring environmental parameters. Figure 65 illustrates a sample of the collected measurements.

Figure 65 Real time monitoring of air quality parameters Temperature (left) and SO2 (right).

MN_2UC1.2: Data processing and evaluation

The activities and results for MG_2UC1.2 will be documented and reported during the second round of the demonstration phase, where the transmission of the data will be integrated.

3.2.1.2 Gaidouromandra Microgrid

3.2.1.2.1 ecoMicrogrid

The first round of demonstration activities at the Gaidouromantra pilot site focused on validating key functionalities of the ecoMicrogrid system, as well as gathering data for refining the use cases associated with the deployment of the tool. This section details the activities performed.

MG_2UC1.1: Real time microgrid monitoring and data acquisition

The purpose of this use case was to showcase the real-time monitoring and data acquisition capabilities of the ecoMicrogrid tool at the Gaidouromantra site. The ecoMicrogrid system is designed to integrate various assets, allowing for enhanced observability of the energy resources. The demonstration focused on real-time data collection from energy meters, diesel generators, battery storage systems, and environmental sensors deployed within the microgrid.

The ecoMicrogrid system implements sophisticated Supervisory Control and Data Acquisition (SCADA) functionality, enabling operators to maintain continuous visibility of the microgrid's operational status. The **system monitors 161 variables in real-time from 21 physical devices**, providing extensive coverage of the microgrid's operations.

The SCADA interface comprises of four distinct operational screens, each serving specific monitoring and control functions:

Main Overview Screen: This screen is divided into three distinct parts (Figure 66):

- **Energy Balance and SOC**: This section provides a summary of the overall energy balance of the microgrid, including the state of charge (SOC) of the storage devices. Operators can view the net energy flows of the system with indicative arrows.
- **Single-Line Diagram**: A graphical representation of the microgrid's distribution network, showing the integrated assets such as photovoltaic (PV) systems, generators, and meters. Real-time operational data, including voltage, current, and power, is displayed alongside each asset for immediate insight. The direction of the power flow is depicted with arrows.
- **Environmental Data**: Real-time measurements of environmental conditions, including solar irradiance, wind speed and direction, and temperature, are presented in this section.

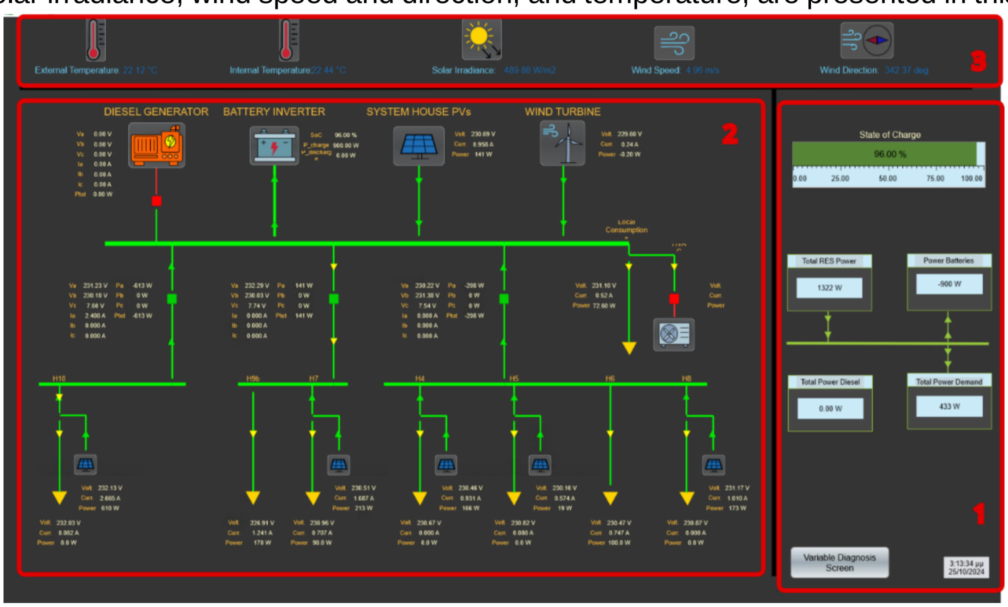


Figure 66 Main Landing Screen is divided into three distinct parts: 1) Energy Balance and SOC section, 2) Single-Line diagram of distribution network section, 3) Environmental data section.

Control Screens: There are two specialized control screens (see Figure 67 and Figure 68):

- **Generator Control Screen**: This screen allows operators to manage and monitor the diesel generator, providing detailed operational data and controls for starting and stopping the generator as needed.
- **HVAC Control Screen**: A dedicated control interface for managing the Heating, Ventilation, and Air Conditioning (HVAC) system, offering real-time operational parameters and control functionalities.

Figure 67 Generator Control Screen

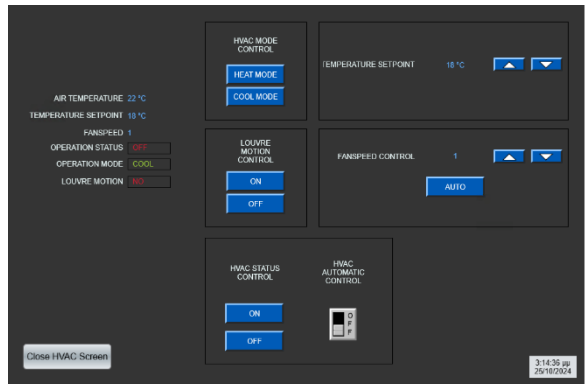


Figure 68 HVAC Control Screen

Debug Screen (Variable Diagnosis): This screen is used for diagnosing issues within the system. It provides access on system variables for troubleshooting and maintenance (Figure 69).

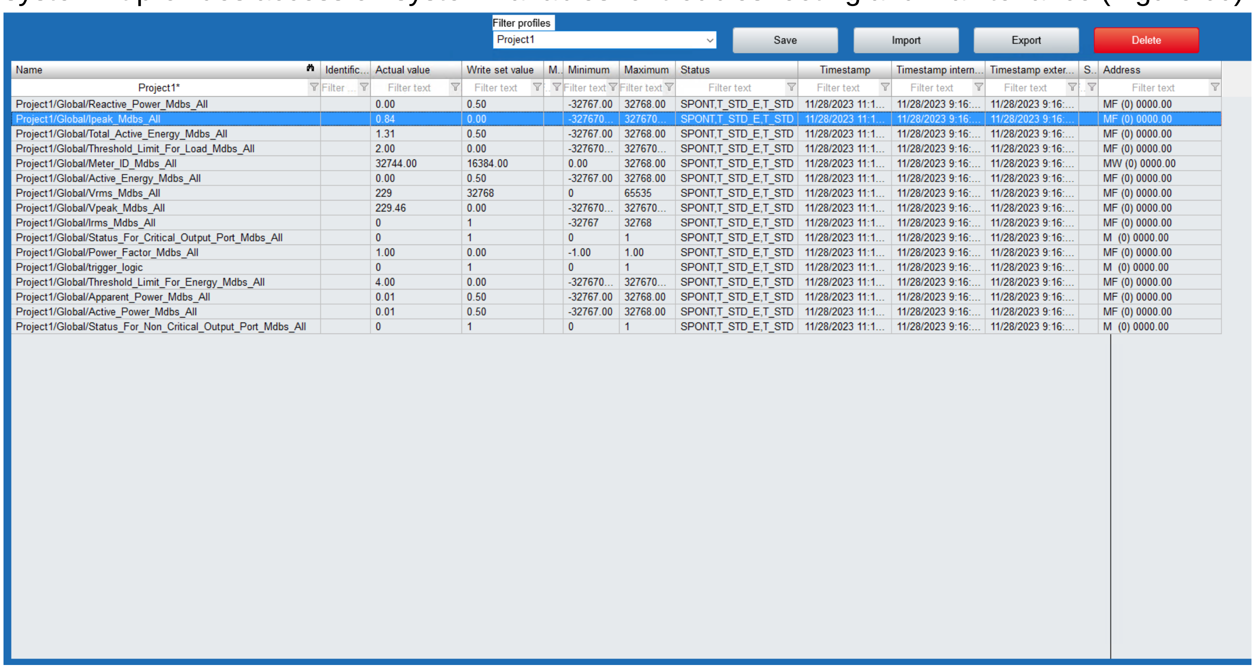


Figure 69 Variable Diagnosis debug screen.

Demonstration Activities:

The use case validation encompassed several key activities to verify the system's capabilities:

- **System Data Integration**: Successfully integrated multiple asset types, smart energy meters, diesel generator, photovoltaic systems, and battery storage systems.
- **Monitoring and Data Acquisition**: Real-time monitoring of electrical parameters, such as voltage, current, active power, from all energy assets.
- Environmental Data Integration: The inclusion of real-time environmental data enabled operators to assess how external conditions influenced the microgrid's performance, particularly the PV systems and wind turbine.

Summary of Results:

The demonstration effectively validated the ecoMicrogrid system's ability to:

- **Reliably Monitor Integrated Assets in Real-Time**: The system consistently provided real-time updates from all assets, ensuring operators had continuous visibility into the microgrid's status.
- **Ensure Accurate and Timely Data Acquisition**: Data collected from energy meters, generators, and environmental sensors was precise and updated in near real-time, supporting reliable monitoring and decision-making.
- **Maintain Stable Communication Across All Devices**: Facilitated robust and stable connections with each asset, ensuring that data flow remained uninterrupted throughout the demonstration.

MG_2UC1.2: RES production estimation

The activities and results for MG_2UC1.2 will be documented and reported during the second round of the demonstration phase.

MG_2UC1.3: Data concentration, storage, and management

This use case demonstrates the data management capabilities of the ecoMicrogrid platform, focusing on the system's ability to concentrate, store, and manage large volumes of operational data from multiple microgrid assets. The implementation showcases advanced data handling features, including data collection, processing, storage optimization, and retrieval mechanisms.

Description of Activities

The primary objective was to validate the full data flow from field devices, through the Data Concentrator Module, and ultimately to the SQL Server database. Key activities during this phase included:

- **Data Collection Validation**: Ensured that data from field devices was collected consistently and reliably, with minimal data loss or delays.
- **Data Accuracy Checks**: Conducted accuracy tests to confirm that the data collected reflected real-time conditions and that any scaling or processing performed by the Data Concentrator Module was accurate.

- **Database Integration Verification**: Verified that the processed data was correctly written and organized according to the ecoMicrogrid data model [D4.1].

The demonstration phase aimed to validate the ecoMicrogrid system's complete data handling process, from data capture at field devices through to organized storage in the SQL Server database. Figure 70 illustrates this data flow, highlighting the stages in which each system component plays a role:

1. **Field Device Data Collection**

Data collection begins with the **field devices** (e.g., smart energy meters, generators, environmental sensors) that monitor various microgrid parameters. These devices continuously measure data points, including energy consumption, generation levels, and environmental conditions. Each device is connected to the system's **Data Concentrator Module** using stable Modbus TCP protocols, ensuring precise data capture at defined sampling rates.

2. **Data Concentrator Module**

The **Data Concentrator Module** (highlighted in the flow diagram) acts as the central data aggregator, collecting information from each field device. Here, data is scaled, processed, and prepared for storage, ensuring that only relevant, calibrated information is passed to the database. During the demonstration, this module was tested for processing accuracy, sampling rate adherence, and real-time communication stability with all connected devices.

3. **Data Transmission and Protocol Stability**

Once processed, data is transmitted from the Data Concentrator Module to the **SQL Server database** using a secure communication protocol. This phase was rigorously tested to confirm that data packets maintained their integrity during transmission, minimizing delays or loss.

4. **SQL Server Data Storage and Organization**

The **SQL Server database** is the ecoMicrogrid system's designated storage location, responsible for storing all collected data in an organized, relational format. During testing, each data point was validated for accuracy and integrity upon entry, ensuring it met storage requirements and could be easily retrieved for analysis. This final step confirms data availability for ecoMicrogrid's operational insights, system optimization, and historical analysis.

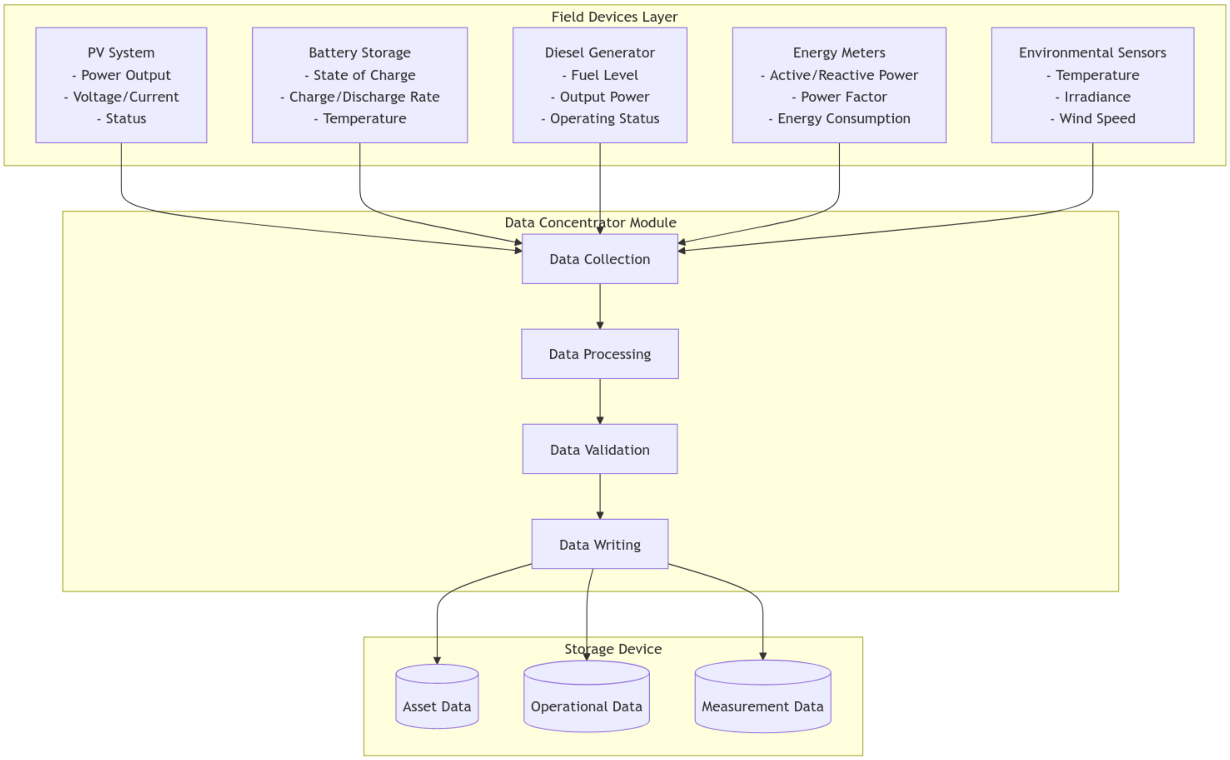


Figure 70 A hierarchical diagram showing the flow of data.

Summary of Results:

- **Reliable and Comprehensive Data Aggregation**: Real-time and historical data from all microgrid assets are centralized without loss or corruption, ensuring a complete dataset is available for analysis.
- **Secure and Scalable Data Storage**: The system effectively stores both short-term and long-term data, supporting on-demand access for real-time monitoring and in-depth analysis over extended periods.
- **Efficient Data Management**: Data retrieval is streamlined, and operators have access to organized data for performance tracking, diagnostics, and optimization of the microgrid. This supports data-driven decision-making and enhances the overall efficiency of microgrid operations.

Demonstration Summary

During the demonstration phase, the ecoMicrogrid system demonstrated effective data handling capabilities, with the Data Concentrator Module and SQL Server proving their ability to manage and store vast datasets efficiently. The storage device logged over **161 million measurement records**, capturing real-time data from all monitored microgrid assets. Additionally, the system recorded substantial amounts of application data essential for operational management and forecasting, including records from forecast modules, demand-side management (DSM) modules, pricing, and EMS module.

Figure 72 illustrates the number of entries per table within the SQL Server database, highlighting the distinction between measurement data (depicted in red) and application/system control data (shown in blue).

	Timestamp	AssetID int	MeasPropertyID int	NumericValue float
	Filter	Filter	Filter	Filter
1	2024-09-28 08:02:36	17	17 ActivePowerB	110
2	2024-09-28 08:02:36	17	5 CurrentB	0.945
3	2024-09-28 08:02:36	17	1 TotalActivePower	110
4	2024-09-28 08:02:36	16	18 ActivePowerC	0
5	2024-09-28 08:02:36	16	7 VoltageA	232.81
6	2024-09-28 08:02:36	16	6 CurrentC	0
7	2024-09-28 08:02:36	16	5 CurrentB	0
8	2024-09-28 08:02:36	16	4 CurrentA	8.85
9	2024-09-28 08:02:36	16	1 TotalActivePower	-2036
10	2024-09-28 08:02:36	15	18 ActivePowerC	0
11	2024-09-28 08:02:36	15	17 ActivePowerB	0
12	2024-09-28 08:02:36	15	9 VoltageC	6.18
13	2024-09-28 08:02:36	15	7 VoltageA	232.51
14	2024-09-28 08:02:36	15	6 CurrentC	0
15	2024-09-28 08:02:36	15	5 CurrentB	0
16	2024-09-28 08:02:36	15	1 TotalActivePower	33
17	2024-09-28 08:02:36	14	17 ActivePowerB	0
18	2024-09-28 08:02:36	14	16 ActivePowerA	-129
19	2024-09-28 08:02:36	14	9 VoltageC	6.23
20	2024-09-28 08:02:36	14	8 VoltageB	229.85
21	2024-09-28 08:02:36	14	7 VoltageA	231.47

Figure 71 Snapshot of the Measurement data table illustrating stored numeric values from various assets.

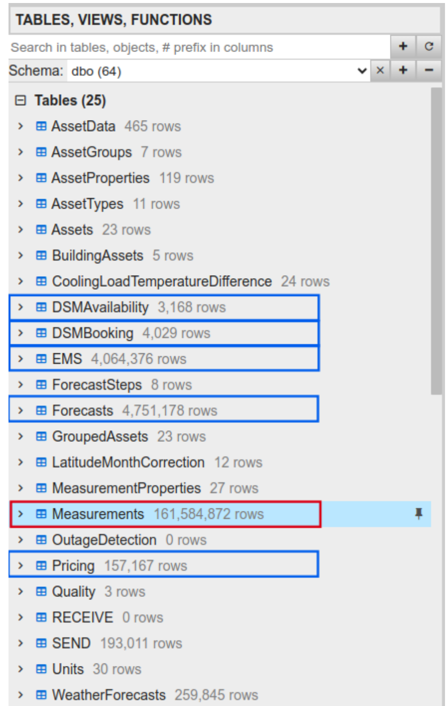


Figure 72 Summary of SQL tables that highlights the number of records per table. In red the measurement data table. In blue the application/system control data tables.

MG_2UC2.1: Effective communication with controllable assets

The MG_2UC2.1 use case focuses on establishing reliable communication between the ecoMicrogrid platform and controllable assets within a microgrid environment. This phase of the project emphasizes the validation of data flow to vital components, specifically the diesel generator and HVAC systems.

Description of Activities

The primary objective of this phase was to validate the comprehensive data flow from the ecoMicrogrid platform to controllable assets, ensuring that operational set points and associated data are effectively communicated to and actuated by the diesel generator and HVAC systems.

Key activities conducted during this phase included:

- **Set Point Validation**: Verified that operational set points generated by the optimization module of ecoMicrogrid were accurately transmitted to the data concentrator, which relays this information to the relevant devices.
- **Data Accuracy Checks:** Performed accuracy tests to ensure that data dispatched to the data concentrator was appropriately scaled to meet device specifications and confirmed the correctness of any processing undertaken by the Data Concentrator Module.
- **SCADA Control Functionalities Verification:** Conducted thorough verification of the functionalities offered by the custom-designed Supervisory Control and Data Acquisition (SCADA) interfaces for Generator Control and HVAC Control.
- **Set Point Assessment:** Ensured that processed data was effectively implemented by the devices, verifying that they responded appropriately to the operational set points received from the ecoMicrogrid platform.

Demonstration Summary

During the demonstration phase, the ecoMicrogrid successfully controlled the operations of both the diesel generator and the HVAC systems. This phase yielded critical data that facilitated the comprehensive validation of the tool, conducted at UC MG_2UC2.3 during the second validation period.

MG_2UC2.3: Multi-energy vector microgrid management of operation

The activities and results for MG_2UC1.2 will be documented and reported during the second round of the demonstration phase, where the optimization algorithms and associated performance metrics will be fully evaluated.

3.2.1.2.2 ecoDR

The ecoDR tool has been installed at the system house of Gaidouromantra to interface with the flexible load of the Heating Ventilation and Air Conditioning (HVAC) system. This installation is designed to monitor the energy consumption of the flexible load and support the start/stop functionality of the flexible load.

DR_2UC1.1: Real time monitoring of energy consumption

The DR_2UC1.1 use case focuses on validating the monitoring capabilities of the ecoDR tool by providing real-time energy consumption data. This data should be accessible through both the local display screen and the Modbus TCP interface. The ecoDR system includes a display unit for real-time visualization of energy measurements, while the Modbus TCP interface enables external acquisition of energy parameters for further analysis. In our case this UC is only partly completed, as the communication with the tool via it’s nonstandard Modbus implementation has not yet been established due to complications and is expected to be completed at the demonstration round 2.

The primary objective of this phase is to ensure the ecoDR system effectively monitors energy-related parameters and validates its Modbus TCP interface.

Figure 73 ecoDR installed in Gaidouromantra

Figure 74 The display of ecoDR in Gaidouromandra

Demonstration Summary

The demonstration of the ecoDR tool at the Gaidouromantra system house successfully validated its real-time energy monitoring capabilities. The tool's display unit provided accurate real-time visualization of energy consumption data for the HVAC system's flexible load. Communication with the tool via it's Modbus implementation has not yet been established and will be assessed at the demonstration round 2.

3.2.1.2.3 ecoPlatform

PT_2UC2.1: Facilitate data exchange between dependent tools

During the demonstration, ecoPlatform played a critical role in facilitating seamless data exchange between various dependent tools. These tools included energy management systems, real-time monitoring modules, and load forecasting algorithms. The platform ensured that data, such as energy production, battery storage levels, and consumption patterns, flowed efficiently between the tools in real time. This enabled the microgrid to respond dynamically to changes in energy demand and supply, optimizing resource allocation and improving overall grid performance.

RabbitMQ™ RabbitMQ 3.12.2-beta.1 Erlang 25.3.2.3

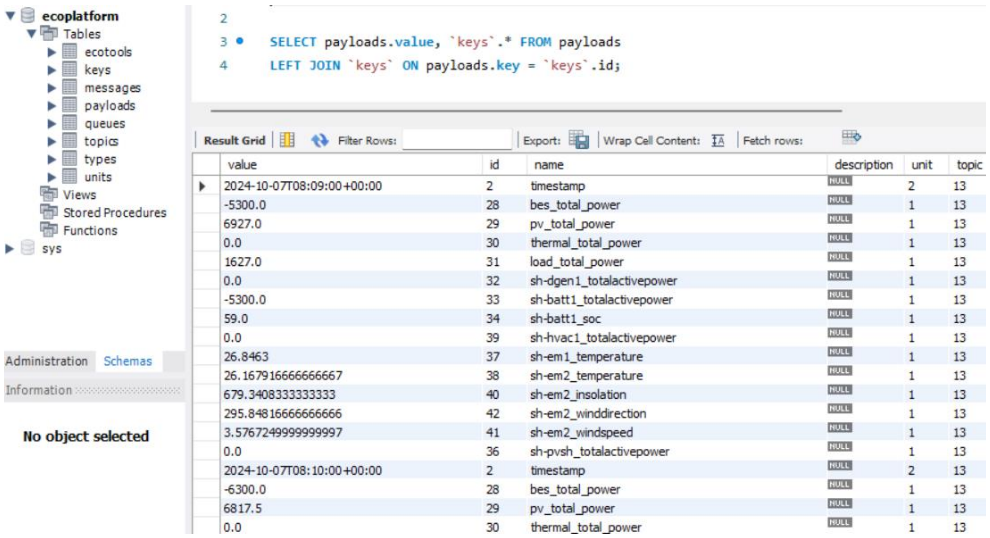
Overview | Connections | Channels | Exchanges | **Queues and Streams** | Admin

Overview					Messages		
Virtual host	Name	Type	Features	State	Ready	Unacked	Total
reEmpowered	ecoCommunity	classic	D TTL	idle	0	0	0
reEmpowered	ecoCommunity/available	classic	D TTL	idle	0	0	0
reEmpowered	ecoCommunity/booked	classic	D TTL	idle	0	0	0
reEmpowered	ecoEMS	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid/forecasts	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid/realtime	classic	D TTL	idle	0	0	0
reEmpowered	ecoMonitor	classic	D TTL	idle	0	0	0
reEmpowered	ecoPlanning	classic	D TTL	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959792974qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959798084qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959842770qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959859051qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558960071124qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558960076301qos1	classic	D Excl	idle	0	0	0

Figure 75 Queues for data exchange between dependent tools

PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database

In this use case, ecoPlatform routed vital data from the microgrid and its dependent tools to a secure cloud database. Real-time data from energy generation units, consumption points, and storage systems were continuously transmitted to the cloud for archiving and future analysis. The cloud storage solution ensured that critical energy system data was available for long-term studies, improving energy management decisions and system optimization.



value	id	name	description	unit	topic
2024-10-07T08:09:00+00:00	2	timestamp	NULL	2	13
-5300.0	28	bes_total_power	NULL	1	13
6927.0	29	pv_total_power	NULL	1	13
0.0	30	thermal_total_power	NULL	1	13
1627.0	31	load_total_power	NULL	1	13
0.0	32	sh-dgen1_totalactivepower	NULL	1	13
-5300.0	33	sh-batt1_totalactivepower	NULL	1	13
59.0	34	sh-batt1_soc	NULL	1	13
0.0	39	sh-hvac1_totalactivepower	NULL	1	13
26.8463	37	sh-em1_temperature	NULL	1	13
26.167916666666667	38	sh-em2_temperature	NULL	1	13
679.3408333333333	40	sh-em2_insolation	NULL	1	13
295.8481666666666	42	sh-em2_winddirection	NULL	1	13
3.5767249999999997	41	sh-em2_windspeed	NULL	1	13
0.0	36	sh-pvsh_totalactivepower	NULL	1	13
2024-10-07T08:10:00+00:00	2	timestamp	NULL	2	13
-6300.0	28	bes_total_power	NULL	1	13
6817.5	29	pv_total_power	NULL	1	13
0.0	30	thermal_total_power	NULL	1	13

Figure 76 Data from dependent tools to cloud database

PT_2UC3.2: Facilitate archived data access for dependent tools using API

The ecoPlatform in the microgrid enabled dependent tools to retrieve archived data efficiently through an API. This functionality allowed various tools, such as energy management systems and forecasting algorithms, to access historical microgrid data, including energy consumption, generation, and storage metrics. The API-based data retrieval was critical in ensuring that these tools had real-time access to the historical data they needed without manual intervention, thereby improving the accuracy and responsiveness of the energy management processes.

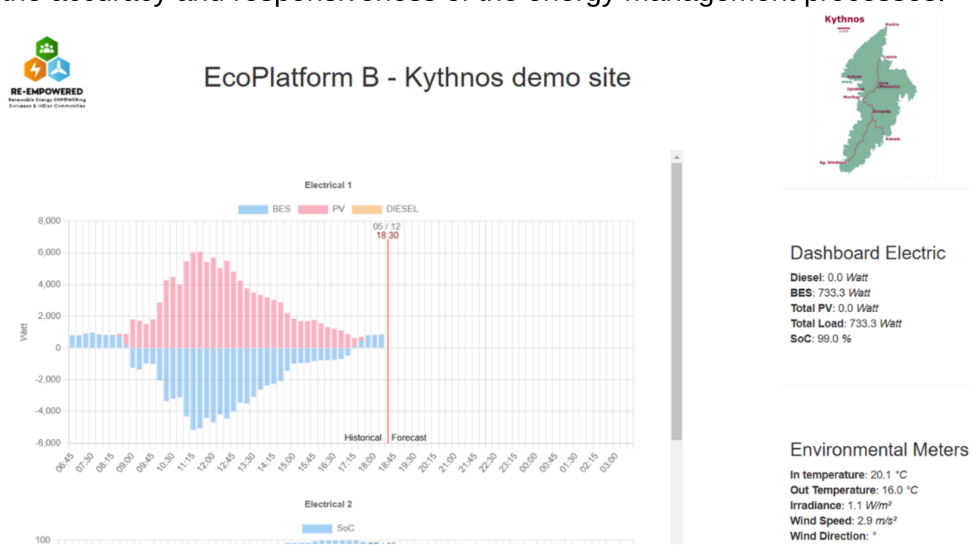


Figure 77 ecoPlatform – B dashboard in Kythnos via API

3.2.1.2.4 ecoCommunity

The first round of demonstrations of the ecoCommunity tool in Gaidouromandra demo site was conducted on 8th October 2024. The various use cases demonstrated are described below.

CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile

The use case aimed to display dynamic pricing information. The screenshots of the pricing module are shown below.

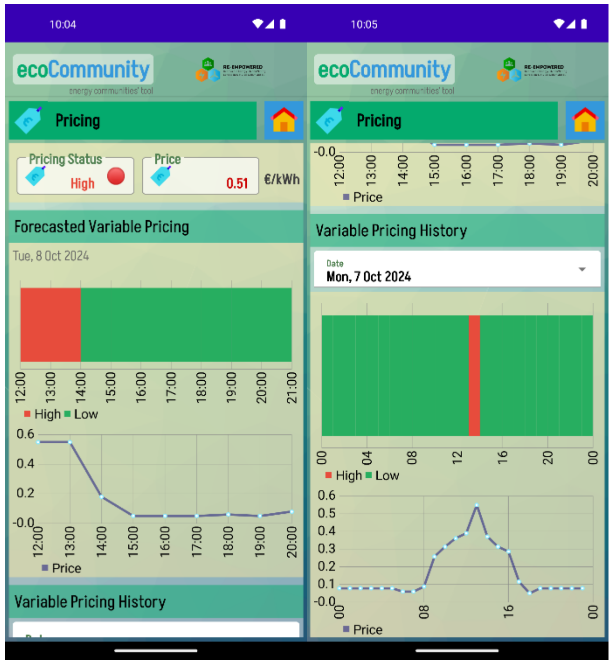


Figure 78 Screenshots of ecoCommunity Dynamic Pricing Module for Gaidouromandra demo site: (Left) Forecasted pricing for next set of hours. (Right) pricing variation during the previous day

A red-green pricing band indicates the high-low forecasted pricing for the following hours. The forecast is updated every hour based on the data received from ecoMicrogrid. It provides consumers with an indication of whether or not they should use the noncritical loads. The module aims for voluntary control over the consumption of the consumers, so that the energy system stays stable and efficient.

CM_2UC1.3: Data security and privacy

The data security and privacy are considered as important requirement for the tool. The access to the tool is restricted through username and password. The user will have to enter the login credentials when they are using the tool on a new device.

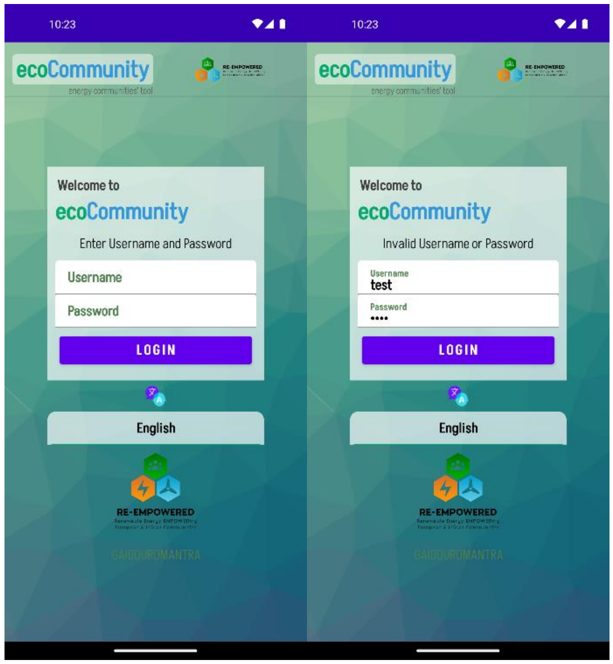


Figure 79 Screenshots of ecoCommunity login page for Gaidouromandra demo site (Left) login page (Right) error message for invalid credentials

The user can change the login password anytime from the user profile if they feel that their password has been compromised. Apart from that, any read/write to the cloud database is also restricted with authentication. This avoids access or corruption of the cloud database through external sources.

A privacy and information statement and consent form are displayed on the tool interface when a new user logs in to the tool for the first time.

The user access is managed by the demo site administrator using the Users modules. The module lists all the users in the demo site and is able to control the access of the users.

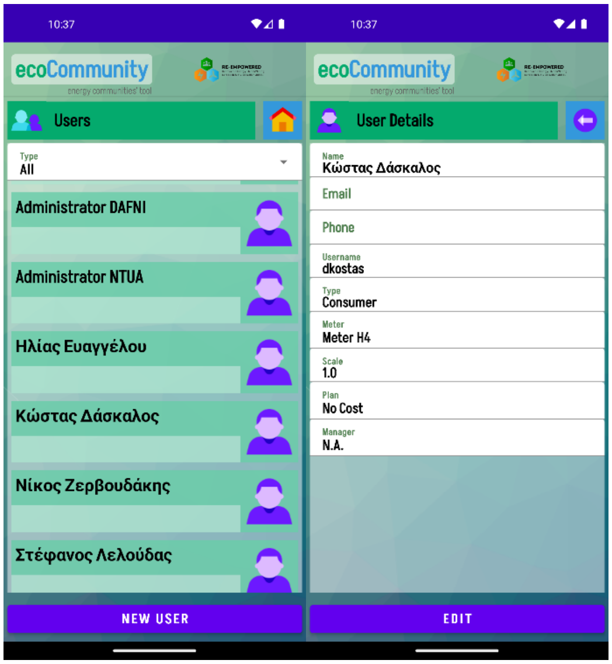


Figure 80 Screenshots of ecoCommunity user module for Gaidouromandra demo site (Left) list of users (Right) user details

A total of four consumers and two administrators were included to the tool user database during the first round of demonstration.

CM_2UC2.1: Facilitating (display) of the scheduling and shifting of non-critical and flexible loads

The use case was demonstrated by indicating a set of time slots which can be booked by the consumers for the use of noncritical consumer loads. In case of Gaidouromandra the consumers utilized this facility to book time slots for the use of water pumps based on the available energy The screenshots of the booked time slot from the consumer user interface and the increase in energy consumption during that period are shown in the following screenshots.

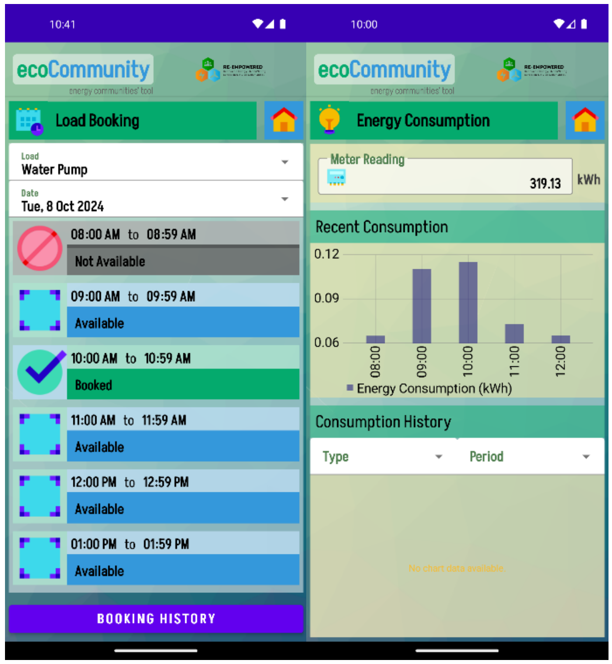


Figure 81 Screenshots of flexible load booking use case in Gaidouromandra demo site: (Left) consumer interface showing the booking details. (Right) consumer consumption during the booked period

The administrator user manages the creation of the time slots based on the availability data received from ecoMicrogrid and the booking summary is sent back to ecoMicrogrid at the end of the day. The following screenshot shows the booking summary page from administrator user.

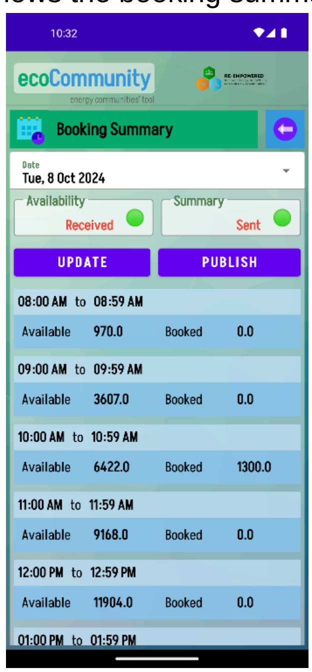


Figure 82 Screenshots of flexible load booking summary page in Gaidouromandra Demo site

The screenshot indicates that the data on availability and the booking summary is successfully sent and received for the date. The available energy and booked energy for each time slot is also displayed.

CM_2UC3.1: Feedback and suggestions from users about the tools

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.2: Reporting of problem

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.3: Forum to share experiences

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC4.1: Training material (troubleshooting)

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)

Manuals and help materials are added to the tool which can provide guide to the various tool users and demo site administrators.

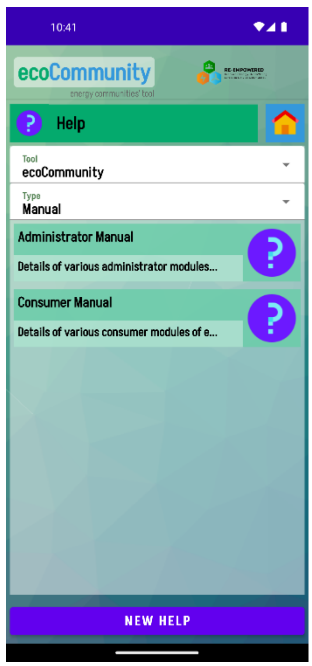


Figure 83 Screenshots of help module in Gaidouromandra demo site

CM_2UC5.1: Monitoring of electricity consumption of energy consumers

The energy consumption of the consumers can easily be monitored by recent, daily or monthly consumption information in the consumption module.

Figure 84 Screenshots of consumption module in Gaidouromandra demo site (Left) cumulative reading and recent consumption (Center) daily consumption of selected month (Right) monthly consumption of selected year

3.2.1.2.5 ecoResilience

RS _2UC3.1: Testing of Small Wind Turbines using Standards

The small wind turbine manufactured locally under the ecoResilience tool, was tested in the Gaidouromandra microgrid using guidelines from the IEC international standard IEC 61400-12-1: “Power Performance Measurements of electricity producing wind turbines”, and specifically from Annex H, which refers to small wind turbine testing. With the use of these guidelines the recorded electrical and meteorological data were used to plot the small wind turbine’s power curve, to calculate the wind energy conversion system’s power coefficient Cp and to predict the annual energy production of the small wind turbine for different mean wind speeds. Furthermore, the appropriate installation of the meteorological and electrical sensors was directed by the standard, along with the appropriate manner of analyzing logged data, and estimating uncertainties.

For the collection of the necessary meteorological data an NRG-40C anemometer and an NRG-200P wind vane were used. The anemometer was used for measuring wind speed and correlating it to associated electrical power measurements, while the wind vane was used to verify the appropriate measuring sectors and so discard data from others. The positioning of the sensors was specified in the IEC 61400-12-1 standard, while the vertical positioning of the anemometer was determined by the rotor diameter of the small wind turbine under test. For the collection of the necessary electrical power data, the ecoMicrogrid infrastructure was used.

Figure 85 shows a scatter plot of the logged data, for 10 second intervals, displaying values of AC power versus wind speed. From these, 1-minute averages are calculated, and the results are binned per 0.5 m/s. The resulting power curve is displayed in Figure 86. As can be seen, the data around the rated conditions of the small wind turbine, i.e. close to 10 m/s, are limited, and for this reason the binned power averages display large deviations between consecutive wind speeds.

To calculate power performance indicators of the small wind turbine, such as the wind energy conversion system's power coefficient and the annual energy production of the small wind turbine, a more refined data set is required. For this to be achieved, more data collection campaigns need to perform, until the data set has enough data points so as to produce consistent binned 1-minute averages, especially in areas of interest, such as the rated wind speed region.

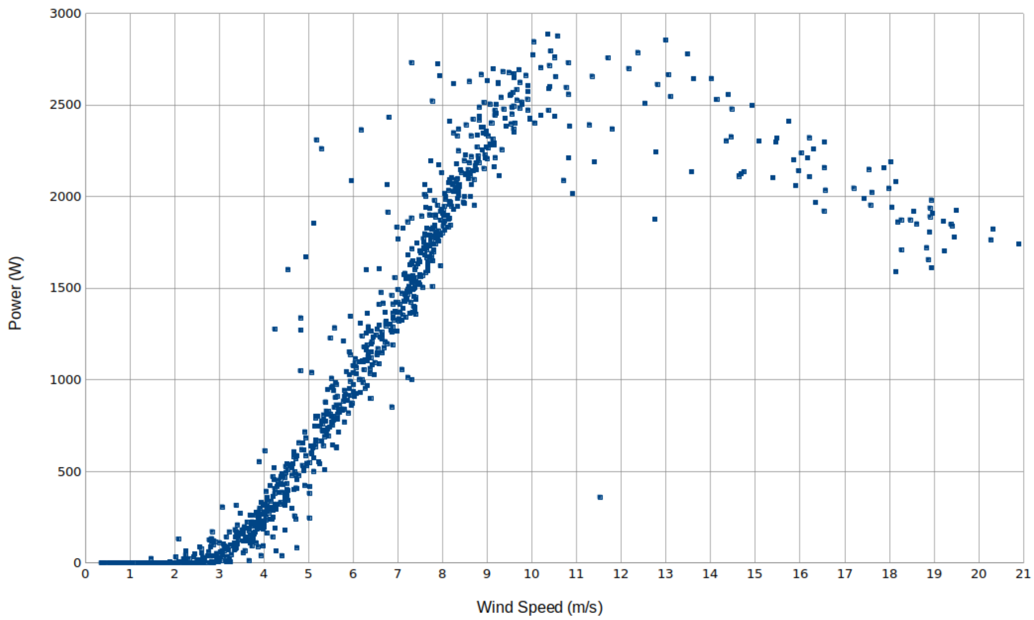


Figure 85 Logged data of AC power produced by the locally manufactured wind turbine at different wind speeds

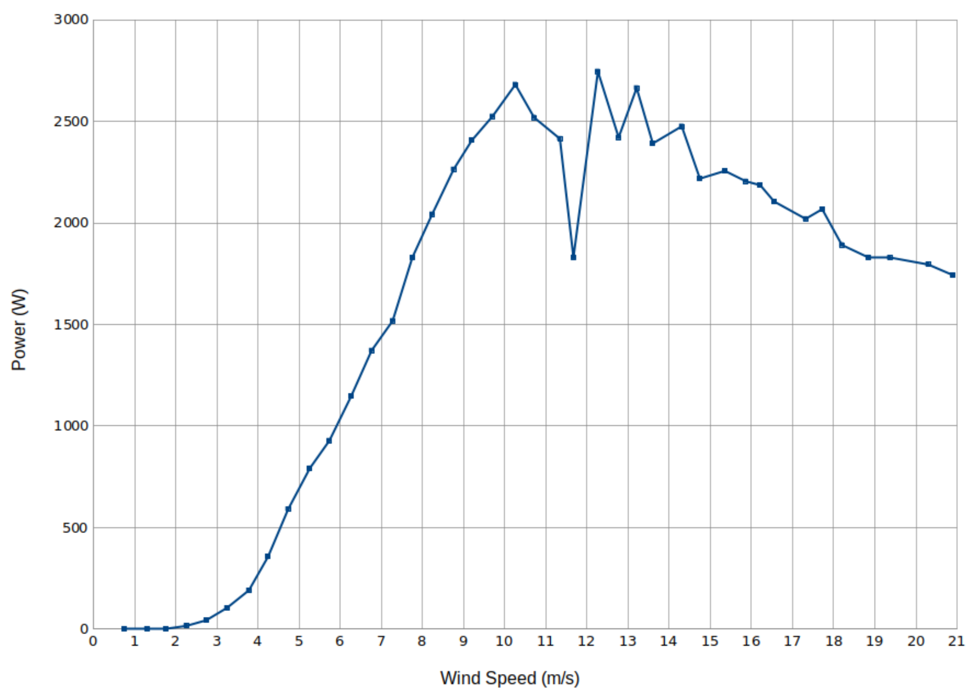


Figure 86 Power curve of the locally manufactured wind turbine derived from the scatter data

3.2.2 List of adaptations for demonstration round 2

3.2.2.1 Kythnos Power system

According to the results of ecoEMS during the demonstration round 1, the adaptation that needs to be done in order to prepare it for the final demonstration round 2 and the export of the KPIs, is to analyze and use an error message with its description, in case some communication fails, and the execution of the simulation is impossible. Concerning ecoPlanning, due to technical bugs of the front end, the use cases PN_2UC3.1, PN_2UC3.2 were not thoroughly assessed in the scope of the demonstration round 1 and will be examined analytically at the demonstration round 2. Also, at demonstration round 2, the RE-EMPOWERED logo will be included in the output graphs.

3.2.2.2 Gaidouromandra Microgrid

To ensure the seamless operation and reliability of the ecoMicrogrid system for Demonstration Round 2, several adaptations and debugging efforts were undertaken. These adaptations addressed issues identified during the first demonstration round, ranging from communication errors to operational challenges with key assets. The following section outlines the key improvements implemented to enhance system functionality, optimize performance, and resolve any technical inconsistencies.

- **Register Mapping Errors**: During the initial deployment, multiple errors were detected in the register mapping of connected devices. These errors caused discrepancies in data readings and hindered the seamless communication between ecoMicrogrid and various microgrid assets.
- **Assignment Errors**: A house in the system was erroneously assigned to the wrong individual, leading to mismatches in ecoCommunity visualisation. The resolution required revisiting the database records and reassigning the house to the correct owner.
- **Critical Issue in DG Control**: One of the most significant issues identified was the inability of the DG to respond to start/stop setpoints through its Modbus interface, making automated control unfeasible. As a workaround, the physical open/close contact of the DG was utilized, which is typically used for manual start/stop operations. To streamline this process and integrate it into the automated system, the RTAC was programmed to act as an intermediary. The RTAC’s analog ports were used to drive a low-voltage relay for controlling the DG's start/stop function. This functionality was then exposed as Modbus registers, allowing it to align seamlessly with the existing configuration of the ecoMicrogrid system.

  Concerning ecoPlatform, the debugging Process concerned the following aspects:
  - Communication Delays between dependent tools were identified and addressed by optimizing data exchange protocols.
  - API Stability was improved to enhance response times for archived data retrieval.
  - Cloud Data Transmission issues were resolved by strengthening network stability and failover mechanisms.
  - Error Logging was enhanced to streamline problem detection and resolution.

  The list of adaptations for ecoPlatform follows:

- Improved Data Exchange (PT_2UC2.1): Optimized communication algorithms reduced latency in real-time data sharing between ecoTools.
- Enhanced Data Routing to Cloud (PT_2UC3.1): Improved reliability of cloud data transmission through better network redundancy and stability measures.
- Optimized API for Archived Data (PT_2UC3.2): Enhanced caching and retrieval processes for faster, stable access to archived data.
- Scalability Enhancements: Adaptations were made to handle larger datasets and increased tool integration.
- Security Features: Strengthened encryption and secure authentication for data transmission and API access.
- Customizable Dashboards: Added flexibility for operators to visualize and monitor real-time and archived data.
- Tool Integration Debugging: Resolved compatibility issues between ecoPlatform and other ecoTools.

3.3 Ghoramara

3.3.1 Report of the demonstration round 1 activities

This section presents the status of the use cases for the Ghoramara demo-site.

3.3.1.1 ecoMicrogrid

MG_2UC1.1: Real time microgrid monitoring and data acquisition

This use case in Ghoramara highlights the real-time monitoring and data acquisition capabilities of the ecoMicrogrid tool at the pilot site. The demonstration showcased feasibility of data collection from energy meters interfacing the ecoConverter, photovoltaics, wind turbine and battery storage units.

The ecoMicrogrid SCADA interface designed to include all the collected data into the main operational screen (Figure 87):

- **Battery Storage Monitoring**: Offers real-time insights into the battery's state of charge estimation, DC voltage, current measurements, and total battery power status.
- **Solar Photovoltaic Monitoring**: Enables real-time tracking of PV active power generation. It also monitors energy export to evaluate solar performance and contribution to the grid.
- **Wind Turbine Monitoring**: Provides real-time data on turbine performance, including active power generation, and monitors energy exported to the grid, ensuring seamless integration with the microgrid system.
- **Load Monitoring**: Provides a detailed breakdown of active and reactive power across all three phases at grid-side, including energy consumption and energy exported back to the grid., total power consumption, system frequency, and overall power factor. Individual meter data is aggregated to deliver a clear and uncluttered summary, focusing on critical metrics.

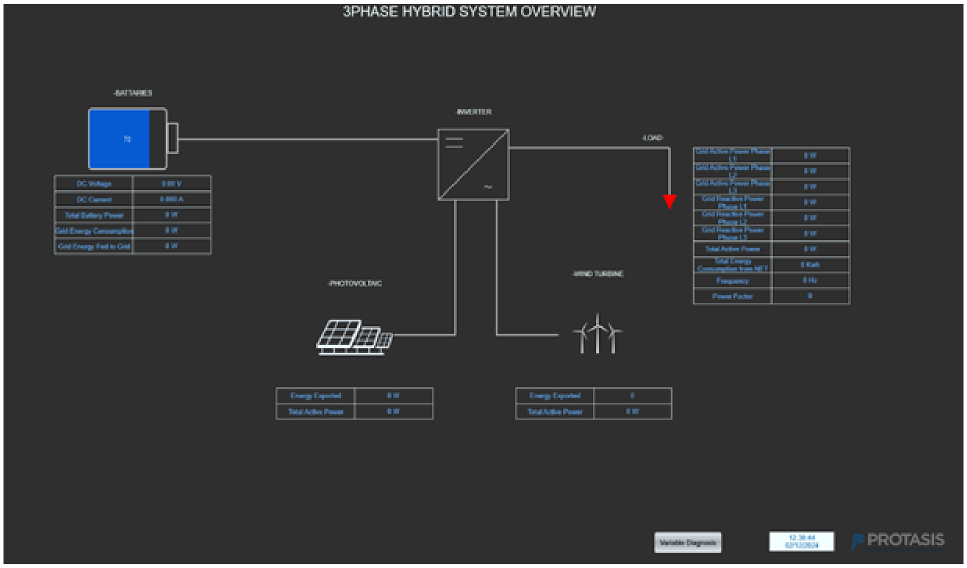


Figure 87 SCADA main screen of ecoMicrogrid instance at Ghoramara

Demonstration Activities:

The use case validation involved several activities to assess the system's functionality:

- **System Data Integration**: Validated the integration of data from actual installed meters, including three DC meters (PV, wind turbine, and battery) and the AC energy meter, ensuring seamless communication and accurate data acquisition.
- **Monitoring and Data Acquisition**: Verified that the real-time monitoring of electrical parameters such as voltage, current, and active power across all energy assets was accurately represented within the system.

Summary of Results:

The demonstration successfully validated the integration of the ecoMicrogrid system with the energy meters, ensuring that the system could communicate effectively with the connected devices. This milestone highlighted the functionality of the system in terms of data acquisition and system interaction. However, as the ecoConverter was not yet operational during the demonstration, certain critical aspects of data accuracy, such as the directionality of current flow and precise measurement validation, could not be thoroughly assessed. These validations are planned for subsequent phases once the ecoConverter is fully commissioned and integrated into the system.

MG_2UC1.3: Data concentration, storage, and management

The activities and results for MG_2UC1.3 will be documented and reported during Round 2 of the demonstration phase.

3.3.1.2 ecoDR

The ecoDR tool focuses on the development of advanced smart meters 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 loads. It incorporates advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities, allowing for efficient measurement of household energy consumption. Additionally, it communicates with ecoMicrogrid, to implement demand-side management services through non-critical load scheduling.

DR_2UC1.1: Real time monitoring of energy consumption

In this use case, the goal was the real time monitoring of accurate energy consumption data, to reduce inefficiencies and support sustainable energy practices. Specifically, ecoDR maintains log of events for important electrical parameters like Vpeak, Vrms, Ipeak, Irms, active energy, power factor, apparent power, and reactive power, along with timestamps and aims to transmit the time stamped data to ecoMicrogrid using MODBUS TCP with MBAP protocol via RJ45 cable.

The validation of this use case has been carried out by installing one ecoDR tool at the demo site and connecting the electrical appliances (such as lights and fans) of the high school as load. As can been seen in the below figure, the real time data of electrical parameters such as voltage, current, energy consumption are being monitored and displayed.

Figure 88 ecoDR (top left of the left picture) installed at Ghoramara and ecoDR monitoring load threshold data

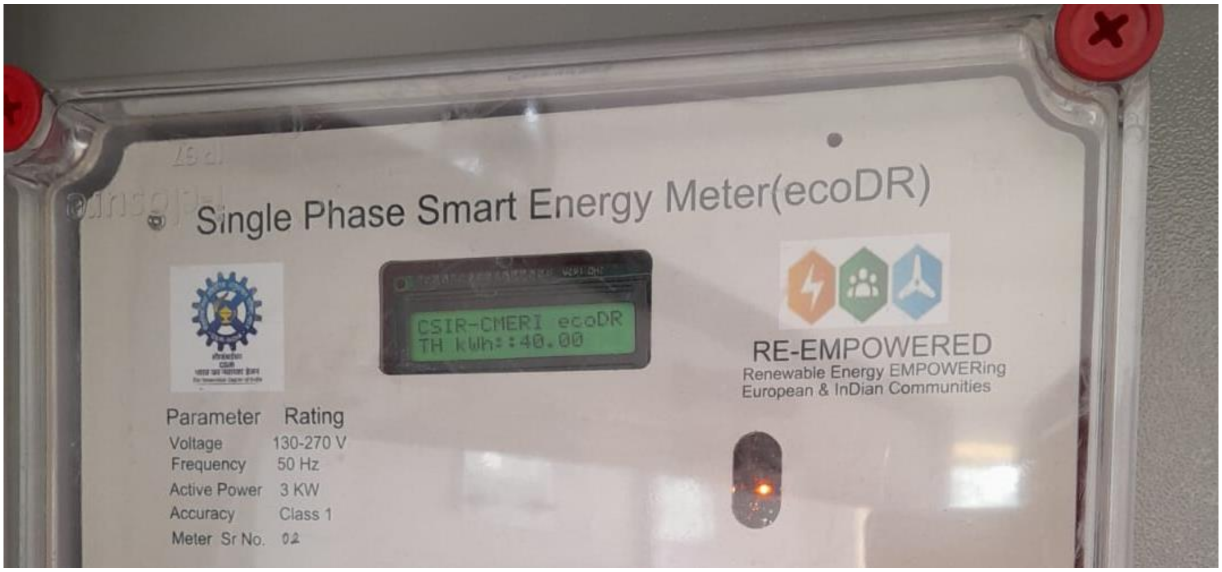


Figure 89 ecoDR monitoring energy consumption for connected load

DR_2UC2.1: Scheduling of loads

In this use case, the goal was to manage the non-critical loads through scheduling and control based on commands from the ecoMicrogrid.

This is being validated by issuing a load ON/OFF command to a load connected to the non-critical port of the ecoDR device. The command is sent from a PC emulating the ecoMicrogrid via MODBUS protocol. The figure below demonstrates that upon receiving load scheduling commands, such as a disconnect instruction, there is no energy consumption recorded for loads connected to the non-critical port.

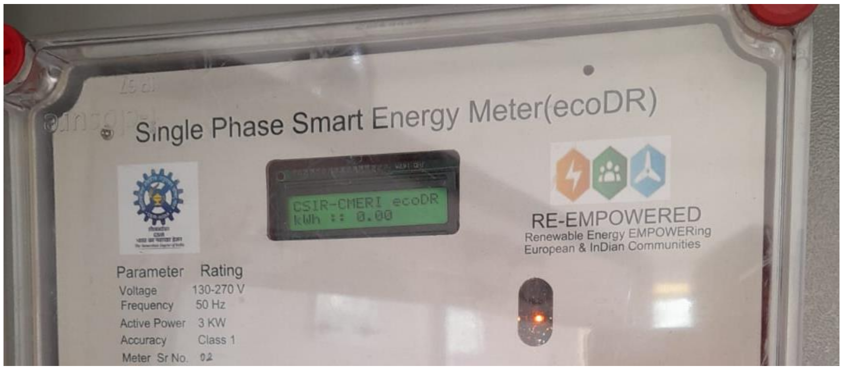


Figure 90 ecoDR demonstrating energy consumption (as nil) of non-critical load when load scheduling command received from ecoMicrogrid

The following table validates the status of non-critical load due to load scheduling commands received from ecoMicrogrid.

Sl no.	Command sent from PC via MODBUS	Status of the Critical Load	Status of the Non-critical Load
1.	Initial State	ON	ON
2.	Coil 1 set to 0	ON	OFF
3.	Coil 1 set to 1	ON	ON

Table 12 Validation for status of non-critical load due to load scheduling commands

DR_2UC2.2: Programmable Load shedding controller

In this use case, the objective was to implement localized load shedding when energy consumption surpasses a predefined threshold. Based on real-time measurements of the applied load, the system also disconnects the output supply to either the critical or non-critical port if the load exceeds the specified limit. This functionality ensures a balance between energy demand and supply by automatically disconnecting non-critical loads during energy shortages.

This functionality is validated by configuring various energy limit values, as shown in the table below. The table also highlights the corresponding energy readings from the ecoDR at which load shedding is triggered for each programmed energy threshold.

Sl no.	Energy limit value(kWh)	Load applied (kW)	Energy consumption allowed by meter for the day
1	0.450	Domestic loads such as lights, fans or combinations	0.454
2	2.6		2.603
3	3		3.004

Table 13 Validation of load cut off due to energy threshold

The following figure demonstrates the functionality of load disconnection during an overload condition. It shows that the load is disconnected when a 1.2 kW load is applied, exceeding the preset threshold of 1.1 kW at the non-critical port of the ecoDR.

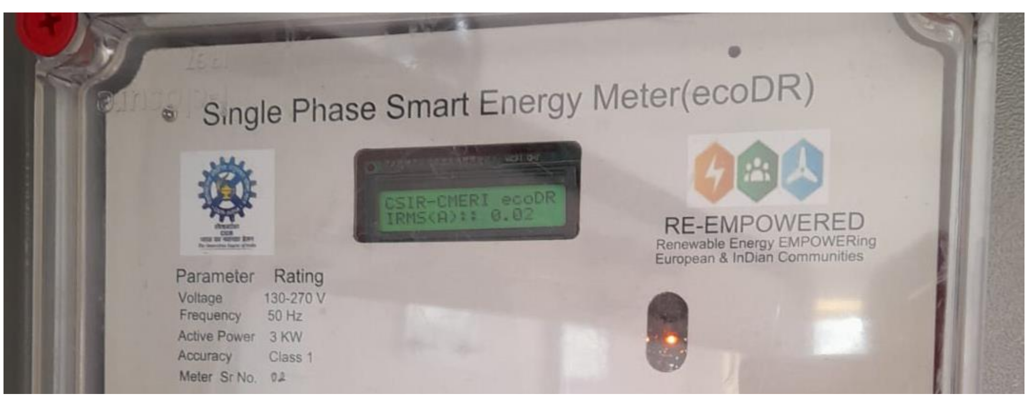


Figure 91 ecoDR demonstration load cut off in the event of overload conditions

3.3.1.3 ecoMonitor

ecoMonitor tool is essentially an air quality monitoring system equipped with multiple sensors and a digital control platform. It monitors the ambient air quality parameters in real time and provides useful insights regarding possible corrective actions of air quality parameters.

MN_2UC1.1: Acquisition and transmission of air quality parameters data

The objective of this use case was to monitor the air quality index (AQI) parameters data in real time and transmit the data to central control station for further analysis using MODBUS TCP with MBAP protocol via RJ45 cable. Specifically, key AQI parameters such as CO, Ozone, SO2, NO2 PM2.5 and PM10, temperature and humidity parameters are monitored in real time. The following figures demonstrate that most of the AQI parameters are within permissible limit; however, the PM 2.5 and PM10 reading exceeds the permissible value.

Figure 92 Real time monitoring of air quality parameters CO (left) and Ozone (right)

Figure 93 Real time monitoring of air quality parameters SO2 (left) and NO2 (right)

Figure 94 Real time monitoring of air quality parameters PM2.5 (left) and PM10 (right)

Figure 95 Real time monitoring of air quality parameters temperature (left) and humidity (right)

3.3.1.4 ecoPlatform

PT_2UC2.1: Facilitate data exchange between dependent tools

During the demonstration, ecoPlatform played a critical role in facilitating seamless data exchange between various dependent tools. These tools included energy management systems, real-time monitoring modules, and load forecasting algorithms. The platform ensured that data, such as energy production, battery storage levels, and consumption patterns, flowed efficiently between the tools in real time. This enabled the microgrid to respond dynamically to changes in energy demand and supply, optimizing resource allocation and improving overall grid performance.

RabbitMQ™ RabbitMQ 3.12.2-beta.1 Erlang 25.3.2.3

Overview | Connections | Channels | Exchanges | **Queues and Streams** | Admin

Overview					Messages		
Virtual host	Name	Type	Features	State	Ready	Unacked	Total
reEmpowered	ecoCommunity	classic	D TTL	idle	0	0	0
reEmpowered	ecoCommunity/available	classic	D TTL	idle	0	0	0
reEmpowered	ecoCommunity/booked	classic	D TTL	idle	0	0	0
reEmpowered	ecoEMS	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid/forecasts	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid/realtime	classic	D TTL	idle	0	0	0
reEmpowered	ecoMonitor	classic	D TTL	idle	0	0	0
reEmpowered	ecoPlanning	classic	D TTL	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959792974qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959798084qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959842770qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959859051qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558960071124qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558960076301qos1	classic	D Excl	idle	0	0	0

Figure 96 Queues for data exchange between dependent tools

PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database

In this use case, ecoPlatform routed vital data from the microgrid and its dependent tools to a secure cloud database. Real-time data from energy generation units, consumption points, and storage systems were continuously transmitted to the cloud for archiving and future analysis. The cloud storage solution ensured that critical energy system data was available for long-term studies, improving energy management decisions and system optimization.

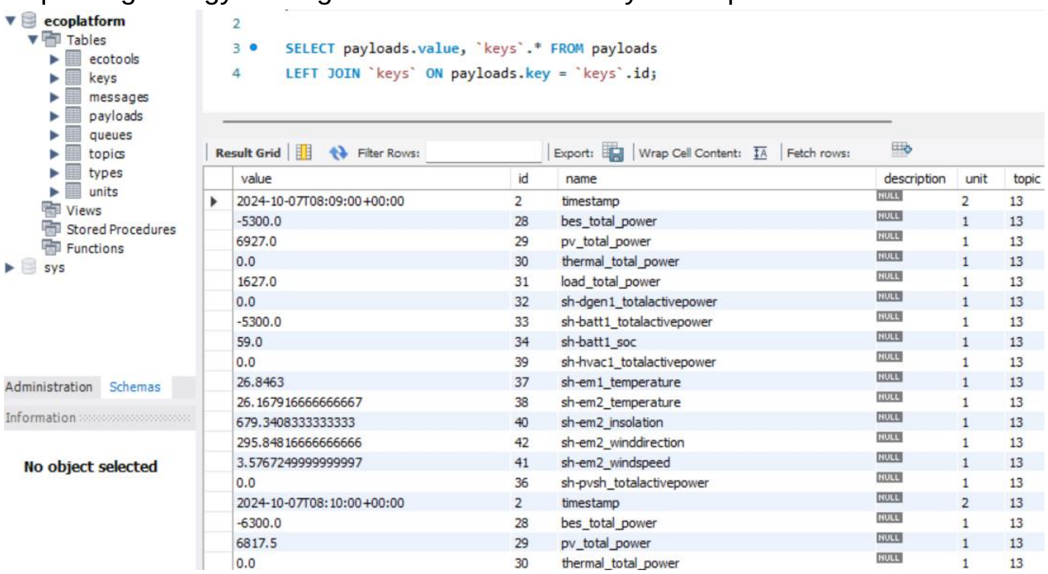


Figure 97 Data from dependent tools to cloud database

PT_2UC3.2: Facilitate archived data access for dependent tools using API

The ecoPlatform in the microgrid enabled dependent tools to retrieve archived data efficiently through an API. This functionality allowed various tools, such as energy management systems and forecasting algorithms, to access historical microgrid data, including energy consumption, generation, and storage metrics. The API-based data retrieval was critical in ensuring that these tools had real-time access to the historical data they needed without manual intervention, thereby improving the accuracy and responsiveness of the energy management processes.

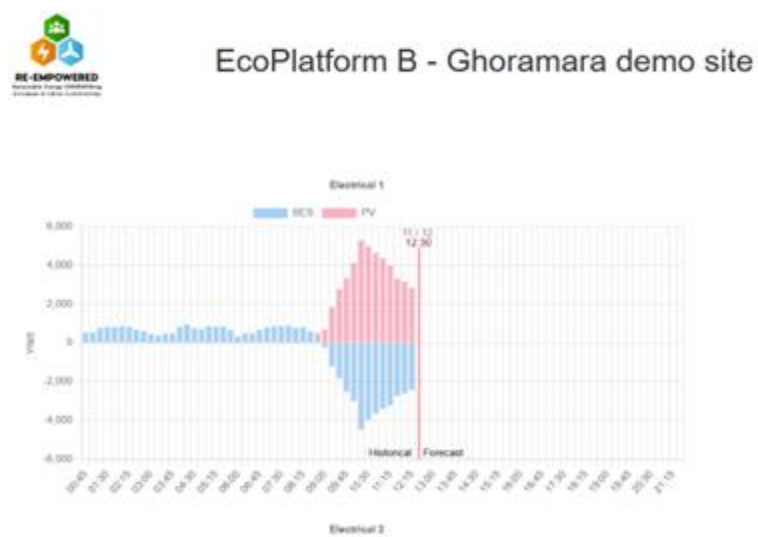


Figure 98 ecoPlatform – B dashboard in Ghoramara via API

3.3.1.5 ecoCommunity

The user page of the ecoCommunity app is shown here. Also in the login page of the app we have the option to choose the language. Three options are given: English, Hindi and Bengali (local language in Ghoramara).

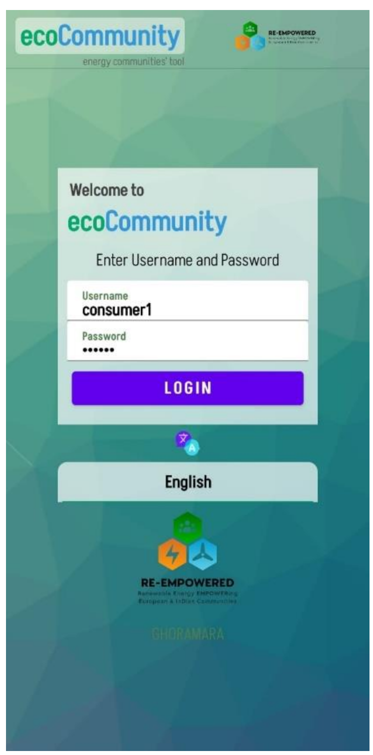


Figure 99 Login page of ecoCommunity

CM_2UC1.1: Displaying the dynamic pricing based on shape of energy profile

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC1.2: Billing and payments

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC2.2: Coordination of communal/shared loads

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.1: Feedback and suggestions from users about the tools

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.2: Reporting of problem

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.3: Forum to share experiences

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC4.1: Training material (troubleshooting)

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC5.1: Monitoring of electricity consumption of energy consumers

This Use case will be demonstrated in the 2nd demonstration round.

3.3.1.6 ecoResilience

The main objectives of ecoResilience tool are the development of cyclone resilient support structures for ground-mounted solar photovoltaic (PV) arrays and wind turbine systems. Moreover, it also targets the development of a complete wind turbine system with locally available materials and tools, including fabrication, installation and training (from basic theory to system development and integration) of the local communities and relevant stakeholders (e.g. entrepreneurs).

When the solar photovoltaic systems are ground mounted and exposed to cyclone, their support structures experience huge aerodynamic forces and moments depending on their geographical location (Ghoramara Island located at 21.9133° N, 88.1297° E, in the Bay of Bengal). The inclination angle for the fixed type of solar photovoltaic systems depends on the latitudes of the installation site. The aerodynamic forces and moments on support structures increase with an increase in inclination angle and air velocity. These forces are extremely high during severe cyclone which needs strong support structures and foundation.

Figure 100 Conventional ground-mounted PV systems

Conventional ground-mounted solar photovoltaic systems have rigid support structure (Figure 100). When these systems are exposed to severe cyclone such as Fani, Amphan, etc., at the Ghoramara site, the aerodynamics forces acting on the support structures are huge as the local wind velocity would be in the order of 150 to 200 kmph. The aerodynamic forces and moments are mainly based on the square of velocity and the frontal area as shown below.

$$\text{Aerodynamic forces} = \tfrac{1}{2}\, C_F\, \rho\, V2\, S$$
$$\text{Aerodynamic moments} = \tfrac{1}{2}\, C_M\, \rho\, V2\, S\, d$$

Where C_F, C_M are forces and moments coefficients. ρ, V, S, and d are density, wind velocity, frontal area and moment arm respectively. Here, the surface area is the only parameter which can be controlled to minimize loads as others depend on the geographical location. In nature, plants and trees reduce aerodynamic forces and moments by minimizing the angle of incident of exposed area with wind velocity through their variations in stiffness and the controlled deformation of each part. Here, an **innovative conceptual passive structure/mechanism is proposed to reduce the angle of the solar photovoltaic panels beyond a designed/critical velocity which minimizes the aerodynamics forces by reducing the frontal area.** The wind load on structure is minimized by incorporating passive aerodynamic surfaces within the main frame of the solar PV. The system was preliminarily designed based on analytical methods and later validated through numerical simulations and scale-down model testing. Further, the positioning of PV modules on support frame, aerodynamic control surfaces are optimized through numerical simulations, scale-down wind tunnel testing, and field tests. The added aerodynamic structures (curved plates with concave & convex surfaces) **minimize the wind load almost by one third at the designed wind speed**.

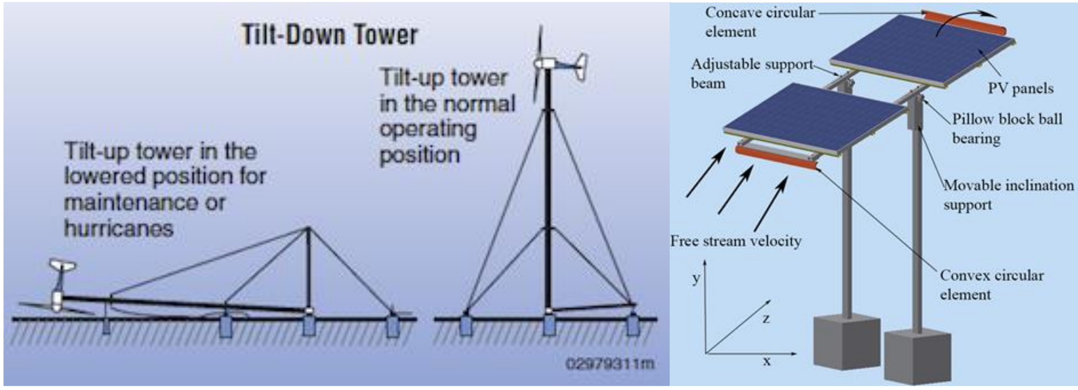


Figure 101 Conventional Tilt-up tower (Image courtesy: Wind exchange) and the designed conceptual ground-mounted PV support structure

Concerning wind turbines, the most vulnerable part of the system during extreme weather events is its moving part, i.e., the blades. Though the support structure can be made rigid to avoid damage, the blades experience massive loads during severe wind occasions which can cause them to break. Moreover, the loads on the support structure increases with the increase in height. Conventionally many variants of tilt-up towers are used for installation of small wind turbines up to 5 kW due to their low cost, simple and ease of tilt-up and tilt-down operations during maintenance. A similar tilt-up tower is used for installing a 2.5 kW wind turbine system developed with locally available material through a hands-on workshop held at CSIR-CMERI Durgapur. Further, it is also used in small wind turbine developed with locally available materials & demonstrated at Gaidouromantra / Kythnos demo site (Greece).

One small wind turbine was manufactured with the help from students and technical staff of ICCS-NTUA and was installed at Gaidouromantra/Kythnos demo site (see section 3.2.1.2) and a similar wind turbine system with tilt-up tower was also fabricated at CSIR-CMERI, Durgapur with the locally available materials involving students, entrepreneurs and technical staff of CSIR-CMERI. Further, a joint online workshop titled “Design and Development of Locally Manufactured Wind Turbines for Empowering Rural India (DWTERI 2023) was organized by CSIR-CMERI and ICCS-NITU on February 24, 2023” to educate students and staff on the fundamentals of wind turbine’s components, types of wind turbines, design and development of blades and wind generators through different open-source online tools developed by RURERG of ICCS-NTUA Athens. The developed wind turbine is being installed at Ghoramara demo site, and it will be followed by training for the local people for maintaining the system.

The tilt-up tower needs sufficient working area for placing guy wires, tilt-up and down operations of tower during maintenance and adverse environmental conditions. However, the demo site, at Ghoramara does not have sufficient area to tilt-down 18 m tower and place guy wires around the monopole due to the solar PV installation & its control rooms. A narrow area having a maximum dimensions of 3 m x 10 m space is available for two numbers of 5 kW commercial wind turbines. Hence, hybrid support structure having a monopole upper part and a truss at the bottom are preferred over monopole tilt-up tower.

In the proposed solution, the designed wind turbine support structure is made with a combination of truss (fixed) having a height of 12 m, and monopole (movable) having a height of 6 m. The top monopole structure can be brought down up to the top portion of the truss structure where a platform is made to give access for removal of the wind turbine blades during maintenance & extreme weather conditions. The wind turbine blades are reattached and raised to the height of 18 m through a mechanically operated chain pulley drive during normal operating conditions.

The complete hybrid tower is designed using CAD software and the rigidity of the tower is examined through numerical simulations using both FEA (Finite element analysis) and CFD. Finally, a field test is also performed to optimize access and the safety of the persons involved in dismantling operations of the blades. Overall, the ecoResilience tool exhibited a high level of maturity, meeting project objectives and showing promising results.

RS_2UC1.1: Optimal selection of parameters

The conceptual design of the proposed ground-mounted PV support structure for reducing the aerodynamic forces on support structure is shown in Figure 101. Here, the photovoltaic panels are placed in a movable support which is connected to the vertical column with the help of pillow block ball bearing. One circular pipe is cut into two equal pieces along the length and attached at two ends (concave & convex) near the solar photovoltaic array. The concept of a difference in drag experienced by different objects is used to minimize the angle of incident of the movable PV frame. The frontal area and the associated aerodynamic forces is reduced once the solar PV frame angle of incident is reduced.

A concave structure has a drag (axial component) coefficient of 2.3 while convex structure has 1.2. This large change in drag coefficient is used for minimizing the angle of attack of flat solar photovoltaic system by installing these structures with appropriate angles at two ends. When the air passes from positive z direction to negative z-direction, the solar panels experience negative lift and positive drag forces. The drag force experienced by the concave structure is almost twice the drag experienced by the convex shape. This huge increase in drag in the upper side causes the solar panels to pitch down with respect to fulcrum. This causes a reduction in angle of attack (AoA) of the solar panels. The aerodynamics forces and moments reduce due to a reduction in frontal area as the AoA reduces.

The functionality of the attached concave and convex structure is also reversed when the wind direction is reversed. This produces a similar effect, and the panels move towards the horizontal position which reduces the aerodynamics forces on these structures compared to fixed structures. The wind flowing from ground (bottom) to upwards may have an adverse effect on PV structures. However, the upward velocity will be minimal as compared to the axial velocity during cyclone. The following flow chart shows the logical sequence of activities performed for the design of a resilient ground-mounted PV system. In the beginning, different combinations of aerodynamic surfaces that would produce a mechanical couple on a movable frame while subjected to uniform wind velocity are examined analytically. Here, the add-on aerodynamic surfaces on the PV frame have to align with the wind irrespective of wind direction such as head or tailwind.

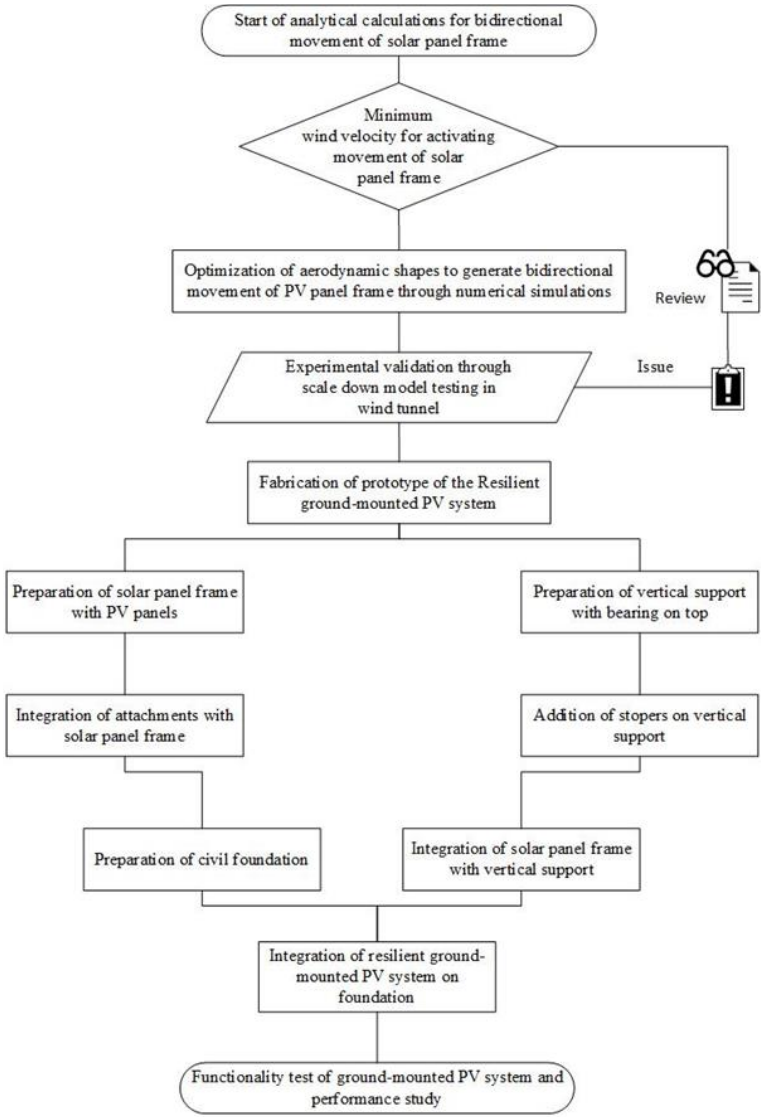


Figure 102 Logical sequence of design solar PV support structure

Once the analytical calculations are established, a minimum velocity required to induce the movement of the solar panel frame is determined based on the offset location of the bearing. The offset location of the bearing on the solar PV frame is also adjusted to change the minimum velocity required for the mechanism to activated to reduce aerodynamic loads.

RS_2UC1.2: Computational fluid dynamics and structural analysis of support structures

The aerodynamic coefficients calculated from analytical relations are compared through detailed CFD analysis involving all flow variables. For CFD simulations, solid models of base solar PV frame, PV frame with addon structures were developed through Autodesk inventor. The computational domain and Meshing were done in ANSYS workbench. Flow analysis is performed through ANSYS Fluent by applying appropriate initial and boundary conditions. The computational domain with 17.6 million grid points is given in the below figure and simulations were performed for different wind velocities from 15 m/s to 60 m/s.

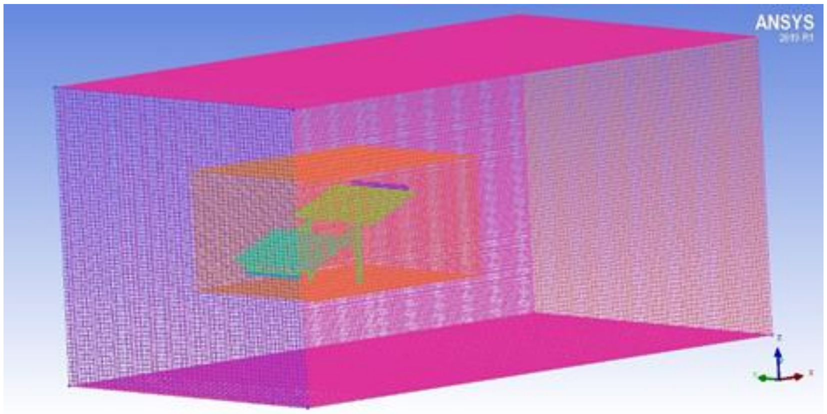


Figure 103 Computational domain with 17.6 million grid points

The numerical simulations were performed for both head (positive x direction) and tail wind (negative x direction) for different free stream velocities. The below tables show the aerodynamic forces at bottom & top PV panels, concave & convex surfaces, and the central support structure for 30 & 60 m/s velocities.

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Structure (N)	Total(N)
23	30	514.92	404.56	209.98	1129.46
	60	2060.66	1616.32	838.38	4515.36
0	30	65.45	33.41	157.97	256.83
	60	264.60	135.60	637.95	1038.15

Table 14 Drag forces during head wind condition without add-on surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Structure (N)	Total(N)
23	30	-960.44	-731.8	-180.27	-1872.51
	60	-3849.27	-2927.36	-721.42	-7498.05
0	30	99.35	-0.09	-74.8	24.46
	60	409.56	7.51	-304.23	112.84

Table 15 Lift forces during head wind condition without add-on surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Structure (N)	Total(N)
23	30	514.92	404.56	209.98	1129.46
	60	2060.66	1616.32	838.38	4515.36
0	30	65.45	33.41	157.97	256.83
	60	264.60	135.60	637.95	1038.15

Table 16 Drag forces during tail wind condition without add-on surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Structure (N)	Total(N)
23	30	797.81	1174.6	-16.95	1955.50
	60	3222.52	4713.4	-66.49	7869.47
0	30	-67.82	169.36	-77.41	24.13
	60	-266.88	671.05	-310.71	93.46

Table 17 Lift forces during tail wind condition without add-on surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Convex (N)	Concave (N)	Structure (N)	Total(N)
23	30	472.40	436.89	19.29	72.31	281.54	1282.43
	60	1890.00	1748.13	76.15	290.1	1128.78	5133.16
0	30	64.24	14.92	67.85	37.88	154.3	339.19
	60	255.02	59.12	276.81	139.12	621.51	1351.58

Table 18 Drag forces during head wind condition with concave & convex surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Convex (N)	Concave (N)	Structure (N)	Total(N)
23	30	-857.55	-916.11	-118.32	47.68	-300.96	-2145.26
	60	-3437.15	-3665.43	-475.94	187.34	-1204.21	-8595.39
0	30	140.37	-56.51	-57.64	4.98	-108.82	-77.62
	60	556.65	-234.79	-228.01	19.55	-436.03	-322.63

Table 19 Lift forces during head wind condition with concave & convex surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Convex (N)	Concave (N)	Structure (N)	Total(N)
23	30	556.40	590.82	5.18	85.85	278.75	1517.00
	60	2234.04	2367.1	18.3	343.9	1115.41	6078.73
0	30	53.3	8.78	68.21	56.72	160.63	347.64
	60	213.15	33.42	273.45	225.61	641.29	1386.92

Table 20 Drag forces during tail wind condition with concave & convex surfaces

Angle (Degree)	Velocity (m/s)	Bottom PV(N)	Top PV(N)	Convex (N)	Concave (N)	Structure (N)	Total(N)
23	30	1168.11	1318	135.81	-45.91	183.09	2759.05
	60	4689.57	5280.8	547.05	-183.37	730.07	11064.15
0	30	103.72	152.64	53.52	-3.67	-33.72	272.49
	60	430.31	607.08	214.95	-14.86	-134.19	1103.29

Table 21 Lift forces during tail wind condition with concave & convex surfaces

Solar PV with addon structures	Velocity, m/s (kmph)	Drag force (N)	Lift force (N)	Remarks
Proposed Aerodynamic design at 23° with fixed support	60 (216)	5133	-8595	Aerodynamics forces increase due to the addition of flow control devices compared to conventional support.
Proposed aerodynamic design at 23° with movable support	60 (216)	1351	-323	The maximum drag & lift forces are 1.35 kN & 0.32 kN compared to fixed structure.

Table 22 Comparison of numerical results of designed solar PV support structures for v=210 kmph with addon structures

The above tables show that the drag force is increased from 4515 N to 5133 N with add-on structures at AoA=23°. Similarly, the drag force is also increased from –7498 N to –8595 N with addon structures. The percentage increase in lift & drag forces are 13% & 15% at AoA=23°. When the solar PV frame is made movable with the bearing, the negative lift force moves the solar PV frame towards AoA=0°. This causes huge reduction in aerodynamic forces on the structures. The drag force is reduced from 5133 N to 1351 N which is 74% reduction in drag force at the cyclonic velocity. Hence, the proposed mechanism helps in reducing teh aerodynamic forces on the structures.

The below figures show the velocity & pressure contours & vorticity production at the structures with and without concave and convex structures for v=60 m/s.

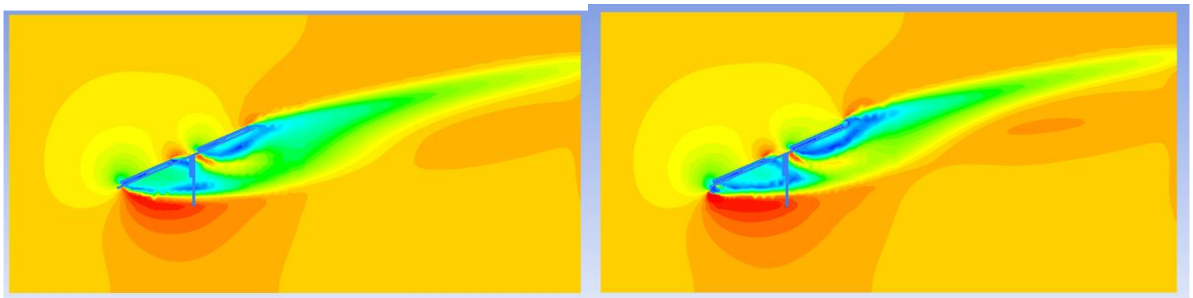


Figure 104 Velocity contours for base and PV frame with addon structures at AoA= 23°.

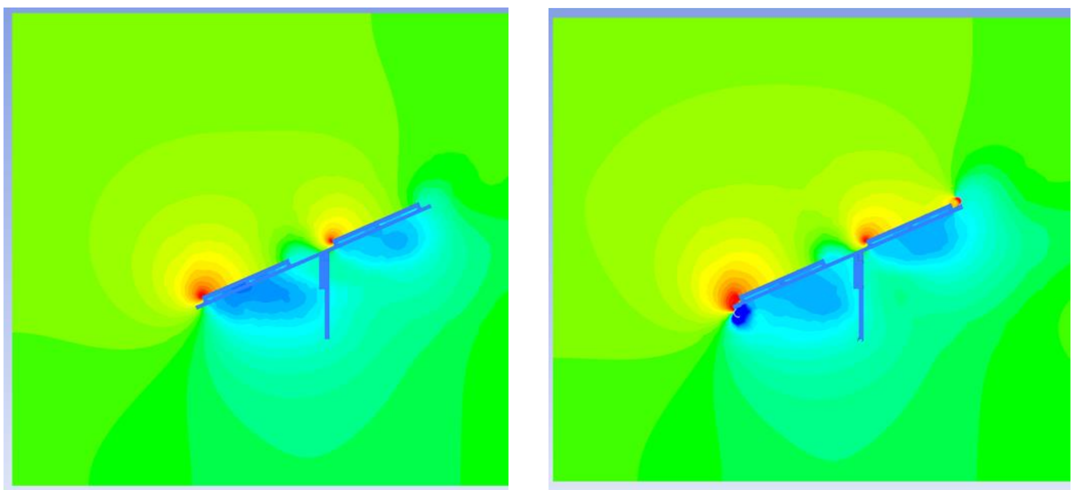


Figure 105 Pressure contours for base and PV frame with addon structures at AoA= 23°.

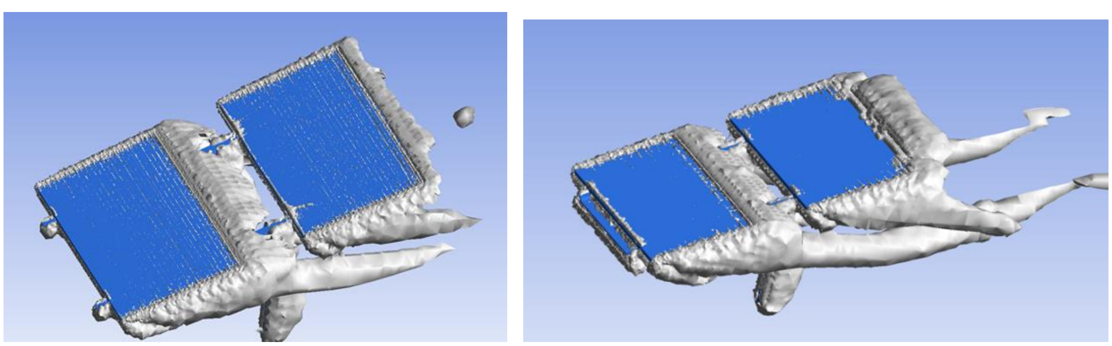


Figure 106 Vorticity production for base and PV frame with addon structures at AoA= 23°

RS_2UC1.3: Experimental validation of the designed structure through wind tunnel testing

The validation of the numerical simulations was performed through wind tunnel testing using 1:10 scale-down models of the support structures having base and add-on structures configurations. Here, the models of individual components of the support structures were made using 3-D printing (see below).

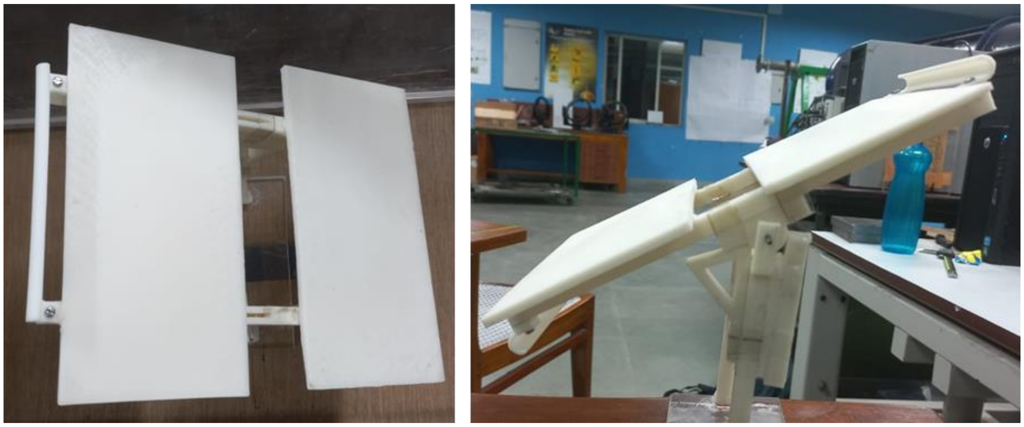


Figure 107 1:10 Scale-down model of the support structure with PV panels

Figure 108 Wind tunnel testing of solar PV with support structure. Aerodynamic loads on support structure are examined using a load cell.

The models were assembled and attached with an internal balance before installed inside the wind tunnel to examine the functionality of the mechanism used for aligning the panels parallel to the wind direction at the designed wind velocity. The wind velocity is increased gradually to observe the deflection of solar PV frame towards the horizontal direction. It is observed that the solar PV panel is aligning with AoA=0° when the designed critical velocity was reached. The aerodynamic loads were also reduced, and they were in similar trend with the numerical simulations. The alignment of the solar PV frame towards the horizontal direction was also tested for different offset locations of the bearing over the middle support structure.

Figure 109 Preliminary design using numerical simulations. The structure had some low-frequency oscillations

It is observed that the mechanism was working fine for many flow velocities with both head and tail wind conditions. It was noticed that the experiments with angle sections at the vertical support experienced some vibrations during the activation of the mechanism. Further, it is noticed that supporting the solar panels through only solar PV frame have induced bent of panels at extreme wind conditions (See above structure). Hence, the vertical support is made with a box structure with stiffeners and a rectangular frame is attached with each PV panel for ensuring stability.

Figure 110 Final fabricated prototype of the solar PV support structures that is being installed at Ghoramara demo site.

RS_2UC1.4: Design of resilient foundation for solar photovoltaic system

The strength of the solar PV support structure's foundation depends on the dead weight of the structure, designed wind loads and soil bearing capacity. The load bearing capacity of soil also depends on its nature. The soft and firm clays have a safe bearing capacity of < 75 kPa and 75 to 100 kPa. The loose and dense gravels have a safe bearing capacity of < 200 kPa and between 200–600 kPa. Literature suggested that our demo site Ghoramara has a bearing capacity of 100 kPa though it lies inside a river. A maximum wind load of 5 kN was considered as lateral load and all dimensions were chosen based on the IS 456 (2000).

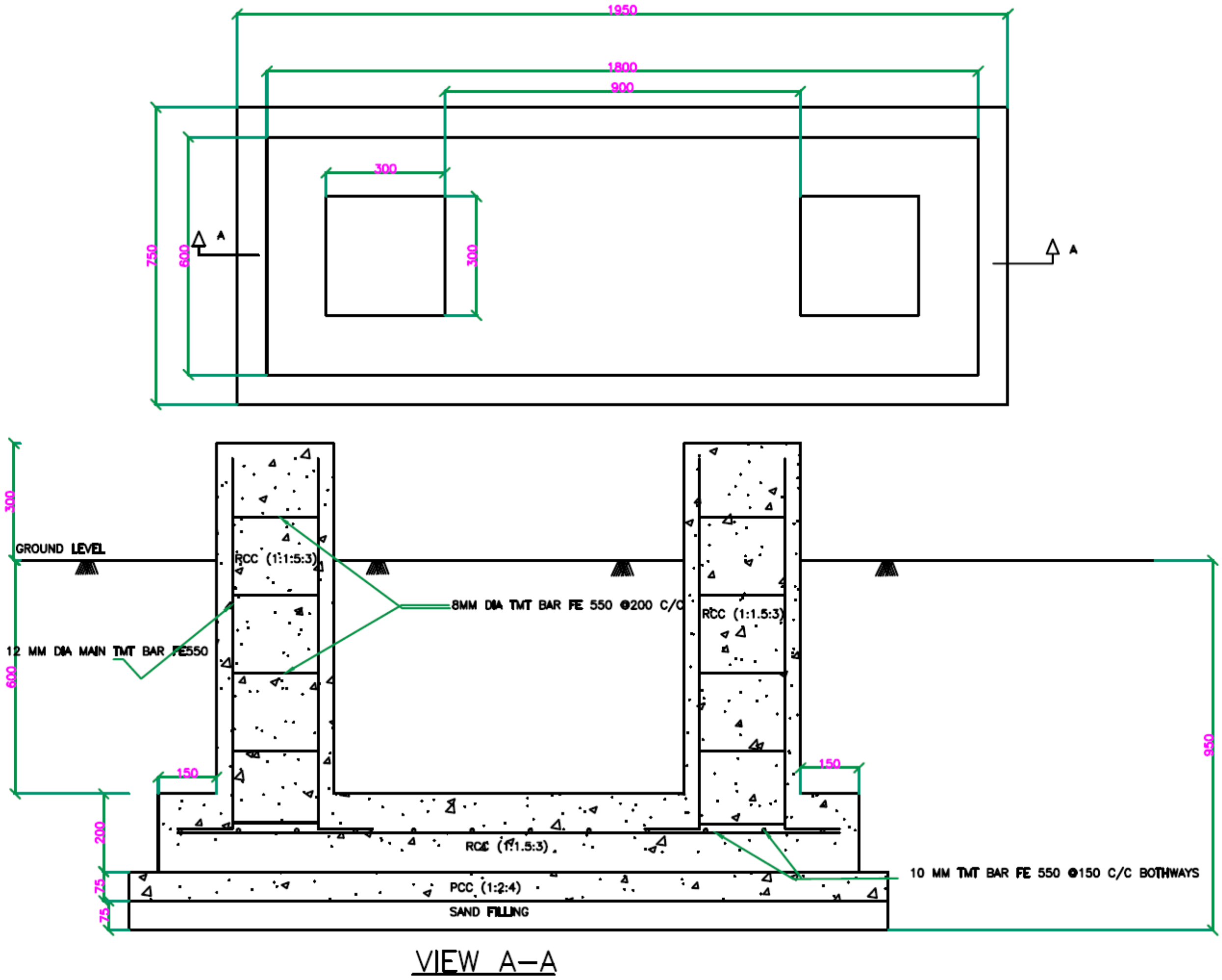


Figure 111 Resilient foundation for the solar PV support structure with RCC and PCC below the ground up to 0.95 m after sand filling

The drawing of the final resilient foundation for solar PV support structures is given below. It must be made with the following specifications:

- Plain Cement Concrete (PCC) must be 1:2:4 (1 cement: 2 coarse sands: 4 graded stone aggregate 20 mm nominal size)

- Centering and shuttering with block board or steel shuttering
- Reinforcement for RCC works shall be done with the dimension specified in the drawing
- Reinforced cement concrete (RCC) must be 1:1.5:3 (1 cement: 1.5 coarse sand: 3 graded stone aggregate 20 mm nominal size)

RS_2UC2.1: Preliminary design of a tower truss structure and its optimization

A hybrid eco-resilient support structure for commercial wind turbine systems was designed based on the requirement of the demo site as mentioned in the introduction. The preliminary dimensions for the truss and monopole were chosen by considering both axial (wind loads) and vertical loads (dead loads) based on the data available in the literature. For structural analysis, 3D solid models were developed through Autodesk inventor software. The computational domain and Meshing were done in Autodesk inventor. Frame analysis is performed through Autodesk inventor by applying appropriate initial and boundary conditions.

The below figures show displacement and von-mises stress against wind load corresponding wind velocity 210kmph. Here, the dimensions of the tower elements are increased to reduce the maximum displacement from 1.2 mm to much less than mm (~10 micron). Each individual part of the tower is analyzed before assembling the whole wind turbine tower for final analysis. Next, we performed preliminary static structural analysis of designed 3D model by using ANSYS software with considering wind load equivalent to wind velocity of 210 kmph. The following figures show total deformation and total equivalent stress in monopole structure with full operating height of the tower, i.e., 12 m.

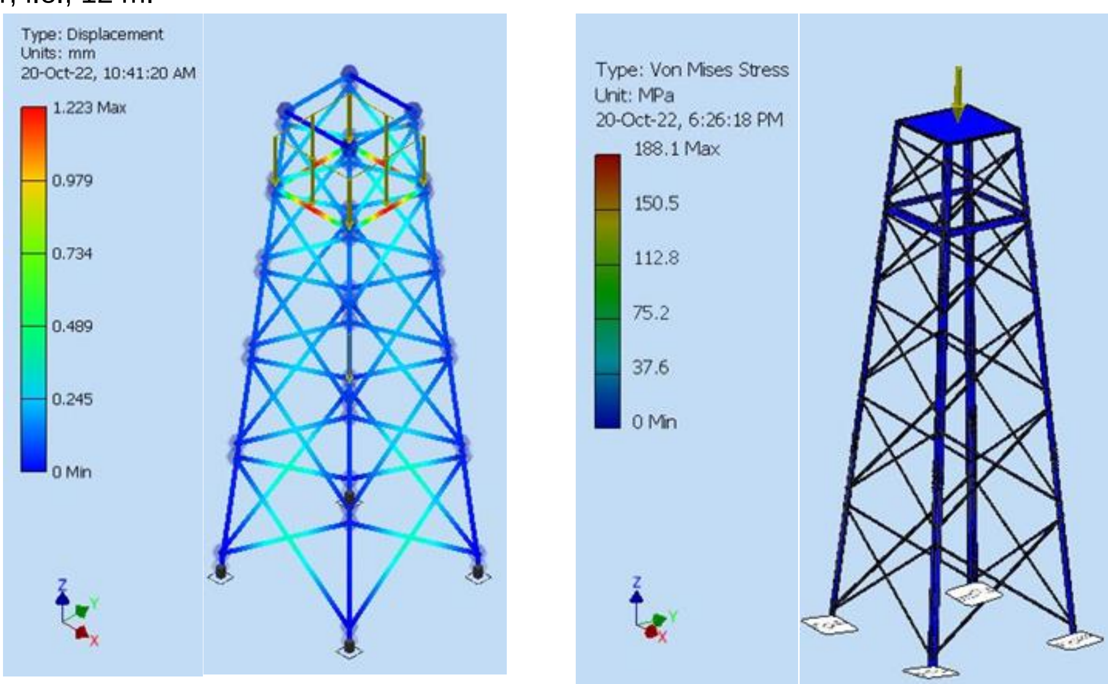


Figure 112 The displacement and von-mises stress plots with a wind load of 210 kmph for the truss structure

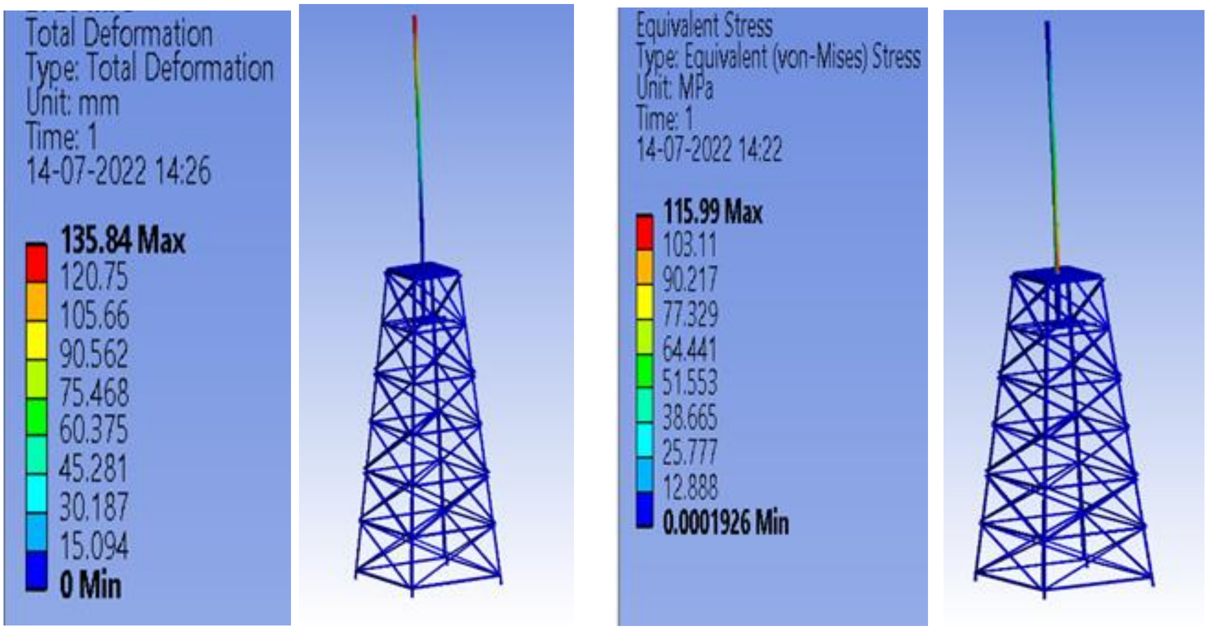


Figure 113 The displacement and von-mises stress plots with a wind load of 210 kmph for the truss structure

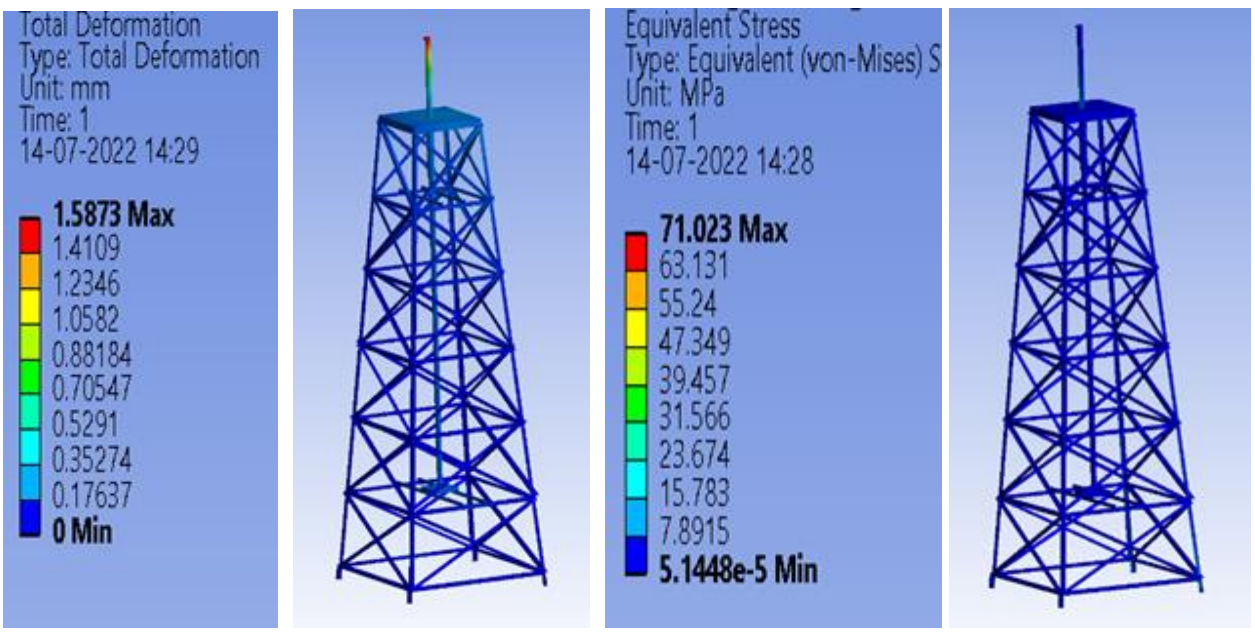


Figure 114 The total displacement and von-mises stress plots with a wind load of 210 kmph for the 6m hybrid support structure (monopole brought down)

Next, numerical analysis is performed with off-condition of wind turbine, i.e., the height of the tower is reduced to 6 m by bringdown the upper monopole part. The above figures show total deformation and total equivalent stress in hybrid tower structure with wind turbine brought down to 6 m height. When the height of the hybrid tower is reduced to 6m, the maximum deflection is reduced to 1.5 mm compared to 135 mm observed with full 12 m height. Further, the Maximum stress is reduced to 60%. This suggested that the loads and deflection were reduced drastically by reducing the tower height.

RS_2UC2.2: Design of a resilient mechanism to reduce wind loads on blades and its optimization

The major issue with conventional tilt-up support structure at Ghoramara demo site is bringing down the tower during cyclone to prevent the damage of blade. The advantage of the proposed design is its ability to access the blades for their removal during cyclones as the blades cannot withstand severe wind loads. Preliminary structural analysis for the monopole & truss structures revealed that the loads on the support structure is greatly reduced when the monopole is brought down & the blades are removed from the wind generators. It is achieved by providing a movable support for the upper monopole rather than a complete rigid truss structure. This movable base helps in bringing down the monopole tower.

The demo site, Ghoramara is not connected well with the mainland. Hence, all materials need to be transported manually. Here, all structural components of the tower are made into small pieces (angles with a maximum of 3m length) for ease of transport. The following are figures showing the conceptual design of hybrid support structure and its components.

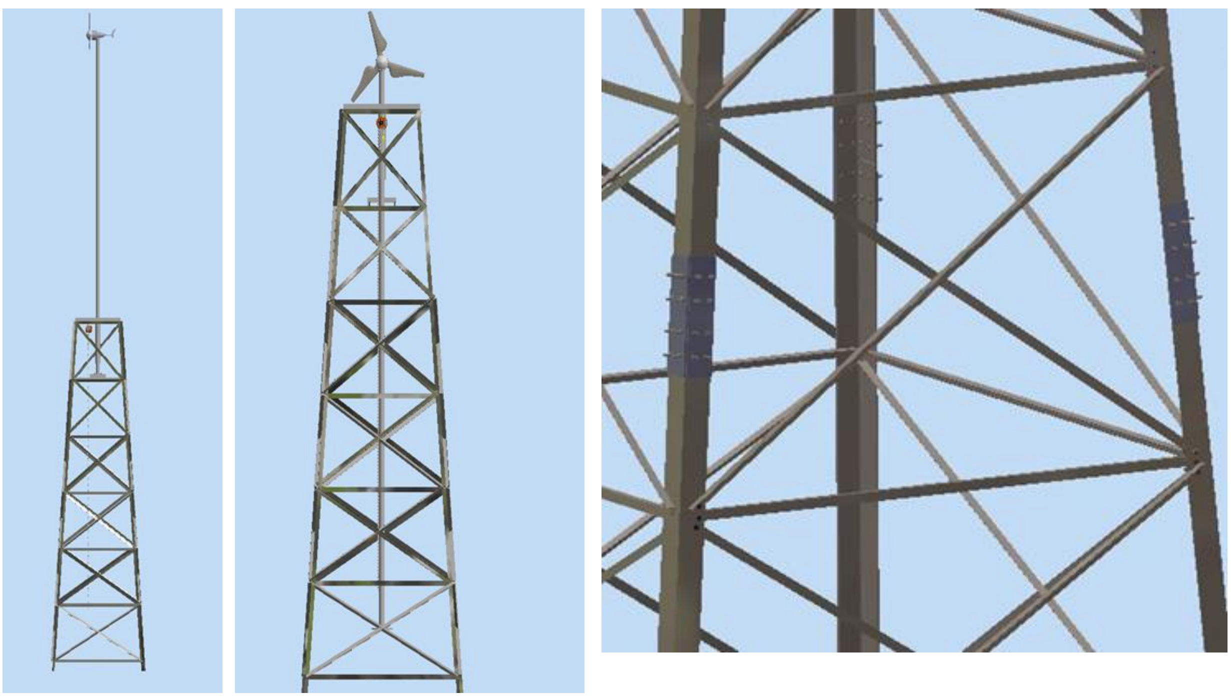


Figure 115 Power generating position (18 m) and rest position (12 m) during cyclone. Each component of the truss structures is connected through nuts & bolts

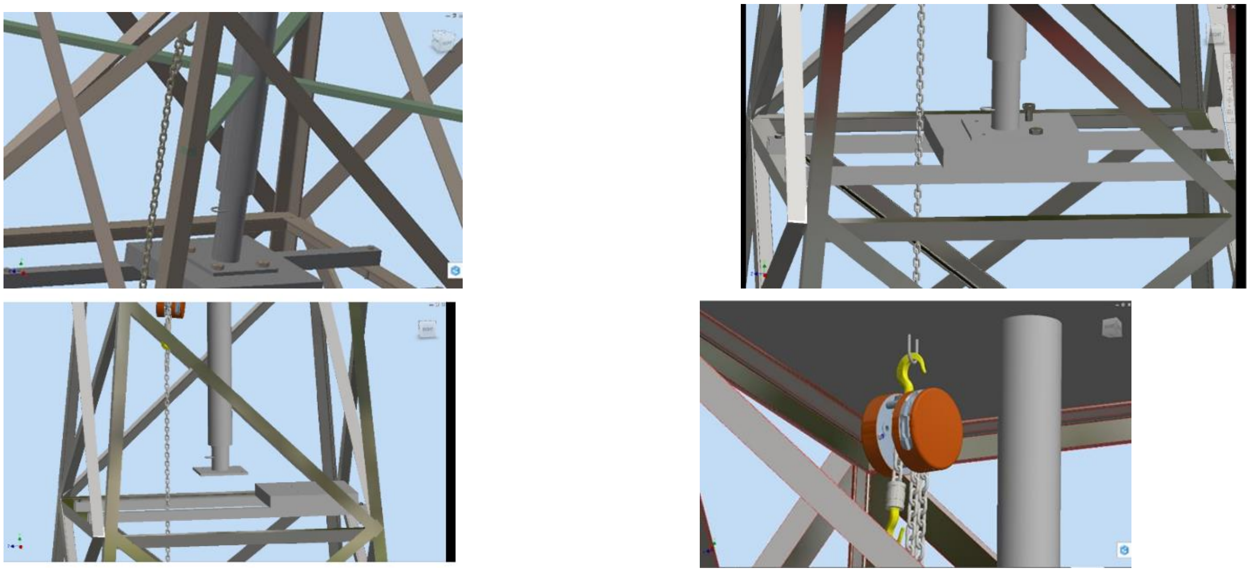


Figure 116Fixing of monopole over the truss structure for power generation & lowing of tower during cyclone using a chain hoist having a capacity of 1 ton.

RS_2UC2.3: Laboratory and field testing of the mechanism

The designed wind turbine support structure is made with a combination of truss (fixed) having a height of 12 m, and monopole (movable) having a height of 6 m. The top monopole structure is rigidly fixed on a movable platform made at a height of 11 m from ground as shown above. Further, a rigid platform is also made over the truss structure for a person climbing through an attached ladder for removal blades after bringing down the monopole tower. One complete hybrid tower is fabricated and installed at CSIR-CMERI Durgapur for testing the functionalities of the tower, such as up & down movement of monopole, removal & fixing of blades and accessibility of wind turbine system through ladder. Further, the rigidity of the complete system is checked during normal operations. The complete testing activities are shown in the figures below.

Figure 117 Making of foundation and fabrication of hybrid tower as the final drawings

The fabricated tower in the laboratory is dismantled and transported to the testing site at CSIR-CMERI where the civil foundation was made. The installation of the complete tower was performed part by part and the commercial wind turbine is placed on top of the monopole as shown below. The height of the tower is increased from 12 m to 18 m by increasing the height of the monopole as shown in the below figure. The monopole is attached with four guy wires welded at a height of 5 m from the monopole base. It was noticed that the wind turbine was working fine, and a slight bending of the monopole was noticed during bad weather (at higher wind velocities of greater than 15 m/s). Hence, the number of guy wires is increased from 4 to 8 and the guy wire angle was also increased from 20° to 40° to enhance the stability of the monopole structure. The complete support structure and wind turbine system are dismantled and transported to Ghoramara for their deployment. Two 5 kW wind turbines were installed on the hybrid support structure at Ghoramara island, and they were attached to the charge controller and dump load. It will be connected to the microgrid system in December 2024 after receiving the DC-DC converter to boost up the wind turbine output voltage from 192 V to 480 V.

Figure 118 Installation of tower at testing at CSIR-CMERI & demo site, Ghoramara for power generation.

RS_2UC2.4: Resilient foundation for wind turbine tower structure

The design of foundation for hybrid support structure is similar to the resilient ground-mounted structure. The maximum wind load on wind turbine was calculated based on the diameter of the of 5 kN wind turbine and all dimensions were chosen based on the IS 456 (2000). The below figure shows the foundation for the hybrid support structure where angles were welded with all four vertical columns to provide more rigidity.

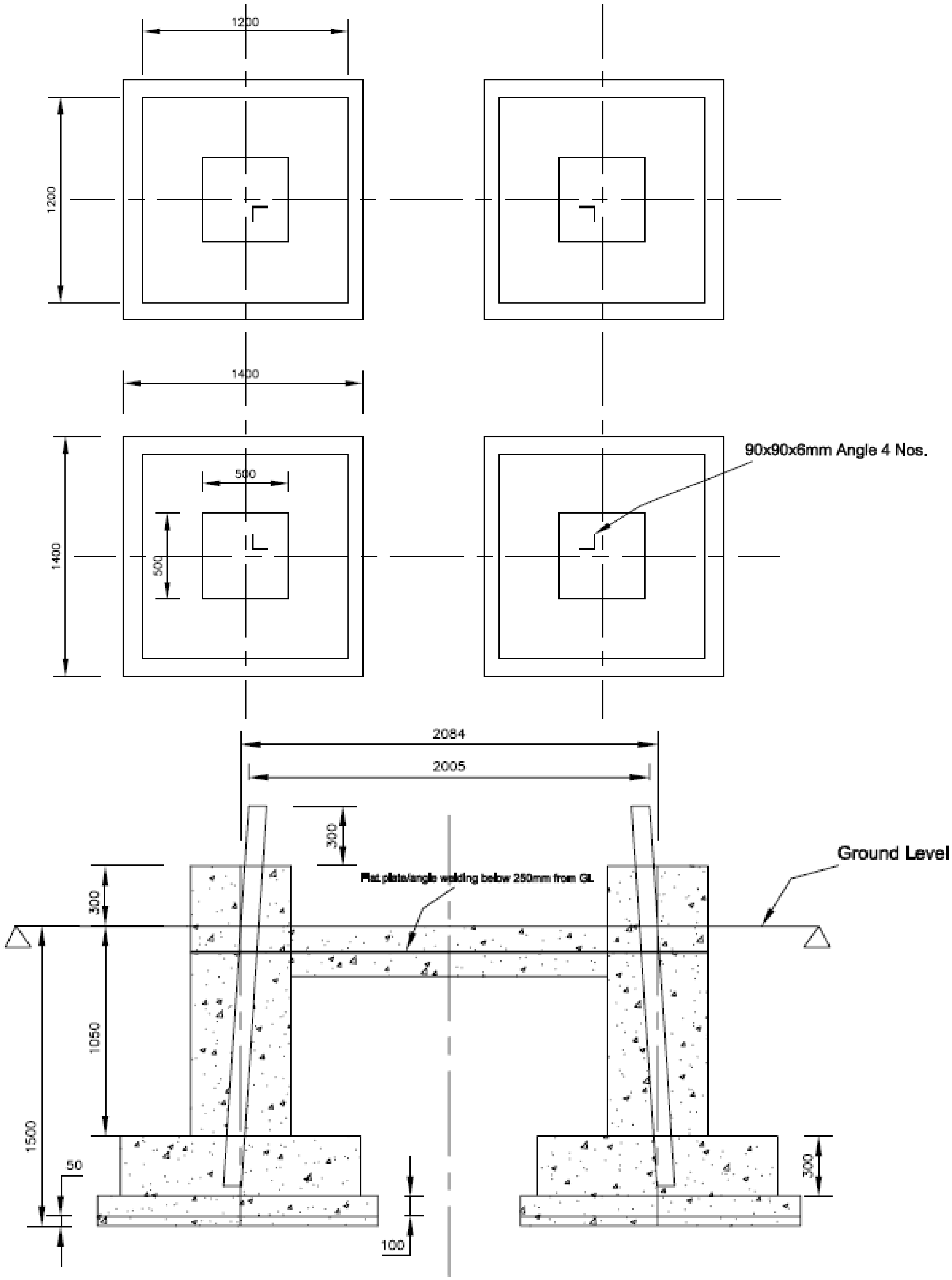


Figure 119 Resilient foundation for the hybrid support structure with RCC and PCC below the ground up to 1.5 m after sand filling

The drawing of the final resilient foundation for hybrid wind turbine support structures is given below. It must be made with the following specifications

- Plain Cement Concrete (PCC) must be 1:2:4 (1 cement: 2 coarse sand: 4 graded stone aggregate 20 mm nominal size)
- Centering and shuttering with block board or steel shuttering
- Reinforcement for RCC works shall be done with the dimension specified in the drawing
- Reinforced cement concrete (RCC) must be 1:1.5:3 (1 cement: 1.5 coarse sand: 3 graded stone aggregate 20 mm nominal size)

The following are reinforcement details:

- FOOTING: 12mm Dia. TMT Bars Fe550@ 150mm c/c both ways
- COLUMN: 8 Nos-12mm Dia. TMT Bars Fe550
- STIRRUPS FOR COLUMN: 4 Legged 8mm Dia. TMT Bars Fe550@ 200mm c/c BEAM: 4 Nos.-12mm Dia. TMT Bars Fe550
- STIRRUPS FOR BEAM: 8mm Dia. TMT Bars Fe550@ 200mm c/c

RS_1UC3: Design, Development and Installation of small wind turbine from locally available materials

Low-cost renewable energy technologies designed for small-scale electricity generation have the potential to facilitate energy access for rural communities, particularly in remote regions, where electrical grid is challenging and does not exist. The locally manufactured small wind turbine (LMSWT) offers a cost-effective solution in areas with favorable wind resources, such as places close to large water bodies (land & sea breeze) & hilly areas as the initial investment is reduced by utilizing locally available materials, tools, and manufacturing methods. Further, the operation and maintenance expenses could be reduced by providing maintenance training to local users and technical partners.

LMSWTs are commonly integrated into hybrid off-grid systems that combine wind and photovoltaic (PV) sources of renewable energy with a maximum renewable energy capacity of 10 kW. The rotor diameters of LMSWTs range from 1.2 to 6 meters, with rated power outputs of 200 W to 5 kW. These turbines feature a variable-speed design and employ a three-blade wooden horizontal axis rotor with a fixed pitch angle and operate at a rated wind speed of 10 m/s. LMSWTs commonly use coreless axial flux permanent magnet generator (AFPMG) with a double rotor single stator configuration due to its uncomplicated manufacturing process for both the disk-shaped stator and rotor. These generators also offer the advantage of straightforward air gap regulation, simplifying maintenance and enabling partial optimization of power matching between the rotor and the generator. Further, AFPMGs use surface mounted permanent magnets, allowing for the creation of low-speed generators that can be directly connected to the blade rotor. This eliminates the need for intricate and potentially expensive gear systems, which can be challenging to maintain in small-scale and often remote installations of this nature.

The LMSWT intended to be developed in this project has rotor diameter of 4.3 m and rated power of 3 kW, at a wind speed of 10 m/s. It can produce an annual energy of 4450 kWh/year, if installed at a location with a typical mean wind speed of 4.5 m/s. The development & fabrication of small wind turbine for Ghoramara demo site was done in two phases through an online and offline workshop. In the first phase, a one-day 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 National Technical University of Athens (NTUA) on 24th February 2023.

The main objective of the online workshop was to educate students and staff who are supposed to participate in hands-on training workshop about the fundamentals of different wind turbines, their types & components, and the advantage of off-grid small wind turbines. Further, the detailed procedure of small wind turbine design starting from the design and validation of wind turbine blades profile, selection of magnet size & grade, magnetic materials well-suited for the specific local environmental conditions, design of generators using ICCS-NTUA developed openly accessible design and analysis tools were discussed. A day long workshop had invited talks from Industries, academia, and talks from ICCS-NTUA and CSIR CMERI.

RS_2UC3.1: Small Wind Turbine Manufacturing and installation

ICCS-NTUA has developed a series of openly accessible design and analysis tools aimed at empowering local SWT manufacturers to reconfigure the axial flux permanent magnet generator AFPMGs based on the materials available, alongside offering data analysis and optimization capabilities. The OpenAFPM suite of modeling tools (developed in the framework of the project 'Online Design Tools for Locally Manufactured Small Wind Turbines' supported by WISIONS - www.wisions.net) is instrumental in AFPMG design for wind electric systems, leveraging the open-source finite element analysis software 'Finite Element Method Magnetics' (FEMM). Comprising three distinct design tools (MagnAFPM, UserAFPM, and OptiAFPM), the OpenAFPM series provides comprehensive solutions to the development small wind turbines. MagnAFPM facilitates generator design tailored to specific rotor blade and permanent magnet dimensions. UserAFPM validates the performance of a generator geometry through 2D finite element analysis using FEMM. The OptiAFPM tool employs particle swarm optimization (PSO) to enhance permanent magnet dimensions within a given generator design for particular rotor blades. This optimization process concurrently refines the generator's efficiency, cost, and/or mass attributes.

A 3-kW nominal power @ 10 m/s velocity at 18 m height at Ghoramara island was designed using online tools of ICCS-NTUA Athens. The locally manufactured wind turbine has horizontal axis three blade wooden rotor with a diameter of 4.34 m. It has constant pitch angle, and passive gravity furling tail system. The generator is a variable speed machine with coreless axial flux permanent magnet and double rotor single stator configuration. The bill of materials for the fabrication of wind turbine system along with detailed design of each component & required tools was shared by ICCS-NTUA (Dr. Kostas Latoufis). All materials such as birch plywood, enameled copper wire, 4 number of planned pines with the dimension of 2.2 m x 23 cm x 7.7 cm, bearing hub, casting materials, 50 number of Ferrite C8 magnets with the dimension of 75 mm x 50 mm x 20 mm, galvanized screws & bolts & electric parts were procured along with the required tools.

A small wind turbine manufacturing hands-on workshop titled "Design and Manufacturing of Small Wind Turbines for Empowering Rural India (SWTERI-2024) was organized under Skill Development Initiative at CSIR-CMERI Durgapur, India from September 17 to 21, 2024. It was co-organized 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, where Dr. Kostas Latoufis and Dr. Alexandros Georgios, senior researchers from NTUA Athens, Greece guided the students and staffs for fabricating different parts of the wind turbine system. It was formally inaugurated by the Director CSIR-CMERI Durgapur (See below images).

Figure 120 Inauguration of SWTERI-2024 hands-on training workshop at CMERI, India

Figure 121 Fabrication of different components of the 3-kW wind turbine system through training workshop at CMERI, with the support of ICCS-NTUA

During the week-long workshop, electrical and mechanical engineering students from nearby engineering & diploma colleges and staffs of CSIR-CMERI collaborated in teams to construct a small wind turbine from scratch, utilizing basic tools, materials, and fabrication methods (see above pictures). The blades having airfoil section and twist from hub to tail were crafted from planar pine wood. The mounting frame for the generator and tail portion were prepared from the steel pipes and sections. The tail end of the wind turbine was prepared from plywood. Copper wire was used for the coils, while Ferrite magnets encased in resin formed the stator and rotor of the generator. RE-EMPOWERED project partners from IIT Delhi and IIT Kharagpur also participated in the workshop. A complete wind turbine system was developed (see below figure) in the workshop and tested with laboratory instruments.

Figure 122 Fabricated 3-kW wind turbine system at CMERI, with the support of ICCS-NTUA

RS _2UC3.2 Testing of Small Wind Turbines using Standards

The fabricated 3-kW wind turbine generator was tested in the laboratory by providing rotation of the blades manually. The output voltage agreed with the change in the rotation of the wind turbine blades. The complete wind turbine system is transported to the Ghoramara demo site. The probable location for the guy wires of the 3-kW wind turbine system's monopole foundation is finalized which was delayed due to many constraints in the available space in the demo site (see below image).

Figure 123 Proposed location of 3-kW wind turbine installation

The locally manufactured small wind turbine will be installed in Ghoramara in the coming weeks for testing purposes.

3.3.1.7 ecoConverter

C_UC1.1: Development and control of power electronic converters

A 10 kW microgrid system was fabricated in the laboratory, in the framework of the project, which will be deployed to Ghoramara island for demonstration. Several ecoTools developed in the project will be validated in connection to 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.

Specifically, multiple power peaks may be generated under the presence of partial shading which may not be tracked accurately by a conventional Perturb-and-Observe (P&O) Maximum Power Point Tracking (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.

The topology of the converter/inverter set is given below.

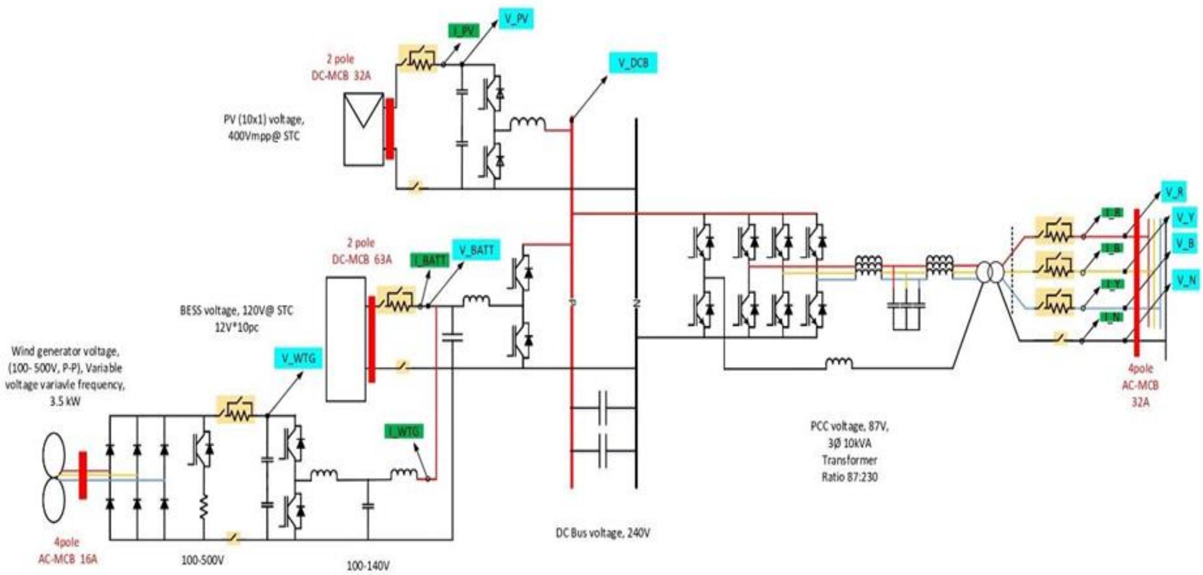


Figure 124 Topology of the converter/inverter in Ghoramara

Converter Side Details	**Inverter side details**
PV converter Details	Inverter DC Bus Voltage: 240V (220-260V)
PV details: 10 panels in series	Two level Inverter, Standalone Mode

PV Voltage: (300-550) 440 VMPP	Inv o/p Voltage: 80V (Vph)
I/P current of DC-DC Converter (PV) - 13 Amp	Inverter current: 22 Amp (rms)
Output side current DC-DC Converter (PV): 24.75 Amp @ mpp	Inverter Rating: (3x80x22)= 5.28 kW
PV Power:5.94kW @ STC	**Transformer Details**
Battery Details	Transformer quantity: Three 1-ph transformer
BESS Details: 9 kWh	Transformer rating: 3.3kVA
Single battery: 75Ah, C10 BESS current: 7.5 Amp (Charging Mode)	Primary side voltage taping: 80V, 115V, 230V
BESS Voltage: 100-140V (10*12V)	Secondary side voltage: 230V
Wind Converter details	**Load Details**
Wind Voltage (100-500V), Variable frequency, 2.5 kW 3-ph.	5 houses near to the control room, School building load.
Input side max current of Wind converter: 5A DC	**Microcontroller details**
Output side Voltage of Wind converter: 120V (100-140V)	Micro Controller: LAUNCHXL – F28379D Development Kit
Output side max current of Wind converter: 21 A	

Table 23 Parameters of converter in Ghoramara

Images:

Figure 125 ecoConverter in Ghoramara

C_2UC1.2: Testing and on-field demonstration of the power electronic converters

PV source:
As per the schematic diagram, a DC-DC buck converter is connected with the common DC bus of 240V. The input of the Buck converter is PV panels. PV panels consist of 10 PV panels in series, PV MPP voltage is 440V, and MPP current is 13 amp.

BESS source:
As per the schematic diagram, a Bi-directional converter is connected in between the BESS and the common DC bus bar. The BESS terminal voltage is 120V, The Bi-directional converter is used for charging and discharging of the battery depending on the SoC of Battery, PV generation and the load demand.

Wind turbine:
As per the schematic diagram 2.5 kW CMERI developed wind turbine will be integrated with the BESS terminal. The output of the wind turbine is ac voltage, a 3-phase full bridge rectifier is connected with this to convert it to DC voltage. The input of the buck converter is connected with it and the output of the converter is integrated with the battery terminal. The terminal voltage of the battery is 120V.

Inverter:
4-leg inverter is used to in the 10kW eco-converter to supply the load voltage. The input of the inverter is connected with the common dc bus of 240V. The output phase voltage is 80V (rms). An LCL filter is connected with the output of the inverter terminal to filter out the harmonic component. 3 single phase transformer of 3.3 KVA each are there to step up the voltage up to 230V, and it will be directly connected with the load.

The results will be shown in the 2nd demonstration round.

3.3.1.8 ecoVehicle

VH_2UC2.2: Customization of the vehicle to the demo site requirements

In this use case, the goal was to modify and customize the e-Three wheelers in such a way that they can be easily converted to carry only goods when there are fewer passengers and vice versa. Further, the vehicles power train was upgraded so that it can be used for transportation of passengers (max 6 persons) and goods within the island.

Figure 126 (Left) Electric three-wheeler converted into an electric loader to transport goods (seating arrangement and canopy removed) and (right) modular seating arrangement and canopy for carrying passengers

Figure 127 Electric three-wheeler powertrain upgraded to 2 kW BLDC motor with matching controller and (right) deployment at Ghoramara demo site

VH_2UC3.1: PV Integration with e-Boat

This use case aimed to enhance the endurance of an e-boat by integrating solar PV panels on its rooftop. A 3 kWp solar PV system is being installed on a 16-passenger electric boat, enabling it to generate approximately 10 kWh of solar energy on a sunny day. This energy is stored in an onboard LiFePO4 battery with a capacity of 2x12 kWh. The integration of solar PV allows the boat to make an additional round trip between Ghoramara and Sagar Island, covering a journey of approximately two hours. The figure below showcases the deployment of the solar-powered electric boat.

Figure 128 Rooftop solar PV integrated electric boat for mainland connectivity

3.3.2 List of adaptations for demonstration round 2

To address the limitations identified in Round 1 and prepare the ecoMicrogrid system for the second round of testing, several key adaptations have been planned. One of the primary focus areas is to consider the small commercial microgrid, including the integration of electric vehicle chargers, into the ecoMicrogrid system. This adaptation will secure the validation of ecoMicrogrid but also broaden the scope by addressing the emerging demand for microgrids that support EV charging infrastructure. In that way ecoMicrogrid will be tested under new conditions, this will ensure the ecoMicrogrid system's scalability and flexibility, making it better suited for the future of energy management in commercial and urban microgrids.

Concerning, ecoPlatform the debugging process addressed the following points:

Debugging Process:

- Communication Delays between dependent tools were identified and addressed by optimizing data exchange protocols.
- API Stability was improved to enhance response times for archived data retrieval.
- Cloud Data Transmission issues were resolved by strengthening network stability and failover mechanisms.
- Error Logging was enhanced to streamline problem detection and resolution.

The list of adaptations concerning ecoPlatform follows:

- Improved Data Exchange (PT_2UC2.1): Optimized communication algorithms reduced latency in real-time data sharing between ecoTools.

- Enhanced Data Routing to Cloud (PT_2UC3.1): Improved reliability of cloud data transmission through better network redundancy and stability measures.
- Optimized API for Archived Data (PT_2UC3.2): Enhanced caching and retrieval processes for faster, stable access to archived data.
- Scalability Enhancements: Adaptations were made to handle larger datasets and increased tool integration.
- Security Features: Strengthened encryption and secure authentication for data transmission and API access.
- Customizable Dashboards: Added flexibility for operators to visualize and monitor real-time and archived data.
- Tool Integration Debugging: Resolved compatibility issues between ecoPlatform and other ecoTools.

3.4 Keonjhar

3.4.1 Report of the demonstration round 1 activities

This section presents the status of the use cases for the Keonjhar demo-site.

3.4.1.1 ecoMicrogrid

MG_2UC1.1: Real time microgrid monitoring and data acquisition

The purpose of this use case is to showcase the real-time monitoring and data acquisition capabilities of the ecoMicrogrid tool at the Keonjhar pilot site. The demonstration focused on real-time data collection from energy meters, photovoltaic, diesel generators (Biomass, Biogas) and battery storage systems within the microgrid.

The ecoMicrogrid system implements sophisticated SCADA functionality, enabling operators to maintain continuous visibility of the microgrid's operational status. The SCADA interface comprises a single operational screen (Figure 129) that provides comprehensive monitoring features:

- The **Battery Storage System** monitoring interface provides real-time visibility of the battery's state of charge, DC voltage and current measurements, and total battery power status. The system also tracks grid energy metrics, including both consumption and energy fed back to the grid.
- The **Solar Photovoltaic** System monitoring capabilities include real-time PV voltage and current measurements, total active power generation tracking, and energy export monitoring, allowing operators to assess solar generation performance and grid contribution.
- The **Biomass/Biogas Generator** monitoring section displays current readings across all three phases, total power output through the AC bus, and generator power factor.
- The **Load Monitoring** section offers a detailed overview of active and reactive power distribution across all three phases, total power consumption, system frequency, and overall power factor. To ensure clarity, individual meter measurements are aggregated, presenting a streamlined view without cluttering the interface with less critical details.

- The **Bio-Fuel Optimization** interface displays the results of optimization algorithms, providing clear suggestions for manually starting or stopping the Biomass/Biogas generator to enhance system efficiency

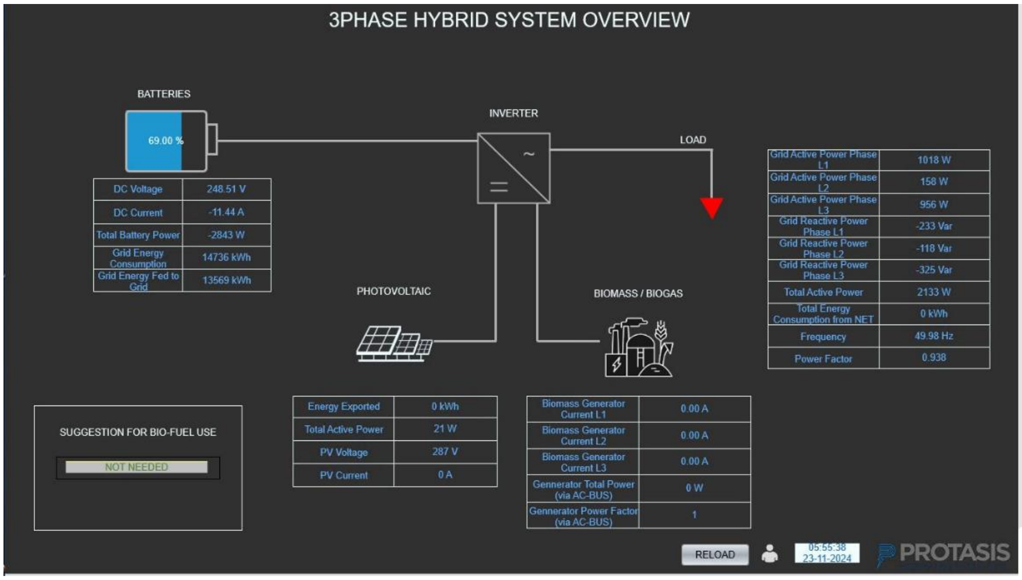
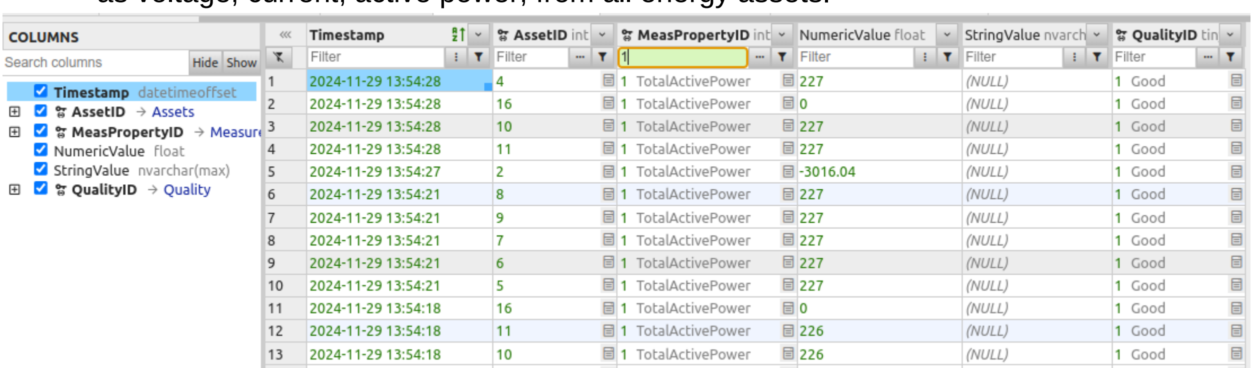


Figure 129 SCADA main screen of ecoMicrogrid instance at Keonjhar.

Demonstration Activities:

The use case validation encompassed several key activities to verify the system's capabilities:

- **System Data Integration**: Successfully integrated multiple asset types, smart energy meters, Biomass/Biogas generators, photovoltaic systems, and battery storage systems.
- **Monitoring and Data Acquisition**: Real-time monitoring of electrical parameters, such as voltage, current, active power, from all energy assets.



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2	2024-11-29 13:54:28	16	1 TotalActivePower	0	(NULL)	1 Good
3	2024-11-29 13:54:28	10	1 TotalActivePower	227	(NULL)	1 Good
4	2024-11-29 13:54:28	11	1 TotalActivePower	227	(NULL)	1 Good
5	2024-11-29 13:54:27	2	1 TotalActivePower	-3016.04	(NULL)	1 Good
6	2024-11-29 13:54:21	8	1 TotalActivePower	227	(NULL)	1 Good
7	2024-11-29 13:54:21	9	1 TotalActivePower	227	(NULL)	1 Good
8	2024-11-29 13:54:21	7	1 TotalActivePower	227	(NULL)	1 Good
9	2024-11-29 13:54:21	6	1 TotalActivePower	227	(NULL)	1 Good
10	2024-11-29 13:54:21	5	1 TotalActivePower	227	(NULL)	1 Good
11	2024-11-29 13:54:18	16	1 TotalActivePower	0	(NULL)	1 Good
12	2024-11-29 13:54:18	11	1 TotalActivePower	226	(NULL)	1 Good
13	2024-11-29 13:54:18	10	1 TotalActivePower	226	(NULL)	1 Good
14	2024-11-29 13:54:18	4	1 TotalActivePower	226	(NULL)	1 Good

Figure 130 Energy meters data as shown within the ecoMicrogrid storage device.

Summary of Results:

The demonstration effectively validated the ecoMicrogrid system's ability to:

- **Reliably Monitor Integrated Assets in Real-Time**: The system consistently provided real-time updates from all assets, ensuring operators had continuous visibility into the microgrid's status.

- **Ensure Accurate and Timely Data Acquisition**: Data collected from energy meters, generators, and environmental sensors was precise and updated in near real-time, supporting reliable monitoring and decision-making.
- **Maintain Stable Communication Across All Devices**: Facilitated robust and stable connections with each asset, ensuring that data flow remained uninterrupted throughout the demonstration.

MG_2UC1.3: Data concentration, storage, and management

This use case showcases the ecoMicrogrid tool's data management capabilities, emphasizing its efficiency in aggregating, storing, and managing data from the Keonjhar microgrid assets.

Description of Activities

The primary goal was to validate the complete data flow—from field devices to the Data Concentrator Module and finally to the Storage Device. The key activities undertaken included:

- **Validation of Data Collection**: Ensured consistent and reliable data acquisition from field devices, with minimal loss or delays.
- **Accuracy Verification**: Conducted rigorous checks to confirm that the collected data accurately represented real-time conditions and that any scaling or processing by the Data Concentrator Module was precise.
- **Database Integration Testing**: Confirmed that processed data was correctly written to the SQL Server database, adhering to the ecoMicrogrid data model outlined in [D4.1].

The demonstration focused on validating the ecoMicrogrid system's end-to-end data handling, from initial data capture to structured storage in the SQL Server database.

Summary of Results:

- **Reliable and Comprehensive Data Aggregation**: Real-time and historical data from all microgrid assets are centralized without loss or corruption, ensuring a complete dataset is available for analysis.
- **Secure and Scalable Data Storage**: The system effectively stores both short-term and long-term data, supporting on-demand access for real-time monitoring and in-depth analysis over extended periods.
- **Efficient Data Management**: Data retrieval is streamlined, and operators have access to organized data for performance tracking, diagnostics, and optimization of the microgrid. This supports data-driven decision-making and enhances the overall efficiency of microgrid operations.

COLUMNS

Search columns | Hide | Show

- AssetID int
- TimestampExec datetimeoffset
- TimestampRef datetimeoffset
- Point0 float
- Point1 float
- Point2 float
- Point3 float
- Point4 float
- Point5 float
- Point6 float
- Point7 float
- Point8 float
- Point9 float
- Point10 float
- Point11 float
- Point12 float
- Point13 float
- Point14 float
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- Point16 float
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	AssetID int	TimestampExec	TimestampRef datetime	Point0 float	Point1 float	Point2 float	Point3 float	Point4 float	Point5 float
	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
1	16	2024-11-29 13:31:10	2024-11-29 13:30:00	-0.759	-0.759	-0.759	-0.759	1042.02888592404	7496.708490054768
2	16	2024-11-29 12:31:20	2024-11-29 12:30:00	-0.759	-0.759	-0.759	-0.759	-0.759	5855.281634536725
3	16	2024-11-29 11:31:09	2024-11-29 11:30:00	-0.759	-0.759	-0.759	-0.759	-0.759	3598.014690131261
4	16	2024-11-29 10:31:11	2024-11-29 10:30:00	1537.3008084998335	-0.759	-0.759	-0.759	-0.759	1040.9306176499254
5	16	2024-11-29 09:31:14	2024-11-29 09:30:00	4085.3969784268284	-0.759	-0.759	-0.759	-0.759	-0.759
6	16	2024-11-29 08:31:20	2024-11-29 08:30:00	7707.635323171001	-0.759	-0.759	-0.759	-0.759	-0.759
7	16	2024-11-29 07:31:13	2024-11-29 07:30:00	7749.457592532384	1537.3008084998335	-0.759	-0.759	-0.759	-0.759
8	16	2024-11-29 06:31:43	2024-11-29 06:30:00	10354.472410401093	4552.376894201005	-0.759	-0.759	-0.759	-0.759
9	16	2024-11-29 05:31:09	2024-11-29 05:30:00	8401.430858432626	7707.635323171001	-0.759	-0.759	-0.759	-0.759
10	16	2024-11-29 04:31:10	2024-11-29 04:30:00	7526.820443466513	9495.384792458268	1719.9092832905344	-0.759	-0.759	-0.759
11	16	2024-11-29 03:31:12	2024-11-29 03:30:00	5889.779264179259	10354.472410401093	4552.376894201005	-0.759	-0.759	-0.759
12	16	2024-11-29 02:31:10	2024-11-29 02:30:00	4326.501310294469	9344.101305654169	6271.086773162769	-0.759	-0.759	-0.759
13	16	2024-11-29 01:32:20	2024-11-29 01:30:00	1279.2831322607442	8387.11976329826	7779.180937197885	1542.966352267167	-0.759	-0.759
14	16	2024-11-29 00:32:16	2024-11-29 00:30:00	-0.759	6588.2592077480585	8509.134871402754	4087.686952583297	-0.759	-0.759
15	16	2024-11-28 23:32:41	2024-11-28 23:30:00	-0.759	4326.501310294469	9344.101305654169	6271.086773162769	-0.759	-0.759
16	16	2024-11-28 22:32:19	2024-11-28 22:30:00	-0.759	1279.2831322607442	8387.11976329826	7779.180937197885	1542.966352267167	-0.759
17	16	2024-11-28 21:32:10	2024-11-28 21:30:00	-0.759	-0.759	6588.2592077480585	8509.134871402754	4087.686952583297	-0.759
18	16	2024-11-28 20:31:59	2024-11-28 20:30:00	-0.759	-0.759	4326.501310294469	9344.101305654169	6271.086773162769	-0.759
19	16	2024-11-28 17:31:58	2024-11-28 17:30:00	-0.759	-0.759	-0.759	5000.363150739034	10592.200736143994	6539.228018885431
20	16	2024-11-28 16:32:22	2024-11-28 16:30:00	-0.759	-0.759	-0.759	1459.4080958158804	9529.683585008985	8102.541774063528
21	16	2024-11-28 15:32:23	2024-11-28 15:30:00	-0.759	-0.759	-0.759	-0.759	5889.029944871922	8476.013066524532
22	16	2024-11-28 14:31:58	2024-11-28 14:30:00	-0.759	-0.759	-0.759	-0.759	3631.4595240265085	8401.42911199573
23	16	2024-11-28 13:32:02	2024-11-28 13:30:00	-0.759	-0.759	-0.759	-0.759	1068.9641177021344	7526.456191044879

Figure 131 PV forecast estimation as shown within the ecoMicrogrid storage device.

Demonstration Summary

The demonstration phase confirmed the ecoMicrogrid system's robust data handling capabilities. The Data Concentrator Module and SQL Server effectively managed and stored large datasets, supporting key functionalities such as forecasting, demand-side management, pricing strategies, and energy management system operations. These results highlight the ecoMicrogrid tool's critical role in operational management and predictive planning for the microgrid.

MG_2UC2.2: Multi objective microgrid management - Optimization of Energy Production, Storage and Purchase

The activities and results for MG_2UC2 will be documented and reported during Round 2 of the demonstration phase, where the optimization algorithms and associated performance metrics will be fully evaluated.

3.4.1.2 ecoPlanning

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

For the scope of the first round of the demonstration phase, especially for the Keonjhar demo site, following the completion of the deployment phase, the target is to perform a series of simulations, in order to assess its functionalities, target any technical issues and proceed to fixes for the finalization and preparation of the final demonstration phase round two, where the target will be to define the most sufficient energy mix to satisfy the load needs of the community.

The first round of demonstration process was to perform all the ecoPlanning simulations, so firstly collecting all the input data, then design the models and finally run the optimization studies (e.g., Energy Planning 7 years, RES Hosting Capacity, etc)

PN_2UC1.1: Data collection and storage

The primary objectives of this use case were to collect and store all necessary data as per the tool's data mapping, evaluate and test data integrity, and analyze the data exchange process between the integrated database and the tool's backend/frontend. Additionally, it aimed to operationally assess the architecture of the ecoPlanning integrated database and the speed of data transfers.
The integrated database is designed to store data from the front end related to the annual RES and load curves, or to import data using SQL Management Studio.
With the data collected and transformed, the integrated database schema, which houses this information, is illustrated in the next two images. These are static tables, meaning they do not change dynamically, but only when users create or import new data. The data is infrequently modified since it includes information that does not undergo regular changes, such as the technical datasheets for installed generation units. The architecture of the integrated database not only ensures quick responses from the tool, reducing data delays, but also allows for debugging to identify whether any issues arise from the database connections, the raw data, or within the ecoPlanning framework itself.

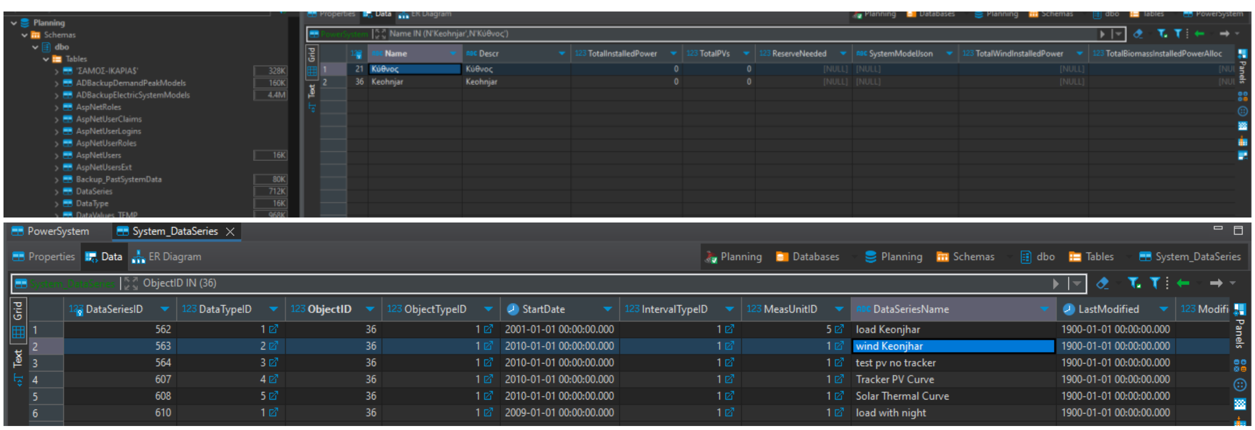


Figure 132 ecoPlanning in Keonjhar

PN_2UC1.2: Electrical models & demand peak models design, RES & Load estimation

The objectives of this use case were to develop both demand-peak and electrical system models, as illustrated in the following images.

- For the demand peak model, after testing various methods, linear extrapolation was selected as the approach to calculate demand and peak load over a seven-year horizon.
- In the electric system model, all tabs were examined. In the renewables management tab, wind farms (WFs) and biomass were modeled. Additionally, reserve requirements and other were defined in the parameters management tab.

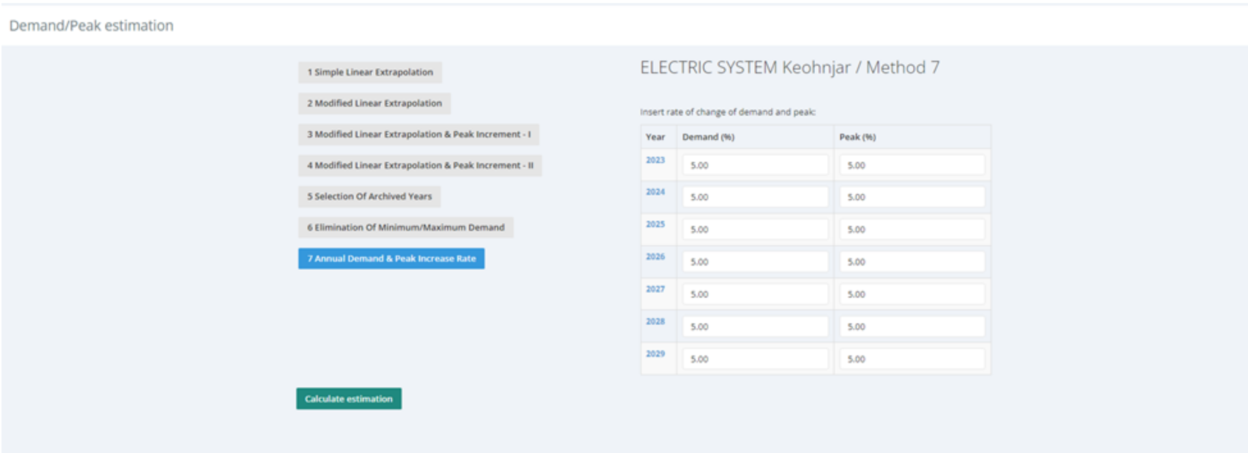
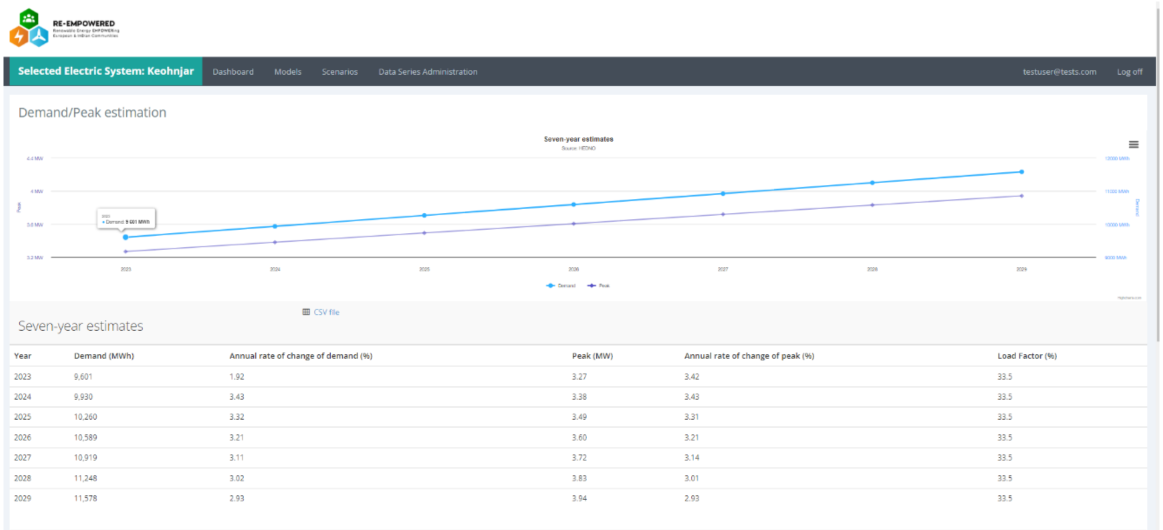


Figure 133 Page from ecoPlanning for demand/peak estimation in Keonjhar demo site



Year	Demand (MWh)	Annual rate of change of demand (%)	Peak (MW)	Annual rate of change of peak (%)	Load Factor (%)
2023	9,601	1.92	3.27	3.42	33.5
2024	9,930	3.43	3.38	3.43	33.5
2025	10,260	3.32	3.49	3.31	33.5
2026	10,589	3.21	3.60	3.21	33.5
2027	10,919	3.11	3.72	3.14	33.5
2028	11,248	3.02	3.83	3.01	33.5
2029	11,578	2.93	3.94	2.93	33.5

Figure 134 Demand/Peak estimation from ecoPlanning for Keonjhar demo site

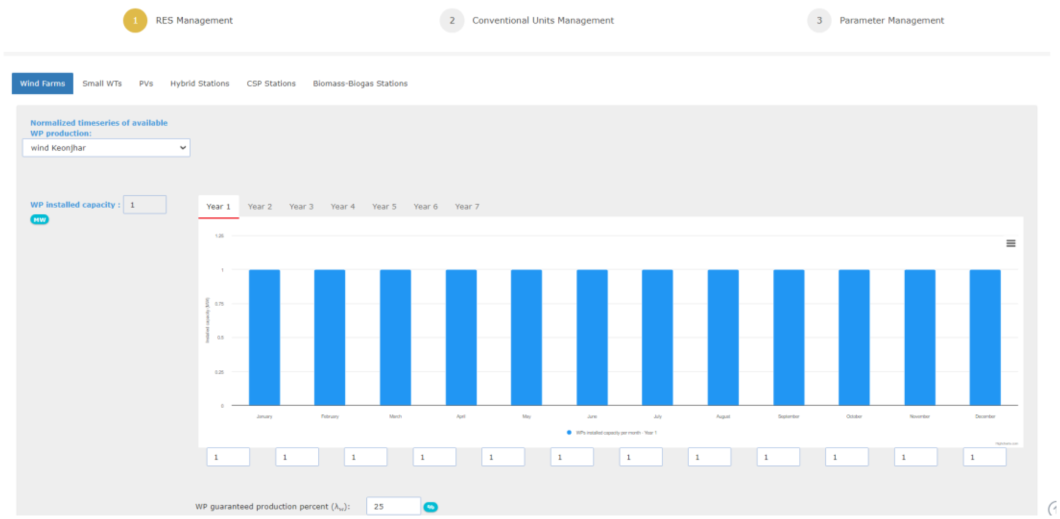


Figure 135 Page from ecoPlanning for wind farms installed capacity modeling in electric system model for Keonjhar demo site

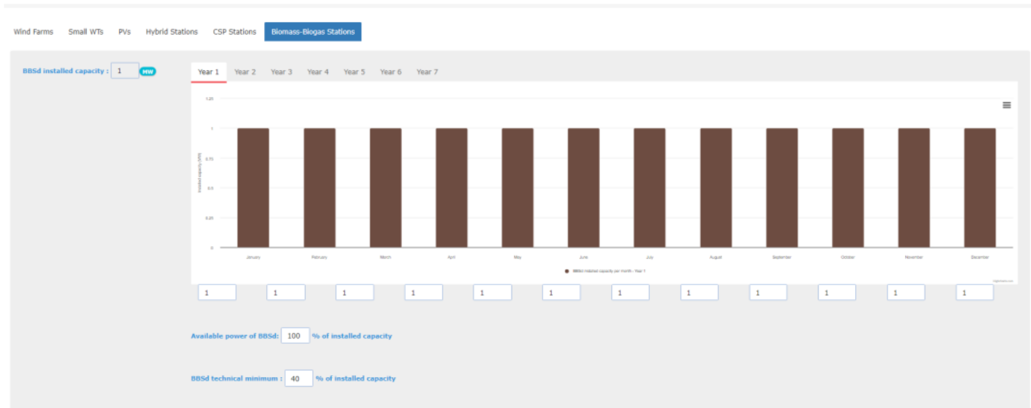


Figure 136 Page from ecoPlanning for biomass/biogas installed capacity modeling in electric system model for Keonjhar demo site

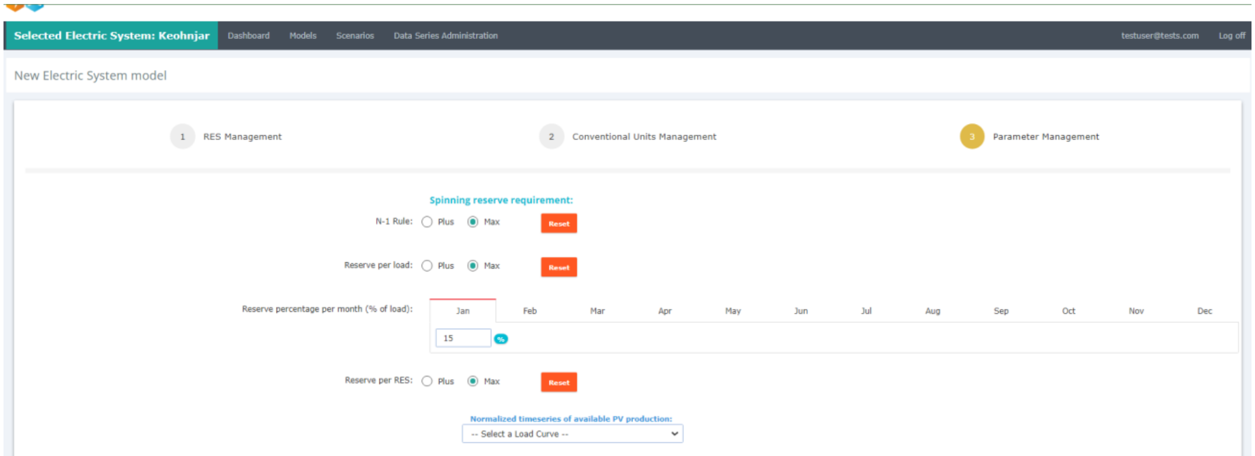


Figure 137 Page from ecoPlanning for reserve requirements in electric system model for Keonjhar demo site

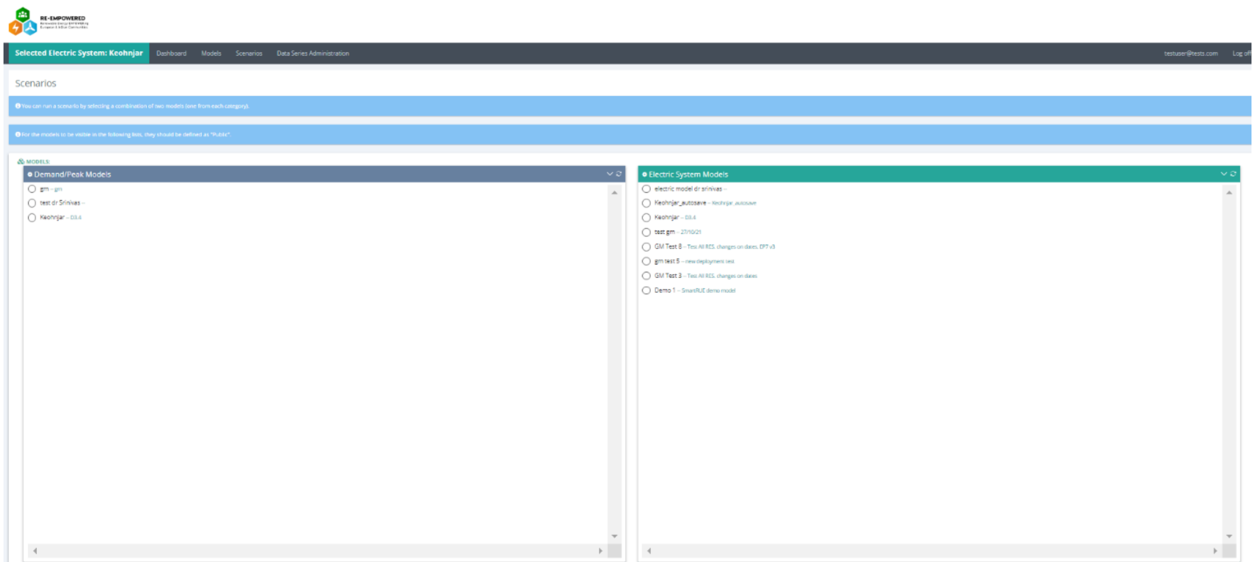


Figure 138 Page from ecoPlanning for selecting demand/peak and electrical system models for simulation

PN_2UC1.3: Optimization algorithm for mid to long term horizon (1 to 7 years), for hourly Unit Commitment, maximizing RES penetration and securing normal operation

In this scenario, the objective was to obtain the export and examine the key performance indicators (KPIs), while also aligning them with the CSV outputs of the analysis. Specifically, as illustrated in the upcoming images, an annual energy mix graph is exported, along with a series of tables that present details on the aggregated annual results for thermal and renewable energy sources (RES) production, general input parameters, various costs, etc.

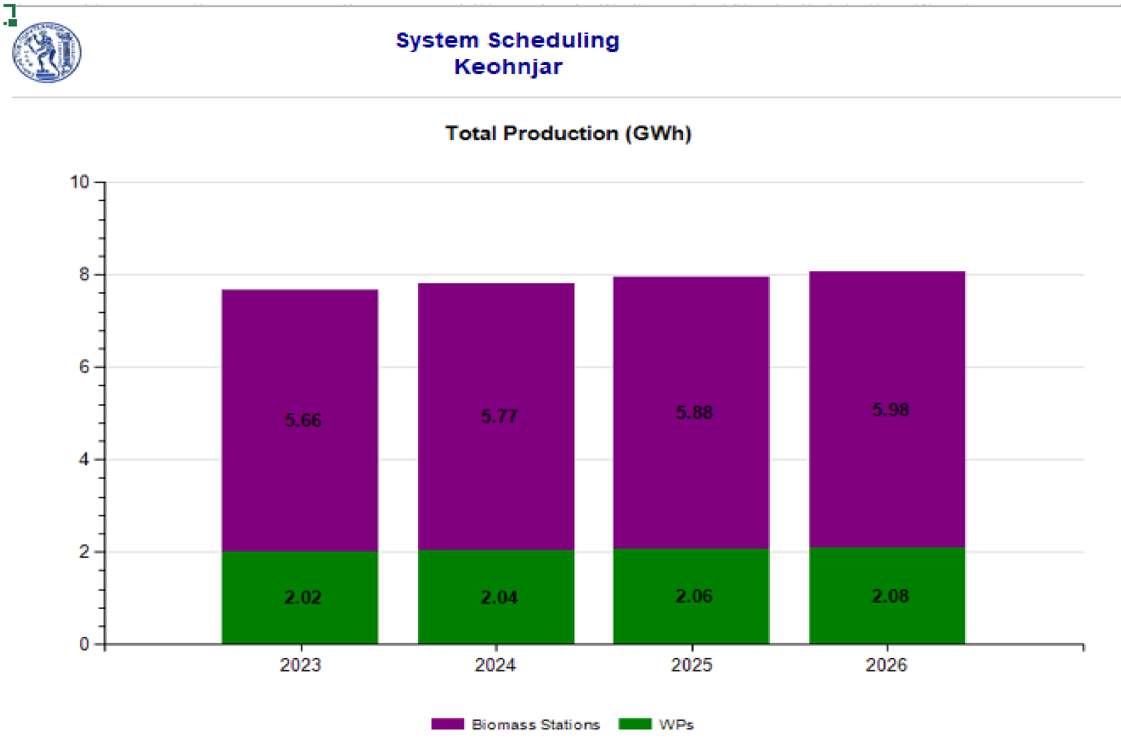


Figure 139 Report output from ecoPlanning displaying the energy mix over the selected horizon for Keonjhar demo site

Aggregated results

	2023	2024	2025	2026
Thermal production (MWh)	0.00	0.00	0.00	0.00
RES production (MWh)	7,678.40	7,814.99	7,944.09	8,064.61
Demand (MWh)	9,601.00	9,930.40	10,259.80	10,589.20
Annual RES penetration (% of	79.98	78.70	77.43	76.16
Maximum instantaneous	46.67	46.67	46.67	46.67
WPs equivalent full load hours (h)	4,219.87	4,345.90	4,470.88	4,597.17
WPs capacity factor (%)	23.02	23.29	23.54	23.76
Diesel consumption (klt)	0.00	0.00	0.00	0.00
Mazut consumption (tn)	0.00	0.00	0.00	0.00
CO2 emissions (tn)	0.00	0.00	0.00	0.00

Figure 140 Report output from ecoPlanning displaying aggregated results over the selected horizon for Keonjhar demo site

Annual production per type of RES (MWh)

Type of RES	Name	2023	2024	2025	2026
Biomass Stations	BIO_D	5,661.47	5,774.38	5,881.95	5,983.01
	Total	*5,661*	*5,774*	*5,882*	*5,983*
WPs	WT	2,016.93	2,040.62	2,062.15	2,081.61
	Total	*2,017*	*2,041*	*2,062*	*2,082*
Total Sum		***7,678.40***	***7,814.99***	***7,944.09***	***8,064.61***

Non-dispatched RES energy per annum (% of declared)

RES type	Name	2023	2024	2025	2026
Biomass Stations	BIO_D	35.37	34.08	32.85	31.70

Rejected RES energy per annum (% of primarily available)

RES type	Name	2023	2024	2025	2026
Biomass Stations	BIO_D	35.37	34.08	32.85	31.70

Miscellaneous results

	2023	2024	2025	2026
Hours with non-served load or non-observed	7,200.00	7,500.00	7,662.00	7,757.00
Maximum non-served load or non-observed	2.75	2.88	3.01	3.13
Total non-served load and non-observed	2,994.58	3,285.13	3,585.64	3,894.91
Hours with non-served load (h)	5,667.00	5,874.00	6,073.00	6,292.00
Maximum non-served load (MW)	2.26	2.37	2.48	2.59
Total non-served load (MWh)	1,922.60	2,115.41	2,315.71	2,524.59
Hours with underload of conventional units (h)	0.00	0.00	0.00	0.00

Figure 141 Report output from ecoPlanning displaying the various results over the selected horizon for Keonjhar demo site

Costs

	2023	2024	2025	2026
Fuel cost (€)	0.00	0.00	0.00	0.00
CO2 emissions allowance cost (€)	0.00	0.00	0.00	0.00
Additional variable cost (O&M) (€)	0.00	0.00	0.00	0.00
Variable cost of thermal production (€)	0.00	0.00	0.00	0.00
WP production cost (€)	201,692.82	204,061.85	206,214.53	208,160.67
Biomass production cost (€)	1,053,034.27	1,074,033.80	1,094,041.97	1,112,839.22
RES production cost (€)	1,254,727.09	1,278,095.65	1,300,256.50	1,320,999.89
Total production cost (€)	1,254,727.09	1,278,095.65	1,300,256.50	1,320,999.89
Average thermal production variable cost (€/MWh)	NaN	NaN	NaN	NaN
Average system cost (€/MWh)	130.69	128.71	126.73	124.75

Figure 142 Report output from ecoPlanning displaying the costs over the selected horizon for Keonjhar demo site

PN_2UC2.1: Electrical models & demand peak models design, RES & Load estimation, RES units dimensions and thresholds

This use case's targets were to create both demand-peak and electrical system models;

- for the demand peak model, the same model as in Energy Planning 7 was chosen. Yet, since the study of the Hosting Capacity that is examined in this use case only runs for the first year of each combination, this method is the suggested one.
- for the electric system model, the one from the previous use case was used, and scenarios with various Wind Farms and PV parks installed capacity were tested.

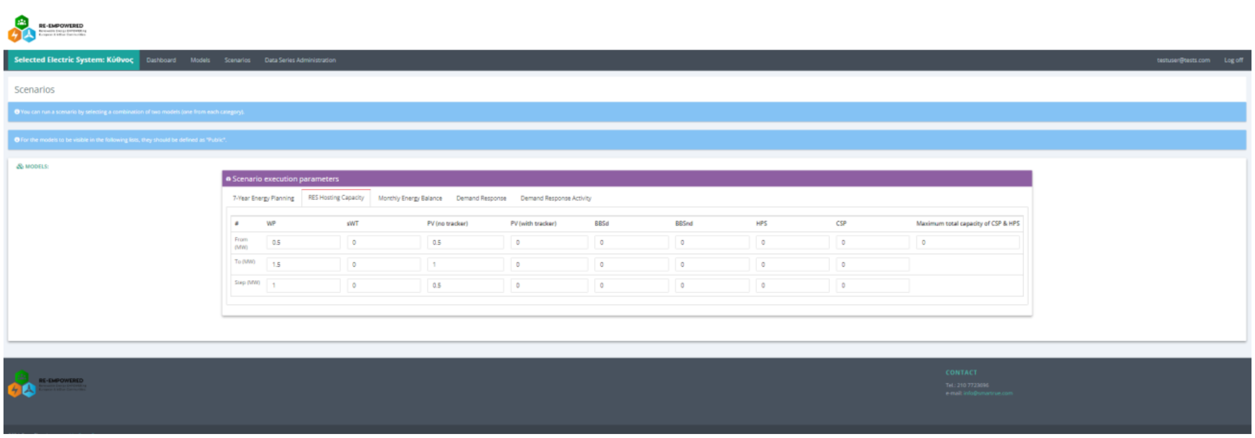


Figure 143 Page from ecoPlanning displaying the input parameters for the Hosting Capacity study for Keonjhar demo site

PN_2UC2.2: Scenario simulation through optimization for 1 year per scenario run, for hourly Unit Commitment

In this case, the aim was to obtain the export and explore the key performance indicators (KPIs) relevant to the study, while also correlating them with the CSV outputs from the analysis. Specifically, during the Hosting Capacity study demonstration, four scenarios were created and simulated, as depicted in the following images. The renewable energy sources (RES) under consideration included various levels of installed capacity for Wind Farms and Biomass, as well as their combinations. The aggregated results feature tables that present information on different costs, various RES outcomes, and instances of RES rejections.

System cost

Scenario No	Fuel cost (€)	CO2 emissions allowance cost (€)	Additional variable cost (O&M) (€)	Variable cost of thermal production (€)	RES production cost (€)	Total production cost (€)	Average thermal production variable cost (€/MWh)	Average system cost (€/MWh)
1	0.00	0.00	0.00	0.00	903,874.96	903,874.96	NaN	94.14
2	0.00	0.00	0.00	0.00	679,928.93	679,928.93	NaN	70.82
3	0.00	0.00	0.00	0.00	923,122.19	923,122.19	NaN	96.15
4	0.00	0.00	0.00	0.00	696,785.36	696,785.36	NaN	72.57

RES cost

Scenario No	WP production	Biomass	Total
1	101,344.54	802,530.41	**903,874.96**
2	53,946.69	625,982.24	**679,928.93**
3	170,833.44	752,288.75	**923,122.19**
4	102,429.25	594,356.11	**696,785.36**

Figure 144 Report output from ecoPlanning - HC displaying various costs over the simulated scenarios for Keonjhar demo site

Miscellaneous RES results

Scenario No	Annual RES penetration (% of load)	Maximum instantaneous penetration of Non-	WPs capacity factor (%)	WPs equivalent full load hours (h)	Non-dispatched energy of Dispatchable RES	Rejected energy of Dispatchable RES units (% of primarily	Spinning reserve ratio (% of the production of the
1	55.50	46.67	5.78	1,921.32	83.58	83.58	22.99
2	40.67	42.41	3.08	1,778.70	90.40	90.40	152.81
3	59.92	46.67	4.88	687.51	84.61	84.61	48.54
4	43.95	46.67	2.92	625.83	90.88	90.88	148.00

RES production (MWh)

RES type	Biomass Stations	WPs	Total
Scenario No	BIO_D	WT	
1	4,314.68	1,013.45	**5,328.13**
2	3,365.50	539.47	**3,904.96**
3	4,044.56	1,708.33	**5,752.90**
4	3,195.46	1,024.29	**4,219.76**

Figure 145 Report output from ecoPlanning - HC displaying RES production results over the simulated scenarios for Keonjhar demo

Non-dispatched RES energy (% of declared)

RES type	Biomass Stations
Scenario No	BIO_D
1	83.58
2	90.40
3	84.61
4	90.88

Rejected RES energy (% of primarily available)

RES type	Biomass Stations
Scenario No	BIO_D
1	83.58
2	90.40
3	84.61
4	90.88

RES investments Internal Rate of Return (%)

RES type	Biomass Stations	WPs
Scenario No	BIO_D	WT
1	-16.26	-21.61
2	549,076,932.70	69,646,951.24
3	-17.46	-24.55
4	548,081,536.35	139,269,766.93

Figure 146 Report output from ecoPlanning - HC displaying various costs over the simulated scenarios for Keonjhar demo

PN_2UC3.1: Electrical models, demand peak models & interconnections design, RES & Load estimation

Due to technical bugs of the front end this use case was not thoroughly assessed in the scope of the demonstration round 1, and will be examined analytically at the demonstration round 2.

PN_2UC3.2: Hourly Unit Commitment, through optimization algorithm for mid to long term horizon

Due to technical bugs of the front end this use case was not thoroughly assessed in the scope of the demonstration round 1, and will be examined analytically at the demonstration round 2.

PN_2UC4.1: Energy carriers' identification, data collection and quantification of impact on total load (hourly)

Through the *"Energy carriers' identification, data collection and quantification of impact on total load (hourly)"* use case, which was fulfilled in round 1 (with limited testing), the user may actually implement strategies such as Peak Shaving, RES production reallocation and desalination activities integration. Their correspond pages are depicted below, yet their thorough examination is left for the second demonstration round, as their algorithm did not converge to an optimal solution.

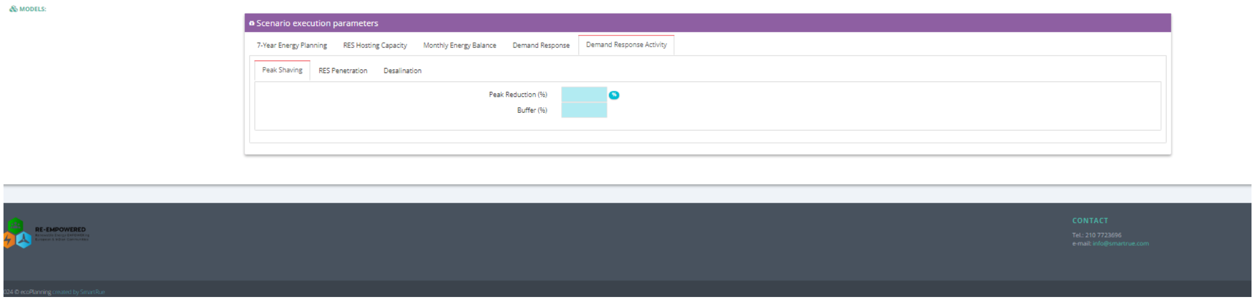


Figure 147 Page from ecoPlanning displaying the input of Demand Response study for peak saving in Keonjhar demo site

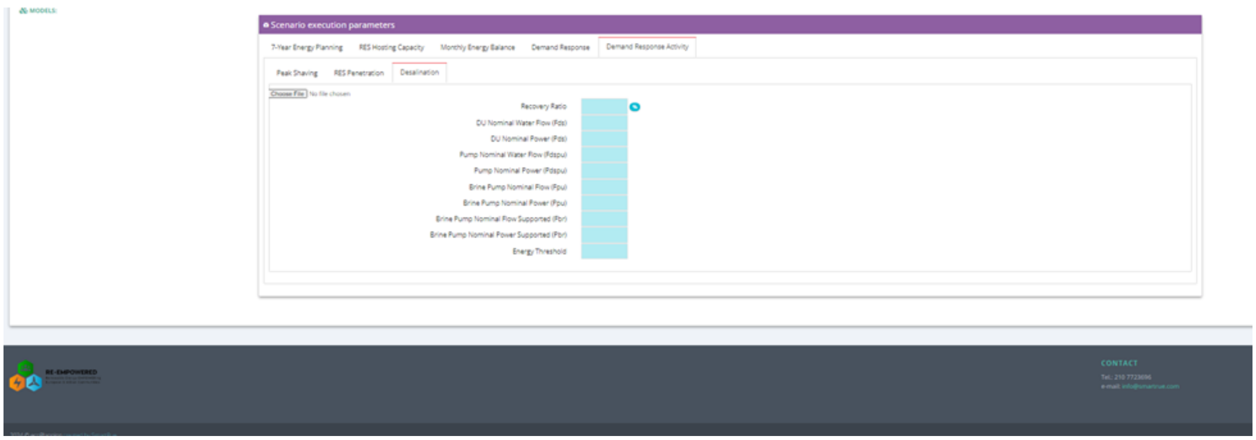


Figure 148 Page from ecoPlanning displaying the input of Demand Response study for desalination in Keonjhar demo site

PN_2UC4.2: Electrical models & demand peak design, RES & Load estimation, energy carriers' scenarios integration

The objectives of this use case were to develop both demand-peak and electrical system models, as illustrated in the following images.

- For the demand peak model, after evaluating all methods, the option that allows the user to import the demand curve for simulation was selected.
- For the electrical system model, the one from earlier use cases was utilized, with the main focus being to verify that the imported load is indeed applied in the simulation.

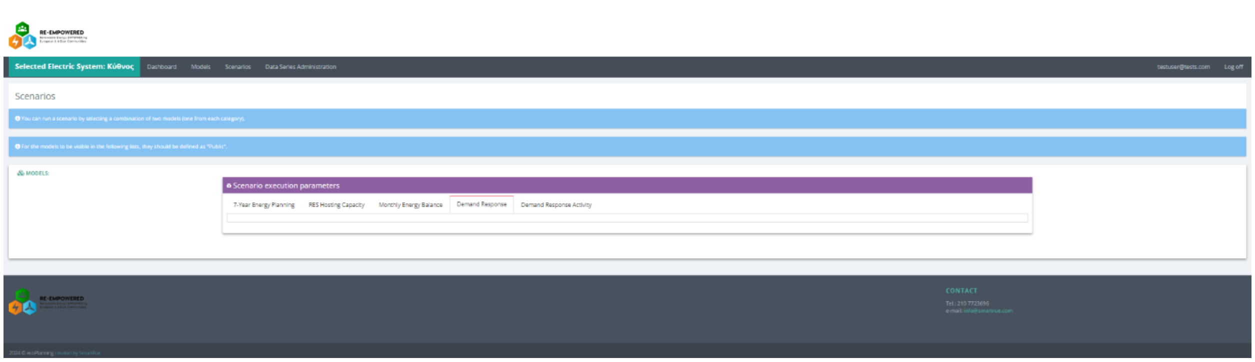
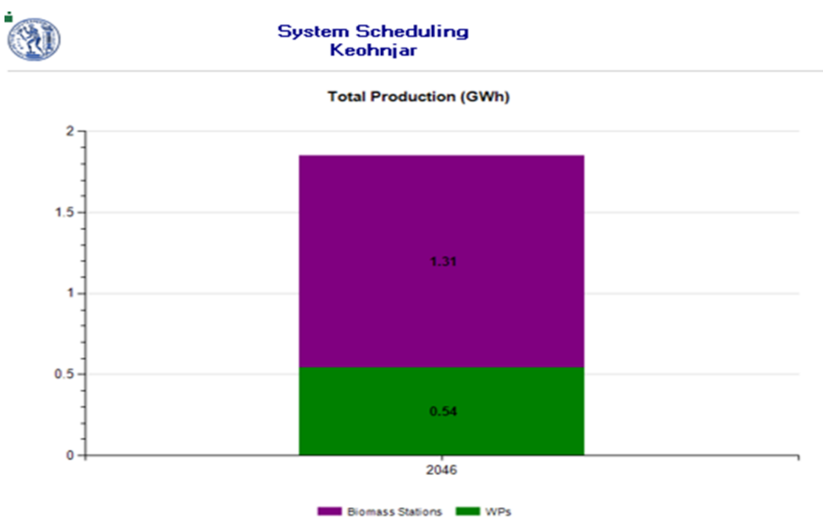


Figure 149 Page from ecoPlanning displaying the input of Demand Response study in Keonjhar demo site

PN_2UC4.3: Optimal Unit Commitment for mid to long term horizon, based on multi energy carriers

In this use case, the objective was to obtain the export and examine the key performance indicators (KPIs), while also aligning them with the CSV outputs of the analysis. Specifically, as depicted in the following images, an annual energy mix graph is exported along with a series of tables detailing the aggregated production results, among other data. The aim of this study is to compare how the integrated demand response activities included in the imported load curve affect these KPIs, in contrast to the load curve that does not incorporate demand response.

Figure 150 Page from ecoPlanning displaying the input of Demand Response study for dedicated load in Keonjhar demo site



Aggregated results

	2046
Thermal production (MWh)	0.00
RES production (MWh)	1,854.29
Demand (MWh)	2,624.00
Annual RES penetration (%	70.67
Maximum instantaneous	46.67
WPs equivalent full load	1,082.77
WPs capacity factor (%)	6.20
Diesel consumption (klt)	0.00
Mazut consumption (tn)	0.00
CO2 emissions (tn)	0.00

Figure 151 Report output from ecoPlanning - DR displaying energy mix over the simulated scenario for Keonjhar demo site

Annual production per type of RES (MWh)

Type of RES	Name	2046
Biomass Stations	BIO_D	1,311.29
	Total	*1,311*
WPs	WT	543.00
	Total	*543*
Total Sum		***1,854.29***

Non-dispatched RES energy per annum (% of declared)

RES type	Name	2046
Biomass Stations	BIO_D	85.03

Rejected RES energy per annum (% of primarily available)

RES type	Name	2046
Biomass Stations	BIO_D	85.03

Miscellaneous results

	2046
Hours with non-served load or non-observed reserve (h)	6,070.00
Maximum non-served load or non-observed reserve (MW)	0.40
Total non-served load and non-observed reserve (MWh)	769.95
Hours with non-served load (h)	6,058.00
Maximum non-served load (MW)	0.40
Total non-served load (MWh)	769.70
Hours with underload of conventional units (h)	0.00

Figure 152 Report output from ecoPlanning - DR displaying various results over the simulated scenario for Keonjhar demo site

3.4.1.3 ecoDR

The ecoDR tool focuses on the development of advanced smart meters 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 loads. It incorporates advanced metering infrastructure (AMI) with inbuilt load controller and protection functionalities, allowing for efficient measurement of household energy consumption. Additionally, it communicates with ecoMicrogrid, to implement demand-side management services through non-critical load scheduling.

DR_2UC1.1: Real time monitoring of energy consumption

This use case was not thoroughly assessed in the scope of the demonstration round 1, and will be assessed at the demonstration round 2.

DR_2UC2.1: Scheduling of loads

This use case was not thoroughly assessed in the scope of the demonstration round 1, and will be assessed at the demonstration round 2.

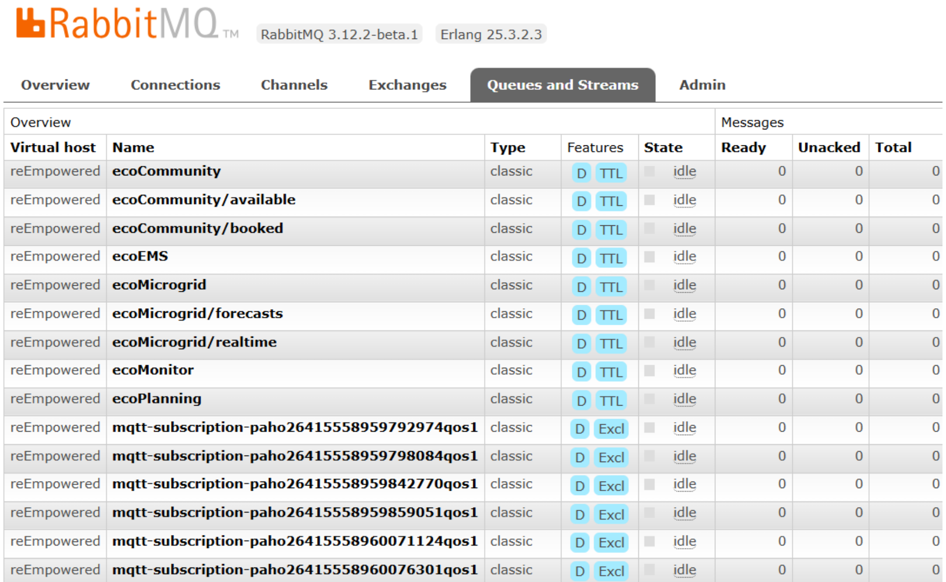
DR_2UC2.2: Programmable Load shedding controller

This use case was not thoroughly assessed in the scope of the demonstration round 1, and will be assessed at the demonstration round 2.

3.4.1.4 ecoPlatform

PT_2UC2.1: Facilitate data exchange between dependent tools

During the demonstration, ecoPlatform played a critical role in facilitating seamless data exchange between various dependent tools. These tools included energy management systems, real-time monitoring modules, and load forecasting algorithms. The platform ensured that data, such as energy production, battery storage levels, and consumption patterns, flowed efficiently between the tools in real time. This enabled the microgrid to respond dynamically to changes in energy demand and supply, optimizing resource allocation and improving overall grid performance.

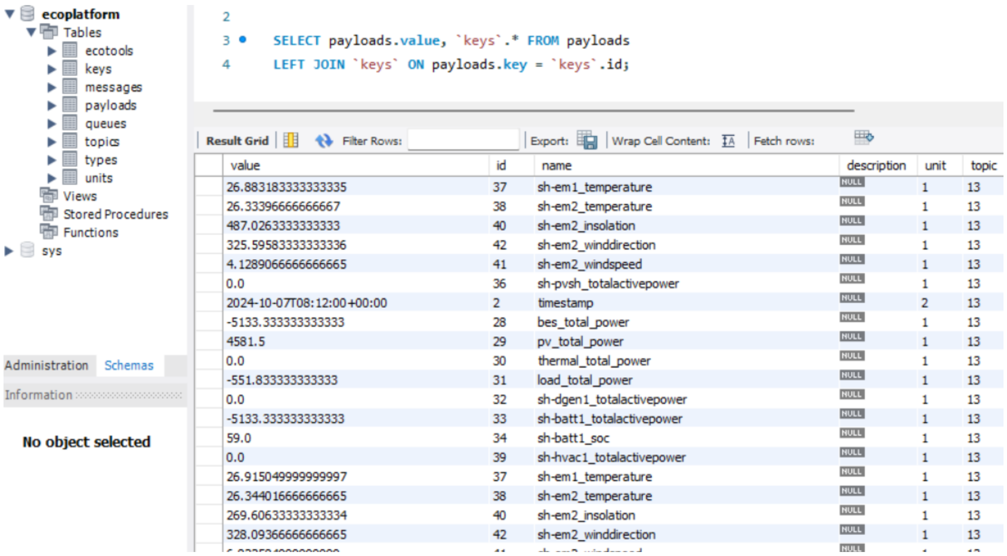


Overview					Messages		
Virtual host	Name	Type	Features	State	Ready	Unacked	Total
reEmpowered	ecoCommunity	classic	D TTL	idle	0	0	0
reEmpowered	ecoCommunity/available	classic	D TTL	idle	0	0	0
reEmpowered	ecoCommunity/booked	classic	D TTL	idle	0	0	0
reEmpowered	ecoEMS	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid/forecasts	classic	D TTL	idle	0	0	0
reEmpowered	ecoMicrogrid/realtime	classic	D TTL	idle	0	0	0
reEmpowered	ecoMonitor	classic	D TTL	idle	0	0	0
reEmpowered	ecoPlanning	classic	D TTL	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959792974qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959798084qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959842770qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558959859051qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558960071124qos1	classic	D Excl	idle	0	0	0
reEmpowered	mqtt-subscription-paho26415558960076301qos1	classic	D Excl	idle	0	0	0

Figure 153 Queues for data exchange between dependent tools

PT_2UC3.1: Route the microgrid data and data from dependent tools to cloud database

In this use case, ecoPlatform routed vital data from the microgrid and its dependent tools to a secure cloud database. Real-time data from energy generation units, consumption points, and storage systems were continuously transmitted to the cloud for archiving and future analysis. The cloud storage solution ensured that critical energy system data was available for long-term studies, improving energy management decisions and system optimization.



value	id	name	description	unit	topic
26.883183333333335	37	sh-em1_temperature	NULL	1	13
26.33396666666667	38	sh-em2_temperature	NULL	1	13
487.0263333333333	40	sh-em2_insolation	NULL	1	13
325.59583333333336	42	sh-em2_winddirection	NULL	1	13
4.1289066666666665	41	sh-em2_windspeed	NULL	1	13
0.0	36	sh-pvsh_totalactivepower	NULL	1	13
2024-10-07T08:12:00+00:00	2	timestamp	NULL	2	13
-5133.333333333333	28	bes_total_power	NULL	1	13
4581.5	29	pv_total_power	NULL	1	13
0.0	30	thermal_total_power	NULL	1	13
-551.833333333333	31	load_total_power	NULL	1	13
0.0	32	sh-dgen1_totalactivepower	NULL	1	13
-5133.333333333333	33	sh-batt1_totalactivepower	NULL	1	13
59.0	34	sh-batt1_soc	NULL	1	13
0.0	39	sh-hvac1_totalactivepower	NULL	1	13
26.915049999999997	37	sh-em1_temperature	NULL	1	13
26.344016666666665	38	sh-em2_temperature	NULL	1	13
269.60633333333334	40	sh-em2_insolation	NULL	1	13
328.09366666666665	42	sh-em2_winddirection	NULL	1	13

Figure 154 Data from dependent tools to cloud database

PT_2UC3.2: Facilitate archived data access for dependent tools using API

The ecoPlatform in the microgrid enabled dependent tools to retrieve archived data efficiently through an API. This functionality allowed various tools, such as energy management systems and forecasting algorithms, to access historical microgrid data, including energy consumption, generation, and storage metrics. The API-based data retrieval was critical in ensuring that these tools had real-time access to the historical data they needed without manual intervention, thereby improving the accuracy and responsiveness of the energy management processes.

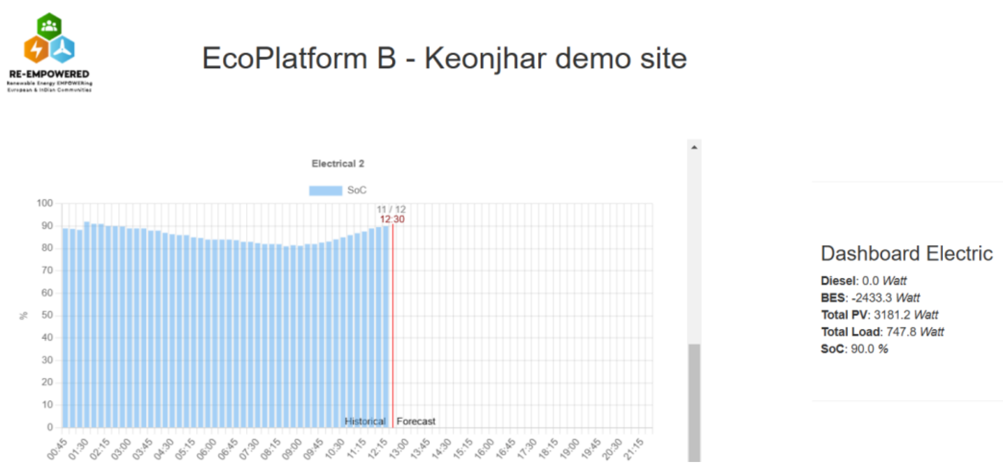


Figure 155 ecoPlatform – B dashboard in Keonjhar via API

3.4.1.5 ecoCommunity

The first round of demonstrations of the ecoCommunity tool in Keonjhar demo site was conducted in November 2024. A total of six consumers were included in the tool user database during the first round of demonstration. The user access is managed by the demo site administrator using the Users modules. The module lists all the users in the demo site and is able to control the access of the users. To enhance usability, the tool supports three languages: English, Hindi, and Odia—offering greater convenience for consumers.

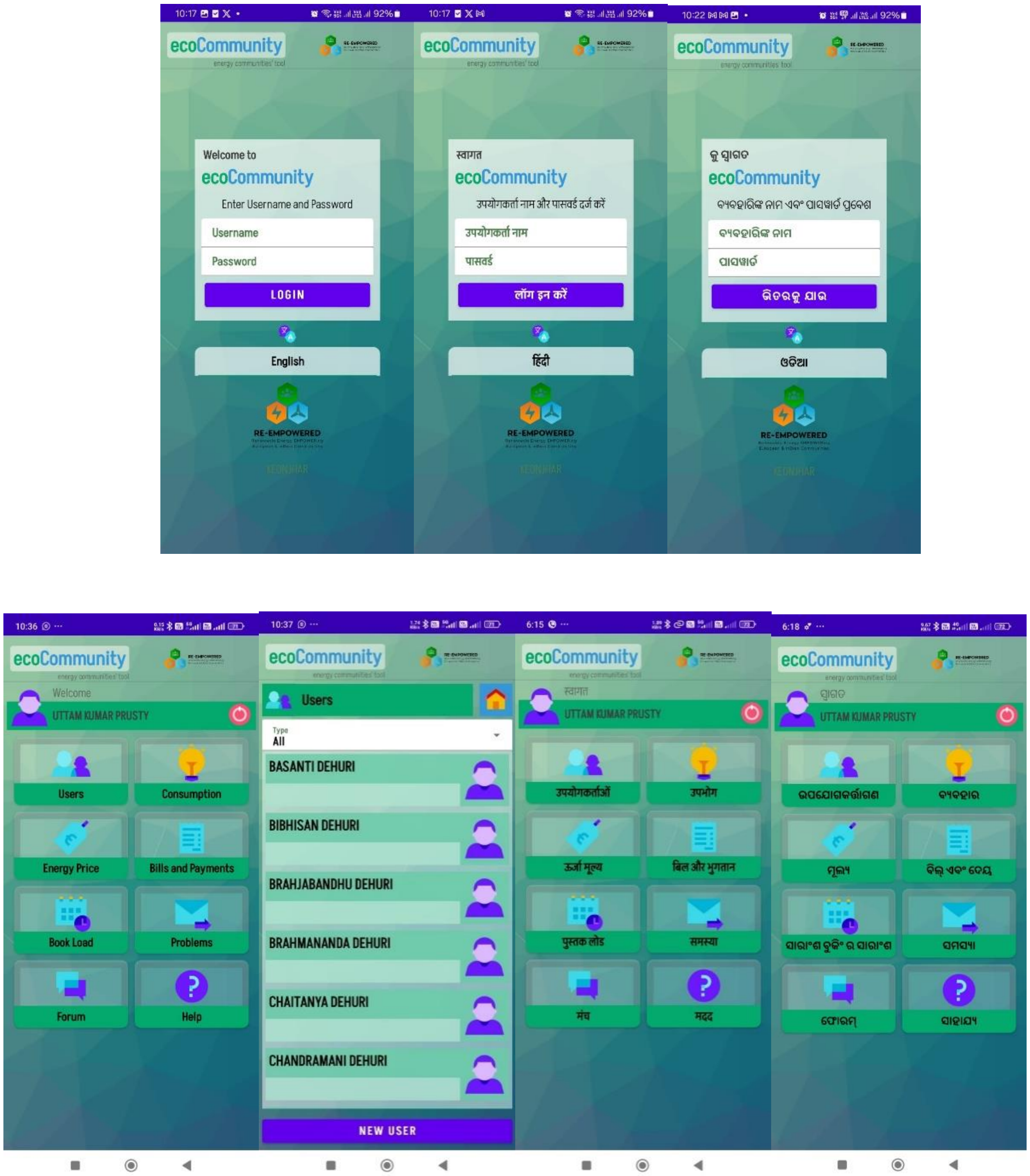


Figure 156 Screenshots of ecoCommunity user module for Keonjhar demo site (above). Login interface in all the three languages (below). List of users and welcome interface

CM_2UC1.2: Billing and payments

The Bills & Payments module in the ecoCommunity tool allows consumers to easily view and pay their bills, as demonstrated in the screenshot below.

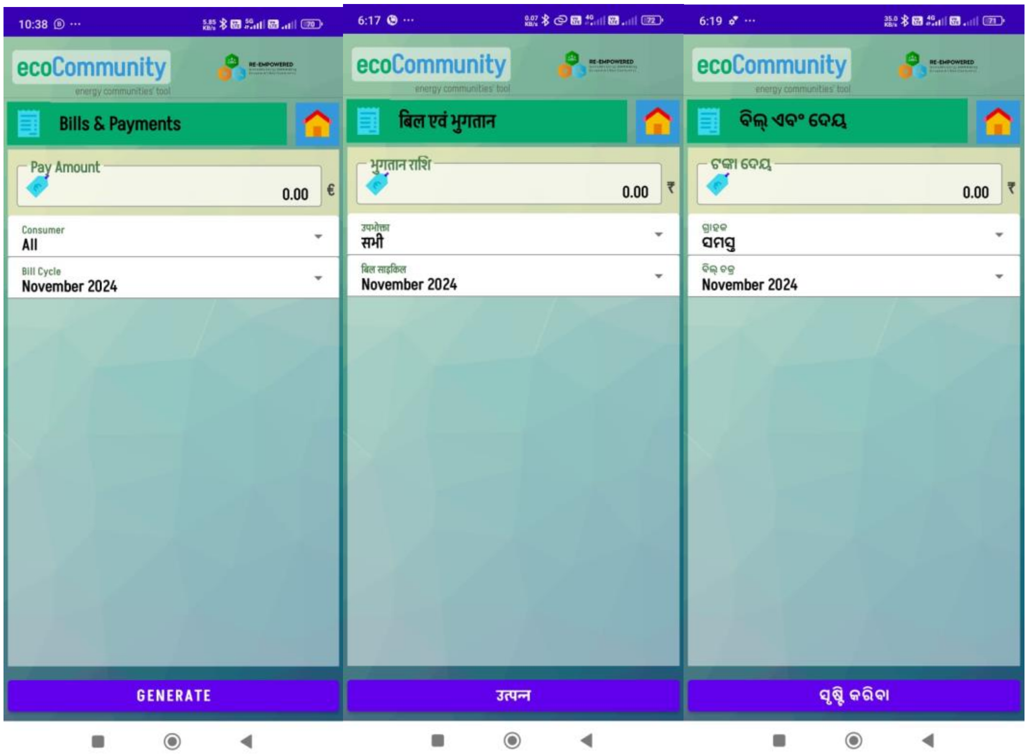


Figure 157 Screenshots of bill payments module for Keonjhar demo site in all the three languages

CM_2UC2.1: Facilitating(display) of the scheduling and shifting of non-critical and flexible loads

The administrator user manages the creation of the time slots based on the availability data received from ecoMicrogrid and the booking summary is sent back to ecoMicrogrid at the end of the day. The following screenshot shows the booking summary page from administrator user. The energy consumption of the consumers can easily be monitored by recent, daily or monthly consumption information in the consumption module.

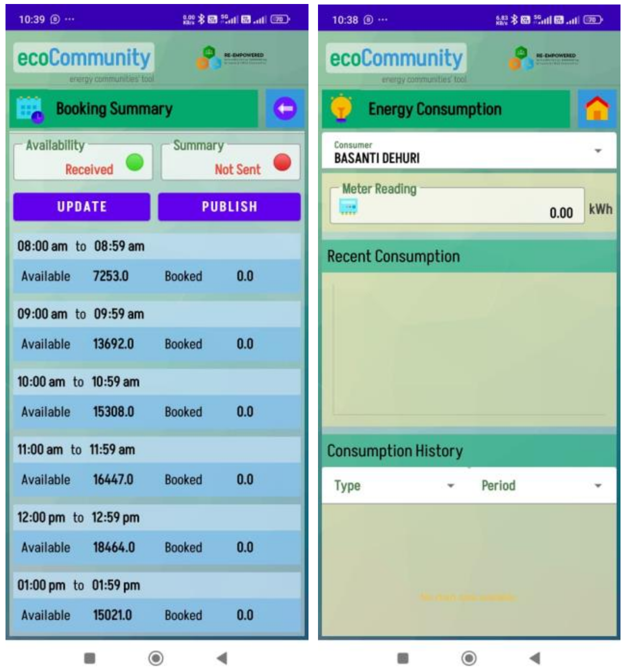


Figure 158 Screenshots of booking summary and energy consumption module for Keonjhar demo site

CM_2UC2.2: Coordination of communal/shared loads

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.1: Feedback and suggestions from users about the tools

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC3.2: Reporting of problem

Problems module is created to report a problem for the ecoCommunity users at Keonjhar demosite as shown in the below figure.

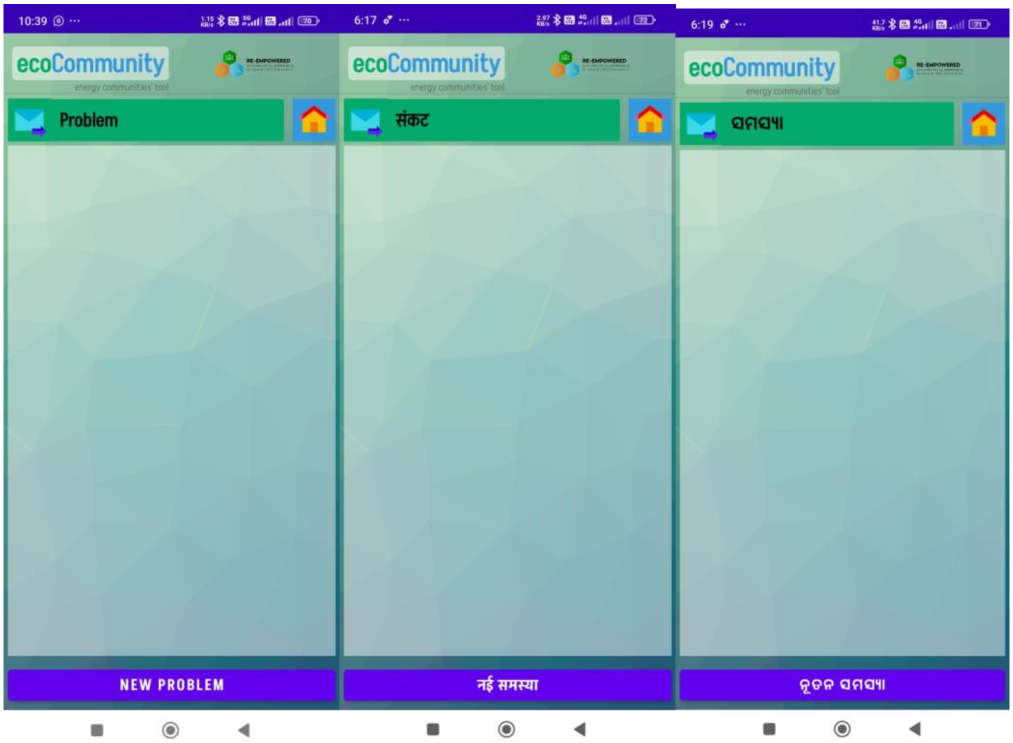


Figure 159 Screenshots of ecoCommunity interface for reporting a problem at Keonjhar demo site

CM_2UC3.3: Forum to share experiences

A module named "Forum" has been developed to facilitate discussions among ecoCommunity users at the Keonjhar demo site, as illustrated below. This platform also allows users to share their experiences with the community and the administrator.

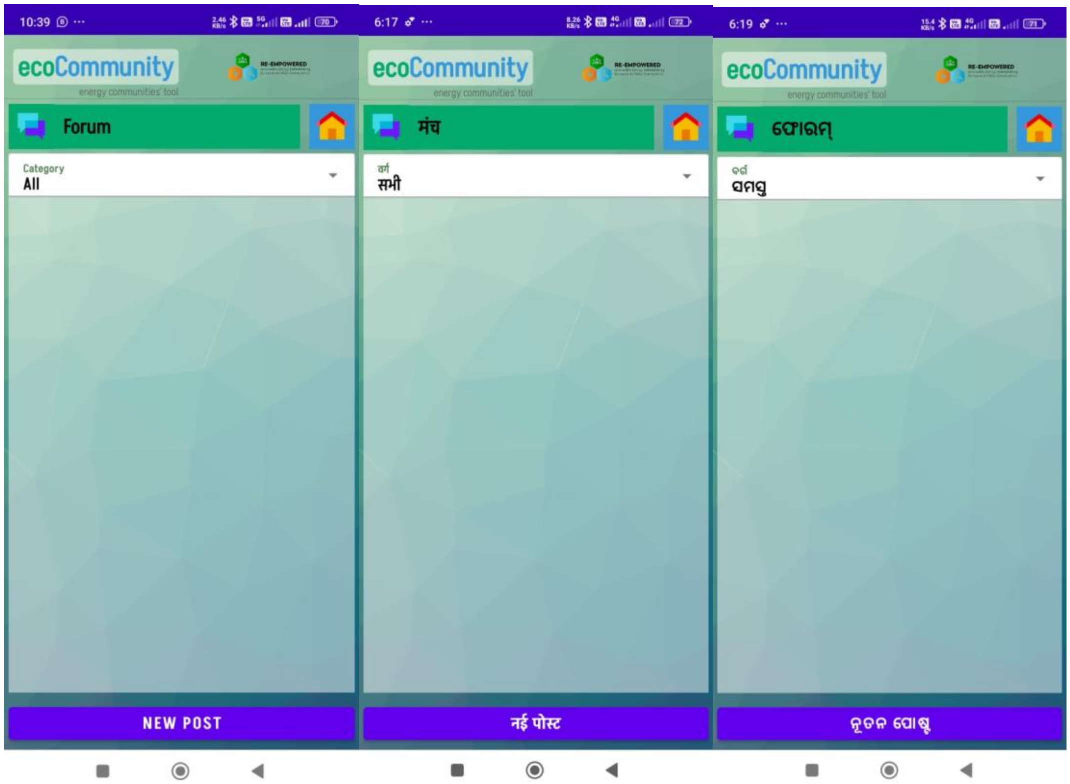


Figure 160 Screenshots of sharing experience module for the consumers at Keonjhar demo site

CM_2UC4.1: Training material (troubleshooting)

This Use case will be demonstrated in the 2nd demonstration round.

CM_2UC4.2: Easy-to-use multimedia material and step-by-step guides (walkthroughs)

Manuals and help materials are added to the tool which can provide guide to the various tool users and demo site administrators.

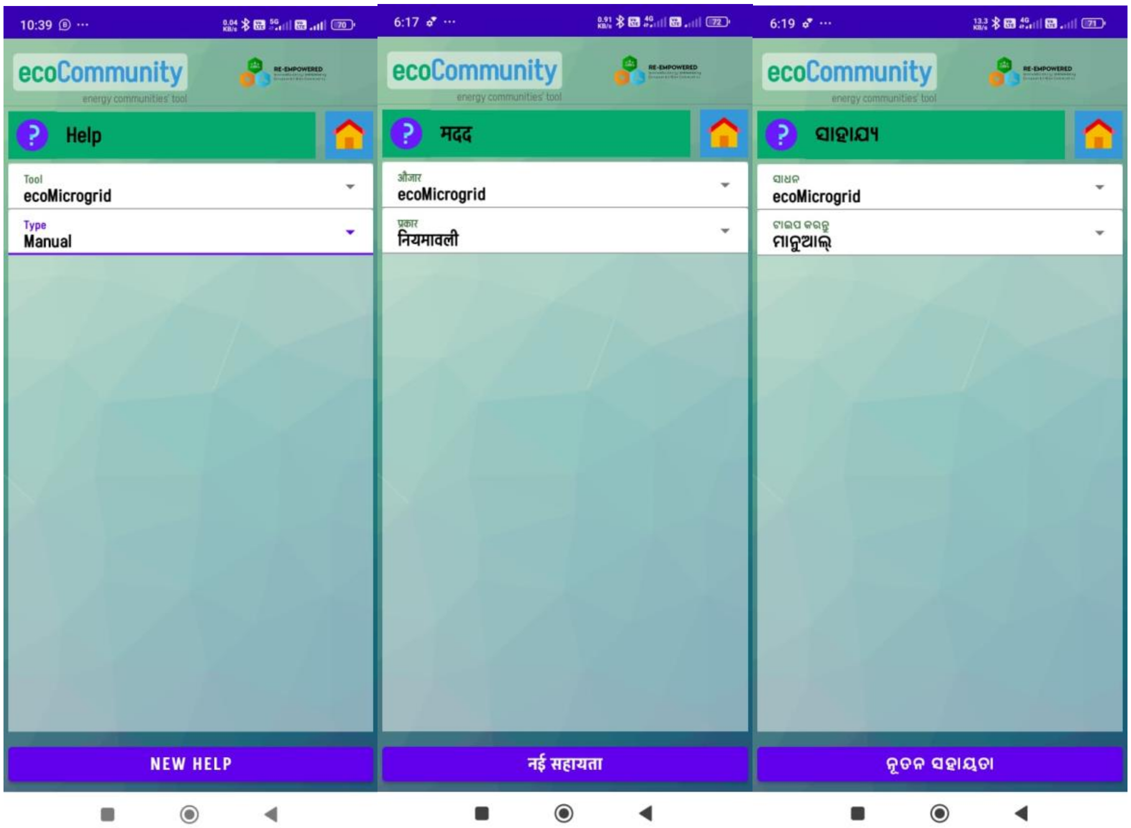


Figure 161 Screenshots of help module in Keonjhar demo site

3.4.1.6 ecoVehicle

VH_2UC2.2: Customization of the vehicle to the demo site requirements

In this use case, the goal was to upgrade the drivetrain to suit hilly regions at Keonjhar demo site. For this, the existing drivetrain has been upgraded to a 2 kW BLDC motor with a matching controller and suitable rear axle to carry max 500 kg payloads. The vehicle is utilized for transportation of passengers (max 6 persons) and goods in the hilly regions at reduced speed. Further, the electric three wheelers are modified and customized in such a way that it can be easily converted to carry only goods when passengers are fewer and vice versa


Figure 162 Electric three-wheeler powertrain upgraded to 2 kW BLDC motor with matching controller and (right) deployment at Keonjhar demo site

Figure 163 (Left) Electric three-wheeler converted into an electric loader to transport goods (seating arrangement and canopy removed) and (right) modular seating arrangement and canopy for carrying passengers.

3.4.2 List of adaptations for demonstration round 2

During the ecoMicrogrid Demonstration Round 1, several debugging efforts were undertaken to ensure the seamless operation for Demonstration Round 2. These efforts aimed to resolve technical inconsistencies, optimize performance, and enhance the overall system functionality. The following bullets outlines the key improvements that were implemented to ensure smoother operations and greater reliability of the ecoMicrogrid system.

- **Register Mapping Errors**: During the initial deployment, multiple errors were detected in the register mapping and registers scaling of connected devices. To resolve this, the register mappings were meticulously reviewed and corrected, ensuring that data was accurately transmitted.
- **SoC Estimation Tunning**: The State of Charge estimation algorithm, designed to support the Keonjhar operation, was refined. The original parameter set was insufficient to accurately reflect the actual battery operations. Based on the insights gained from Round 1, a new set of parameters was selected, allowing for improved accuracy in tracking the battery's real-time SoC and ensuring better alignment with operational conditions.
- **Failed Energy Meter**: During the first demonstration round, the communication card of one of the energy meters was identified to be damaged. To address this, a replacement part was sourced, and the faulty energy meter was replaced promptly.
- **Cellular Network Plan**: It was identified that the cellular network plan in place was insufficient to support remote maintenance activities, resulting in communication delays and limitations in troubleshooting capabilities. In response, a revised network plan was purchased, offering better coverage and bandwidth to facilitate smoother remote monitoring and maintenance.

Concerning ecoPlanning, due to technical bugs of the front end, the use cases PN_2UC3.1, PN_2UC3.2 were not thoroughly assessed in the scope of the demonstration round 1, and will be examined analytically at the demonstration round 2. Also, at demonstration round 2, the RE-

EMPOWERED logo will be included in the output graphs, as well as more technologies which will be simulated in the Hosting Capacity study.

The following aspects concern the debugging process of ecoPlatform:

- Communication Delays between dependent tools were identified and addressed by optimizing data exchange protocols.
- API Stability was improved to enhance response times for archived data retrieval.
- Cloud Data Transmission issues were resolved by strengthening network stability and failover mechanisms.
- Error Logging was enhanced to streamline problem detection and resolution.

The list of adaptations of ecoPlatform follows:

- Improved Data Exchange (PT_2UC2.1): Optimized communication algorithms reduced latency in real-time data sharing between ecoTools.
- Enhanced Data Routing to Cloud (PT_2UC3.1): Improved reliability of cloud data transmission through better network redundancy and stability measures.
- Optimized API for Archived Data (PT_2UC3.2): Enhanced caching and retrieval processes for faster, stable access to archived data.
- Scalability Enhancements: Adaptations were made to handle larger datasets and increased tool integration.
- Security Features: Strengthened encryption and secure authentication for data transmission and API access.
- Customizable Dashboards: Added flexibility for operators to visualize and monitor real-time and archived data.
- Tool Integration Debugging: Resolved compatibility issues between ecoPlatform and other ecoTools.

4 Conclusions

This deliverable provides a detailed report on the status of the first demonstration round activities which is dedicated to the testing and validation of the ecoTools and their functionalities in real-world conditions at the four demo sites: Bornholm (Denmark), Kythnos (Greece), Ghoramara (India) and Keonjhar (India). The UCs, defined in D7.1 [2] and D2.1 [1], served as the foundation for this analysis. Since these UCs were proposed during an early stage of the project, they have been refined as necessary to align with the requirements of the demonstration activities.

Regarding the demonstration of ecoTools at Bornholm site, the first phase for ecoEMS and ecoPlatform was completed with success, resulting in the implementation of the necessary adaptations for the second round. ecoMonitor and ecoDR were successfully tested locally, but due to the required relocation of these tools to DTU laboratory and communication system difficulties, some tasks have been moved to the second demonstration round. As for the ecoCommunity tool, the demonstration activities were delayed and have been rescheduled for the second demonstration round.

At the Kythnos demo site, including Gaidouromandra, the testing demonstration round was successfully completed for ecoEMS, ecoPlatform and ecoResilience. ecoMicrogrid, ecoPlanning and ecoCommunity have been successfully demonstrated, with a few UC activities or fragments of them, mostly of lower priority, planned for the second demonstration round. ecoMonitor and ecoDR have been successfully tested locally, while transmission of data is planned for the second demonstration round.

The first demonstration round for the tools deployed in Ghoramara, concluded mostly successfully for several tools, including ecoDR, ecoMonitor, ecoResilience, ecoVehicle and ecoPlatform. ecoConverter, while laboratory tested and validated, it is undergoing some modifications and thus its on-field demonstration results are planned to be provided in the second demonstration round. The ecoConverter modifications affect the demonstration of ecoMicrogrid and ecoCommunity, which could not be fully completed at this stage.

Regarding Keonjhar demo-site, the first demonstration phase was successfully completed for most of the ecoTools (ecoVehicle, ecoMicrogrid, ecoPlanning, ecoPlatform), with minor delays in certain aspects of ecoMicrogrid and ecoPlanning. The demonstration of ecoDR, along with some UCs of ecoCommunity is scheduled for the second demonstration round.

This deliverable presents a comprehensive and detailed report on the demonstration activities of the ecoTools at each demo site, summarizing the work completed in the first part of Task 7.3. Following the conclusion of the initial testing round, the necessary adaptations of the ecoTools were conducted, setting the stage for the second demonstration round that will be reported in D7.5. The assessment of the tools, based on the data gathered during demonstration, will take place in D8.4.

5 Bibliography

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

[2] RE-EMPOWERED consortium, "D7.1 Deployment and demonstration plan - September 2022".

[3] RE-EMPOWERED consortium, "D7.3 Report on deployment of RE-EMPOWERED solutions- Nomvember 2024".