RE-EMPOWERED

Renewable Energy EMPOWERing European & InDian Communities

Deliverable D6.3: Guidance Documents

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R Document, report	**PU** Public
DEM Demonstrator, pilot, prototype	**CO** Confidential, only for members of the consortium (including the Commission Services)
DEC Websites, patent fillings, videos, etc.	**EU-RES** Classified Information: RESTREINT UE (Commission Decision 2005/444/EC)
OTHER ETHICS Ethics requirement	**EU-CON** Classified Information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)
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EXECUTIVE SUMMARY:

This deliverable of the RE-EMPOWERED project outlines detailed guidelines to manage, operate, and maintain renewable energy systems deployed across diverse demonstration sites in Europe and India. The project has integrated innovative renewable energy solutions into local communities, enhancing energy access, sustainability, and operational efficiency. This document provides structured insights into the technical and operational aspects of advanced renewable energy systems installed at various locations, including Ghoramara Island and Keonjhar in India, Bornholm island in Denmark, and Kythnos island in Greece. Each site features distinct renewable energy systems tailored to local needs, such as solar and wind-powered microgrids, biogas and biomass plants, district heating systems, and standalone microgrids.

The document addresses key aspects of deploying the RE-EMPOWERED ecoTools laying the foundation for the subsequent development of guidelines and technical documentation. Each tool is supported by guidelines and user manuals for seamless integration and scalability. The significant achievements of electrifying Ghoramara Island with a 160 kW microgrid, integrating solar PV, biomass/biogass, and battery systems in Keonjhar, enhancing energy flexibility through heat/power sector coupling in Bornholm, and operating a renewable-friendly system in Kythnos have been successfully realized. Guidance documents are essential for ensuring the smooth operation, maintenance, and troubleshooting of the systems. This document highlights the equipment integration processes, the inventory management, and the training materials to ensure robust system performance. By addressing energy challenges with modular, scalable, and innovative solutions, the RE-EMPOWERED project contributes to sustainable energy access and community empowerment, establishing this document as a vital reference for project stakeholders, and especially the demo-site operators.

It should be noted that guidance documents for community engagement were fully covered in "D6.1 Engagement Status Report" (Task 6.1) and are not repeated in this document. These include the stakeholders' engagement guide, as well as a guide for the creation of an energy community. Moreover, a detailed report on training activities, including awareness material for local citizens is included in "D6.2 Training activities report".

Keywords: Renewable Energy, Microgrid, Energy Management, RE-EMPOWERED ecoTools, Solar Photovoltaic, Wind Energy, Battery Energy Storage System, Energy Optimization, Sector Coupling, Sustainability

TABLE OF CONTENTS

List of Figures

List of Tables

Acronyms

Acronym	Description
AC	Alternating Current
BESS	Battery Energy Storage System
CCTV	Closed-Circuit Television
CO	Carbon Monoxide
°C	Degree Celsius
DC	Direct Current
DH	District Heating
DSM	Demand-Side Management
EMS	Energy Management System
EV	Electric Vehicle
FPGA	Field-Programmable Gate Array
HVAC	Heating, Ventilation, and Air Conditioning
IoT	Internet of Things
IPM	Intelligent Power Module
kW/kWp/kWe	Kilowatt/Kilowatt peak/Kilowatt electrical
L	Liter
LAN	Local Area Network
MWh	Megawatt-hour
MPPT	Maximum Power Point Tracking
MQTT	Message Queuing Telemetry Transport
NWP	Numerical Weather Prediction
PM 2.5	Particulate Matter 2.5
PM10	Particulate Matter 10
Ppm	Parts per million
PPC	Partial Power Converter
PV	Photovoltaic
RES	Renewable Energy Sources
SCADA	Supervisory Control and Data Acquisition
S	Second
SO2	Sulfur Dioxide
SQL	Structured Query Language
STATCOM	Static Synchronous Compensator
TOML	Tom's Obvious Minimal Language
V	Volt
%rh	Relative humidity in percentage
µg/m3	Micrograms per cubic meter
µ	micrometer

1 Introduction

1.1 Purpose and scope of the document

This document serves as a comprehensive guide for managing, operating, and maintaining renewable energy systems and associated technologies deployed across the four demo sites of RE-EMPOWERED (Ghoramara, Keonjhar, Bornholm, Kythnos). It provides essential information to stakeholders, including demo operator, demo leader and end-users, on the deployment, integration, and optimization of equipment and software. First, the inventory of commercial equipment deployed at each demo site is outlined, including details about the necessary software and ecoTools integration (more information in D7.3 “Report on deployment of RE-EMPOWERED solutions” [1]). This information is supplemented by a list of the supporting documents and their classification. Then, important information on the installation, configuration and use of the ecoTools is detailed in the form of manuals. This material was used during the training activities described in D6.2 “Training Activities Report” [3]. Overall, this guide serves as a vital resource for the project’s sustainability, fostering proper operation and maintenance of the systems.

1.2 Structure of the document

Chapter 2 briefly presents the four demo-sites, including general system overview, equipment, deployed ecoTools, electrical diagrams, and information about the relevant manuals. Chapter 3 includes user guide and technical manuals for the ecoTools and delves into their installation, configuration, and maintenance. Chapter 4 concludes the document.

2 Equipment at demonstration sites

2.1 Keonjhar

2.1.1 General description about installed energy systems

Kanheigola, Nola, and Ranipada are small villages/hamlets located in the Harichadanpur Tehsil reserve forest in the Keonjhar District of Odisha State, India. These villages are situated 54 km south of the district headquarters in Keonjhar and 180 km from the state capital, Bhubaneswar.
The villages are not connected to the main utility grid. Instead, a total of 77 kWp of solar PV installations (30 kWp in Kanheigola, 25 kWp in Nola, and 22 kWp in Ranipada) supply electricity to approximately 1,000 residents living in 306 households. These solar PV systems are entirely off-grid and were commissioned by the Odisha Renewable Energy Development Agency during 2017–2018. The site has been further upgraded with additional energy systems, including solar PV (30 kWp), biomass (10 kW), biogas (10 kW), and battery storage (180 kWh), as shown in the figure. These improvements have significantly enhanced the community's living standards.
A control room equipped with a solar MPPT controller, inverter, and a 180 kWh battery energy storage system (BESS) has been established. Additionally, two electric vehicle (EV) loaders with charging infrastructure have been deployed to the site, and CCTV cameras have been installed for monitoring and security.

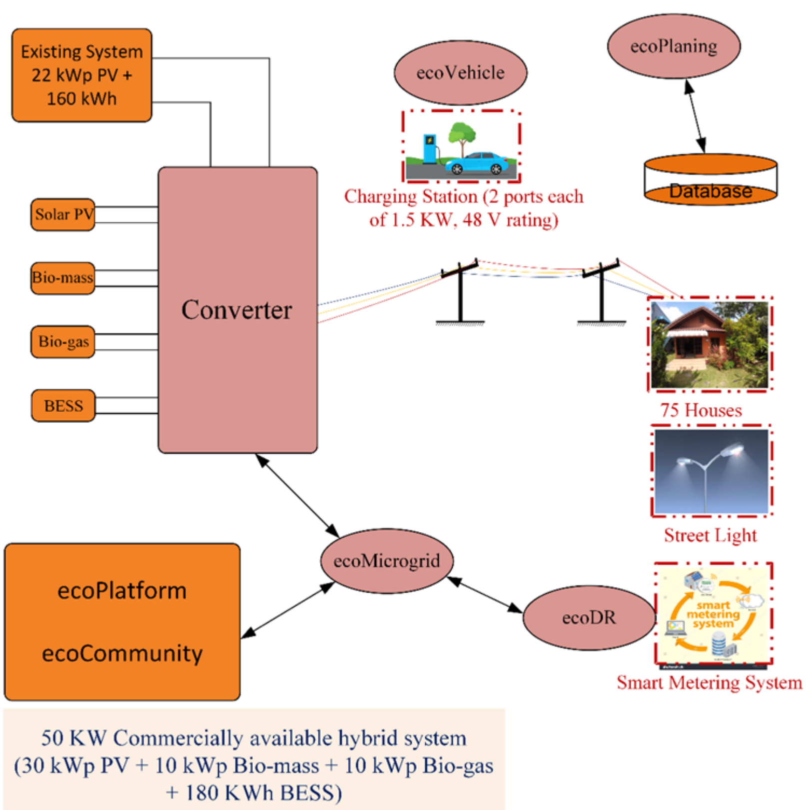


Figure 1: Keonjhar Energy System

2.1.2 Equipment Inventory list

Tables 1-3 detail each component's specifications, model numbers, deployed and spare units, along with supplier contact details ensuring streamlined resource management and support.

Table 1: Inventory details

	Item description	Specifications and model numbers	Deployed Qty	Contact Persons
1	Solar PV Module	Adani Solar, Module type: ASB-M10-144-540	56	Husk Power, Shyam Chakraborty
2	Battery Storage	AMARA RAJA,Type: Valve Regulated Lead Acid ,Rating:240 V - 750 AH	120	
3	Inverter	Statcon Energiaa, Model no.HBD-NG-240-020K-3P-010M1-11-C01	1	
4	Biomass/ Biogas Rectifier Module	Statcon Energiaa, Serial no. 23GN3518A3	1	Husk Power, Shyam Chakraborty
5	EV Charger	BHARAT AC001 EV Charger, Model: LEVBAC001-3.3K	2	VNIT, Dr.Ritesh Keshri
6	MPPT Charger Module	Statcon Energiaa, Serial No. 23GN3518A	1	Husk Power, Shyam Chakraborty
7	Energy consumption monitoring devices	CSL4112 Modbus TCP-RTU Gateway, ETHERNET RF TRANSCEIVER CSL2301-ML, Short range wireless terminal CSL2301-S	1	Husk Power, Shyam Chakraborty

Table 2: Biomass Plant 10 kWp

Particulars	Specification
Gasifier Output	18 kW
Maximum Biomass Consumption	1.5 to 2 kg /kWh (according to condition of Biomass.)
Biomass Engine	20 HP, 1500 RPM
AC Generator	20 KVA, 415 V, 28 A, 50 Hz, 1500 RPM
No. of Units	1 each
Supplier	Husk Power
Contact Person	Shyam Chakraborty

Table 3: Biogas plant 10kWp

Components	Capacity
Digester	45 m3
Mixing Tank	0.71 m3
Y-Junction	0.68 m3
Outlet Tank	11.38 m3
Balloon	40 m3
Biogas Engine	20 HP, 1500 RPM
AC Generator	20 KVA, 415 V, 28 A, 50 Hz, 1500 RPM
No. of Units	1 each
Supplier	Husk Power
Contact Person	Shyam Chakraborty

2.1.3 RE-EMPOWERED ecoTools deployed at Keonjhar

The table provides information about various ecoTools deployed in Keonjhar. It describes the purpose of each tool, the developers, and contact persons for technical support or inquiries, to foster smooth tool integration and usage.

Table 4: Demonstrated ecoTools on Keonjhar Demo site

ecoTool	Description	Developer	Contact Persons
ecoMicrogrid	Energy management system	Athanasios Vasilakis, Dimitris Lagos, Dimitris Charalampidis etc (ICCS-NTUA).	Athanasios Vasilakis
ecoVehicle	Battery operated 3 wheeler	Santu Kumar Giri (CMERI)	Santu Kumar Giri
ecoDR	Electrical smart meter	Santu Kumar Giri, Anirudh Kumar (CMERI)	Santu Kumar Giri, Anirudh Kumar
ecoPlanning	software tool	George Milionis (ICCS-NTUA)	George Milionis
ecoCommunity	Android application	Joseph Thomas (ICL)	Joseph Thomas
ecoPlatform	Monitoring and integration platform: Version B	Vasilis Mouzas (ICCS-NTUA)	Vasilis Mouzas

2.1.4 Equipment/ecoTools/software Integration Details

- **Solar PV System Integration:**

The solar PV plant is configured with total 56 modules, out of which 14 solar modules are connected in series to form a single string, which increases the system's voltage. 4 such strings are then connected in parallel, which increases the system's current. This series-parallel arrangement—14 modules in series and 4 strings in parallel—makes the plant's capacity 30 kWp. The plant is ultimately connected to the DC bus of the inverter through a 30 kW MPPT controller.

- **Biomass System Integration:**

The 10 kW biomass plant consists of essential components that work together to generate energy. The gasifier converts biomass into gas, which is cleaned by a water jacket and charcoal filter. A blower ensures proper gas flow, while a cooling tower controls the system's temperature. The engine-generator set then converts the gas into electricity, with connection pipes and filters ensuring efficient operation. AC power generated from generator is first converted into DC by a rectifier module and then connected to DC bus of the inverter. A changeover switch is installed between biomass/biogas and inverter to ensure that either biomass or biogas is connected to the rectifier module at a time.

- **Biogas System Integration:**

The 10 kW biogas plant features key components like a digester for processing cow dung, a mixing tank, and a Y-junction for directing the flow. The biogas produced is stored in a balloon and purified before being used by the engine-generator set to produce electricity. A heat exchanger and water heater help manage the system's temperature, ensuring efficient energy production. AC power output of the generator is connected to the rectifier module via changeover switch. After rectification, it is connected to the DC bus of the inverter.

- **BESS Integration:**

A battery energy storage system is installed to store excess energy and supply it when needed. The system is composed of 120 battery cells connected in series, providing a total voltage of 240V and a storage capacity of 180 kWh. It is directly connected to the battery port of the inverter.

- **Remote Monitoring System**

For Keonjhar, local and remote monitoring of energy consumption leverages wireless technology through RF (radio frequency) devices. Data from ten smart meters is transmitted wirelessly from slave devices via RS485 ports to the CSL2301 master unit. The master unit then sends data to a SCADA/PC system, enabling seamless integration and monitoring. This setup ensures reliable energy consumption tracking, enabling better control and decision-making for renewable energy systems. The implementation of smart monitoring systems at both locations underlines the project's commitment to using advanced technology for enhanced energy management and sustainability.

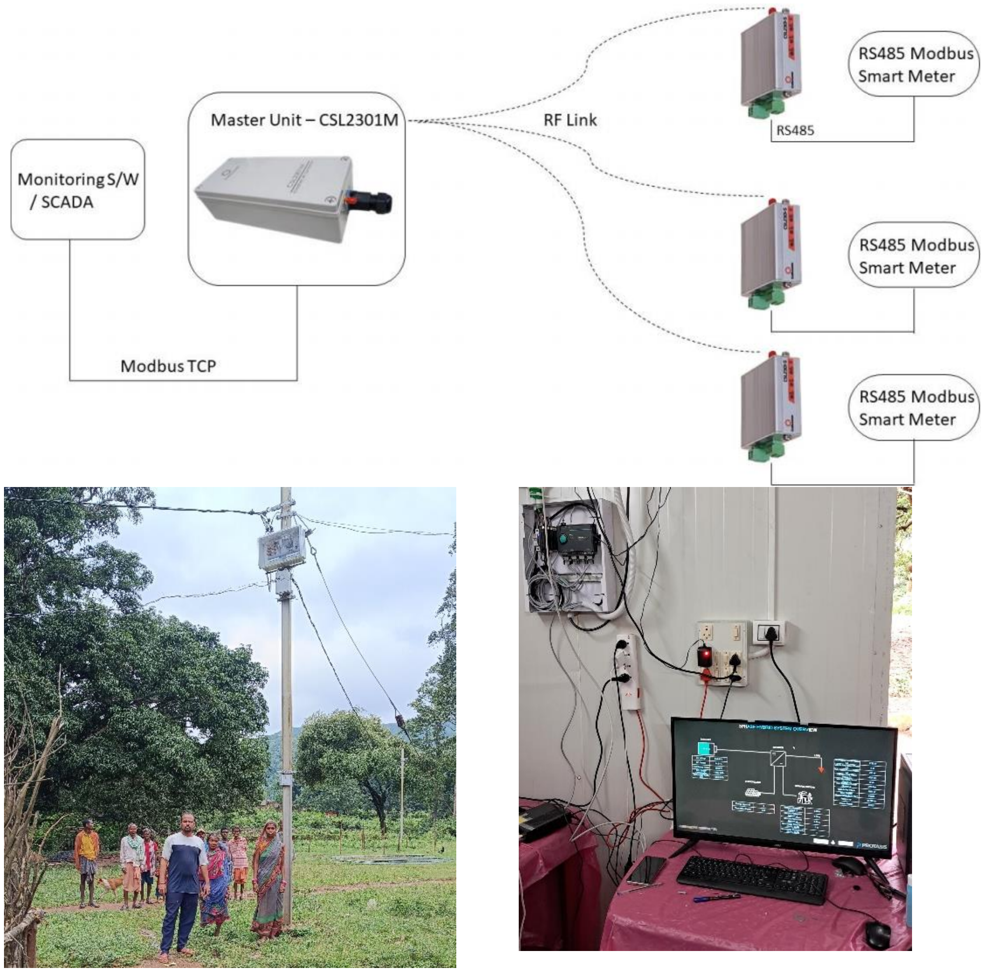


Figure 2: Remote monitoring of energy consumption data with wireless technology

2.1.5 Electrical Connection/Network Diagram

The schematic diagram of Figure 3 represents a 50 kWp energy system at Keonjhar, comprising three energy vectors: solar, biomass, and biogas, which all contribute to electrical power generation. These sources are connected to the DC link of an inverter, which converts the power into 415 V, 50 Hz AC electricity for distribution. A battery energy storage system is also integrated with the DC link, allowing excess energy to be stored and supplied to the load when needed. The biomass and biogas generators are connected via a main changeover switch, ensuring that only one of them can be linked to the DC busbar at any given time.

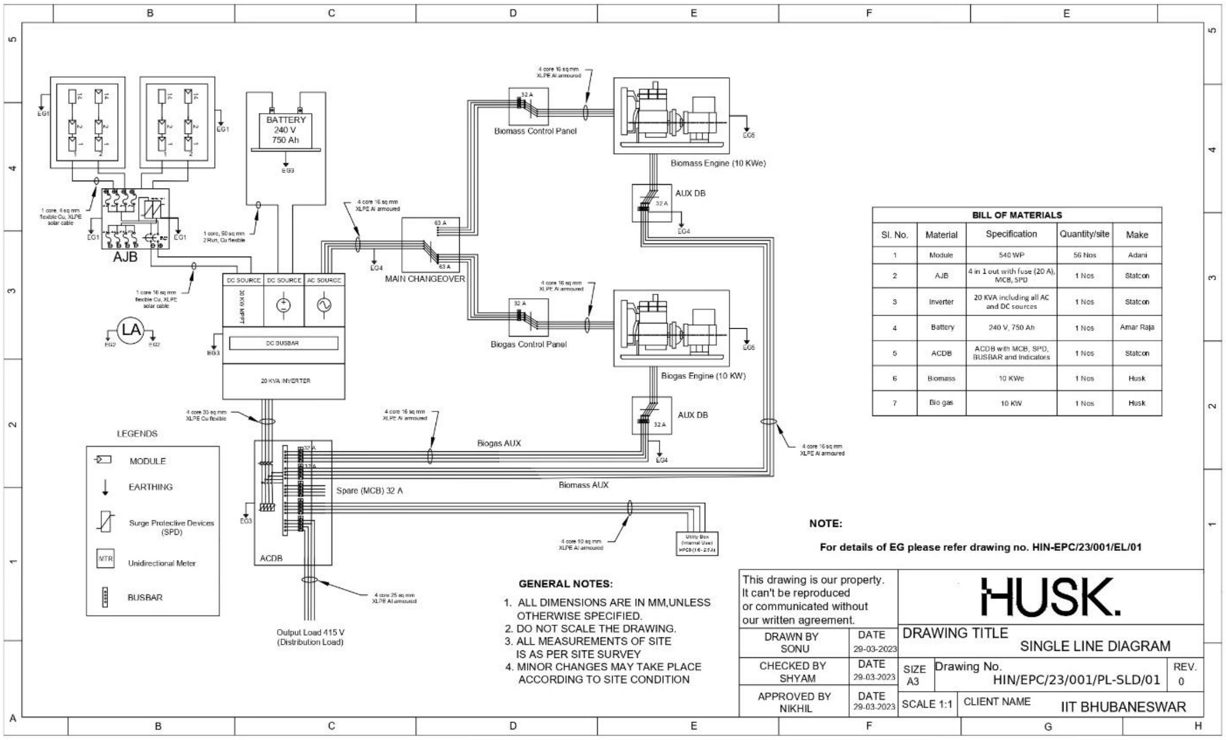


Figure 3: 50 kWp Energy System Schematic

Figure 4 illustrates the synchronization between the new 50 kWp energy system and the existing 22 kWp system. In this setup, the new system functions as the master, while the existing system operates as the slave. Since the biomass and biogas generators generate AC power, there is an option to directly supply the load through switches SW1 and SW2 when required, bypassing the inverter. This allows for greater flexibility in how the systems manage power distribution.

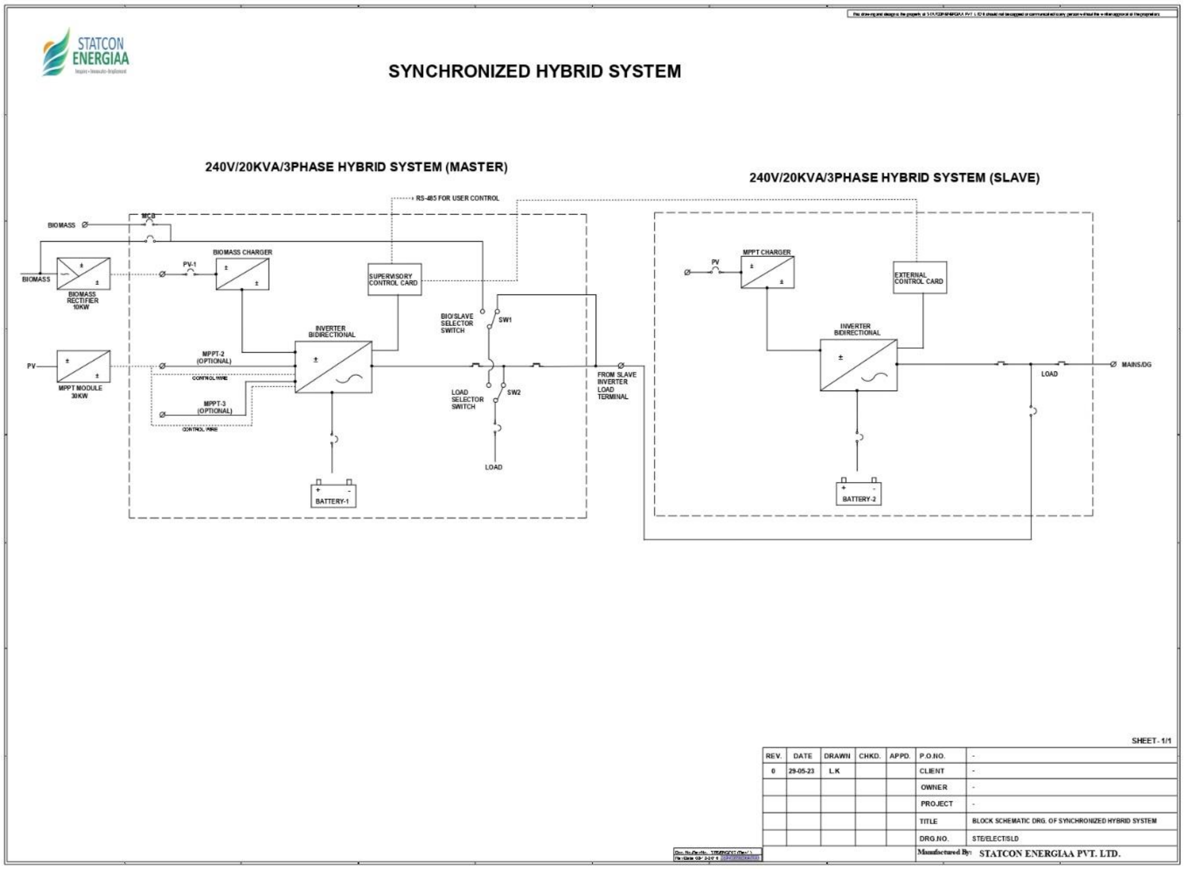


Figure 4: Synchronization Diagram of New system with the Existing System

2.1.6 Manuals for the equipment

Table 5 lists the available manuals and technical documentation for the main equipment installed in Keonjhar demo site. The equipment supplier has provided the demo-site operator with all necessary manuals. Each equipment manual has been categorized, documented, and properly stored according to the type of manual. These manuals/materials have not been included in D6.3 report, due to size constraints.

Table 5: Classification of manuals

S/No	Item description	Available Manuals (Technical, User, Quick Reference etc.)
1	Inverter	User manual, Test Report
2	Battery Bank	User manual
3	5000 ltr water tank	User manual
4	EV Smart charger	User manual
5	Cromption motor & starter	User manual

6	DC/AC Digital Energy meter	User manual
7	RF Device for data comunication	Test Report
8	CSL4112 Modbus TCP-RTU Gateway	User Manual
9	STATCON Inverter/MPPT Charger/Rectifier	Manual
10	DC Energy Meter	Operating Manual
11	EV Charger	Manual
12	ACDB Elite 440	Technical Reference Manual

2.2 Ghoramara

2.2.1 General description about installed energy systems

Ghoramara Island is located approx. 92 km south of Kolkata, in the Sundarban of the Bay of Bengal. The island comprises of five different villages. The nearest mainland is Kakdwip which is approximately 5 km away and takes around 1 hour through diesel operated boats. Around 3000 residents are staying there, over 1100 houses. Utility grid is not available on the Island. A total 160kW microgrid system has been installed on Ghoramara Island. Out of the total 160kW, 150kW are installed in the form of PV modules and 10kW are installed in the form of a wind turbine. Along with the renewable generation a battery backup system is used. Additionally, to the above-mentioned units and ecoTools, electric three-wheelers, solar high-mast light, e-boat, smart meter, charging station with local PV and BESS, wind turbine, remote monitoring unit and load limiter, are being installed.

2.2.2 RE-EMPOWERED ecoTools deployed at Ghoramara

Table 6, provides information about various ecoTools deployed in Ghoramara island. It describes the purpose of each tool, the developers, and contact persons for technical support or inquiries, to foster smooth tool integration and usage.

Table 6: ecoTool details

ecoTool	Description	Developer	Contact person
ecoMicrogrid	Energy management system	Athanasios Vasilakis, Dimitris Lagos, Dimitris Charalampidis etc (ICCS-NTUA)	Athanasios Vasilakis
ecoVehicle	Battery operated vehicle and charging station	Santu Kumar Giri (CMERI)	Santu Kumar Giri

ecoDR	Electrical smart meter	Anirudh Kumar (CMERI)	Santu Kumar Giri Anirudh Kumar
ecoCommunity	Android application	Joseph Thomas (ICL)	Joseph Thomas
ecoConverter	Power Electronic Devices	Suman Maiti (IIT KGP)	Subhojit Das
ecoMonitor	Air pollution measurement	Santu Kumar Giri (CMERI)	Santu Kumar Giri
ecoResilience	Develops & deploys resilient Support structures for PV & Wind turbines. Fabrication and installation of locally made small wind turbine	Murugan Thangadurai (CMERI), Kostas Latoufis (ICCS-NTUA)	Murugan Thangadurai, Kostas Latoufis
ecoPlatform	Monitoring and integration platform: Version B	Vasilis Mouzas (ICCS-NTUA)	Vasilis Mouzas

2.2.3 Electrical Connection/Network Diagram

The Figure below presents the system topology for Ghoramara Island.

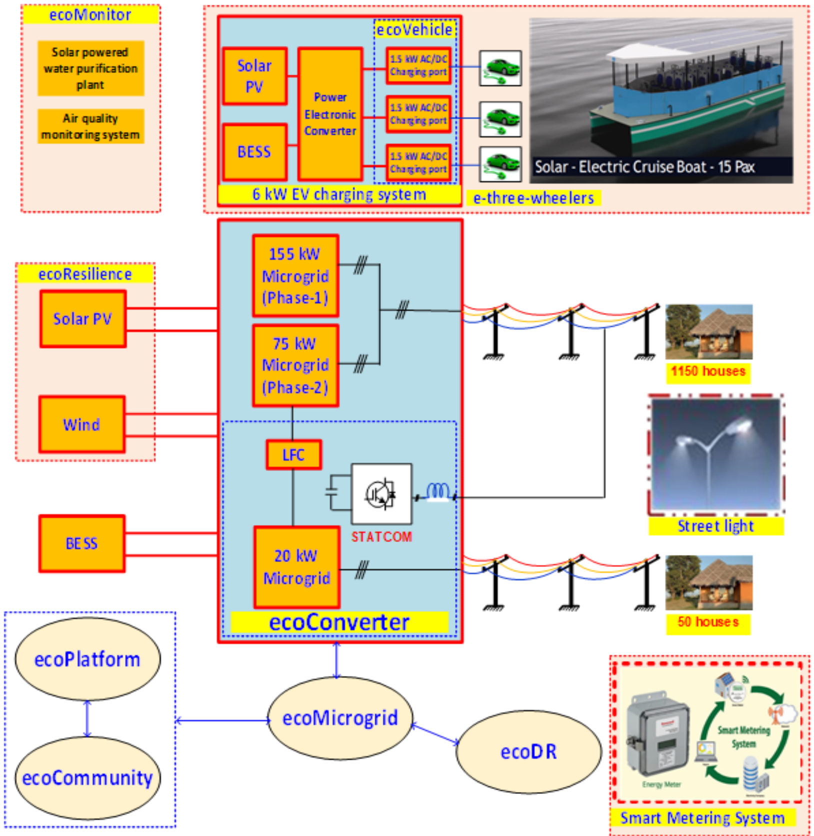


Figure 5: Ghoramara Island system Topology

2.2.4 Manuals for the equipment

The equipment supplier has provided the demo-site operator with all necessary manuals for the commercial equipment. These include user manuals, technical manuals, service and maintenance guides, as well as quick reference guides. Each equipment manual has been categorized, documented, and properly stored according to the type of manual. These manuals/materials have not been included in D6.3 report, due to size constraints.

2.3 Kythnos Power System and Gaidouromandra Microgrid

2.3.1 General description about installed energy systems

Kythnos: Kythnos is a non-interconnected island supplied by an autonomous electricity system with diesel generators and solar energy.

- Total yearly energy production: 11,387.33 MWh (2023).
- Yearly peak load of Local energy systems: 4.05 MW (2022).

Table 7: Energy system at Kythnos

Unit type		Number	Total capacity (kWe)	Total yearly production (MWh)	Is it controllable?	Available characteristics or info?
Thermal	ICE	8	4x300 & 4x1000	10,989,93	Yes	4xMWM TBD603V12 & 4xMITSUBISHI S16R-PTA
Photovoltaics	Power plants	3	98.4 & 69.92 & 69.93	372.64	No	
	Roof units	2	19.875 & 9.66	24.76	No	

Gaidouromandra microgrid is a non-interconnected to the mainland electrical grid that electrifies a settlement consisting of 14 houses with 100% renewable energy. It is based on a Battery system of 48V/1859 Ah and its grid-forming Battery Inverters of 15kW in total. Microgrid is supplied using the following Renewable Energy Sources: 22,4 kWp of PV panels and a small Wind Turbine of 3 kWp. Additionally, a Diesel Generator of 22 kVA is used as a backup in case the State of Charge of the batteries drops below a certain level. Power is shared at the village's consumers through the AC Low Voltage distribution system of 3km. Metering devices are placed to all critical points, power sources and consumptions, as well as devices for the status and condition monitoring of the microgrid. Furthermore, an extensive network is being used to materialize the communications and control algorithms implemented. Gaidouromantra settlement incorporates advanced decentralized techniques for DSM techniques implementation.

2.3.2 Equipment Inventory list

The table details each component's specifications, model numbers of deployed units, along with supplier details, including names, phone numbers, and email addresses, ensuring streamlined resource management and support.

Table 8: Inventory details for the procured/developed equipment

A/A	Item Decription	Model Code	Num. deployed	Supplier	Contact details person/phone/email
1	Data logger	SMA Data Manager M-EDMM-10	1	Solarstore	www.europe-solarstore.com

2	Modbus energy meter	Socomec: Countis E17	7	ELECTRO LEADER	Vaggelis Konstantinou
3	Modbus energy meter	Socomec: Countis E03	4	ELECTRO LEADER	Vaggelis Konstantinou
4	VPN Router	Netgate 6100 MAX Security Gateway	1	Cybertraffic	www.cybertraffic.gr, Panagiotis Kappos
5	Industrial Modbus Serial to Ethernet Gateway	MGate MB3280	1	Netap	Christos Tsakarelos
6	MQTT to Ethernet TCP Gateway	MGate 5105-MB-EIP	1	Netap	Christos Tsakarelos
7	4G Router	Teltonica: RUT 241	1	Hellas Digital	
8	EcoMicrog rid PC	Supermicro Server Sys-540A-TR	1	Braintrust	Nick Avdis
9	Compact 3-ph Energy Analyser	EM24DINA V23XE1X	2	ETA	https://eta.gr/en/
10	Anemomet er / Transduse r	A75-104 SINE Comptus / SIN Freq to 5V	1	ELEMETR ON	https://www.symmetron.gr/
11	Wind Vine	A75-302 10K Comptus	1	ELEMETR ON	https://www.symmetron.gr/
12	Pyranomet er	Silicon - Cell	1	Ecosearch	www.ecosearch.info/home.php
13	Temperatu re sensors	PT1000 RTD sensors	2	RS Greece	https://gr.rsdelivers.com/
14	Modular Remote I/O Controller	MOXA: iO Thinx 4510, 45MK-6600, 45MK-3810	1	NETAP	www.netap.gr/

15	Ultrasonic Level Measuring Head	Charmeg UM40	1	Μικρα ΗΛΕΚΤΡΟ ΝΙΚΑ	https://www.mikra.gr/
16	Zenon Licence	Edit Licence	1	Copa-Data	https://www.copadata.com/en/

2.3.3 RE-EMPOWERED ecoTools deployed at Kythnos

The tables provide information about various ecoTools deployed in Kythnos Power System and Gaidouromandra microgrid. They describe the purpose of each tool, its developer, and contact persons for technical support or inquiries, to foster smooth tool integration and usage.

The following ecoTools are demonstrated on Kythnos Power System:

Table 9: ecoTools detail at Kythnos Power System

ecoTool	**Short Description / Notation (Speciality, version etc.)**	**Developer**	**Contact Persons**
EcoEMS	Energy management system	George Milionis (ICCS-NTUA)	George Milionis
EcoPlanning	Software tool	George Milionis (ICCS-NTUA)	George Milionis
EcoMonitoring	Air quality meter	Santu Kumar Giri, Anirudh Kumar (CMERI)	Santu Kumar Giri, Anirudh Kumar
EcoPlatform	Monitoring and integration platform: Version B	Vasilis Mouzas (ICCS-NTUA)	Vasilis Mouzas

The following ecoTools are demonstrated on Gaidouromandra microgrid:

Table 10: ecoTools detail at Gaidouromandra Mircrogird

ecoTool	**Description / Notation (Speciality, version etc.)**	**Developer**	**Contact Persons**
EcoMicrogrid	Energy Management System: Complete version (includes all modules)	Athanasios Vasilakis, Dimitris Lagos, Dimitris Charalampidis etc (ICCS-NTUA)	Athanasios Vasilakis
EcoDR	w/o energy limitation functionality	Santu Kumar Giri, Anirudh Kumar (CMERI)	Santu Kumar Giri, Anirudh Kumar

EcoPlatform	Monitoring and integration platform: Version B	Vasilis Mouzas (ICCS-NTUA)	Vasilis Mouzas
EcoCommunity	Specifically configured for Gaidouromantra's peculiarities	Joseph Thomas (ICL)	Joseph Thomas
EcoResilience	includes resilience Wind Turbine construction	Kostas Latoufis (ICCS-NTUA)	Kostas Latoufis

2.3.4 Equipment/ecoTools/software Integration Details

Kythnos Power System

ecoMonitor communication devices:
MQTT to Ethernet TCP Gateway primary role is the seamless linkage of Modbus devices, enabling the publication of Modbus data to an MQTT broker for remote monitoring. Within our application, this device assumes a pivotal role as it is configured to bridge the communication divide between the ecoMonitor tool, which communicates via the MODBUS TCP protocol, and the upstream ecoPlatform services that exclusively employ the MQTT protocol.

ecoMonitor represents a remote tool with no secured fixed internet connection. Thus, by design a 4G router is necessary for the tool. In this way, also, the ecoMonitor's network configuration remains unaffected no matter the settings of the outer network, making the tools installation much easier.

Gaidouromandra Microgrid

Energy metering:
An extensive network of Energy meters was placed in Gaidouromandra to several Houses, to old PVs w/o integrated interface, at Wind Generator and in the control room for local consumptions, in order to extract Power and Energy data. All metering devices were installed in series with the loads/sources as direct measuring Energy Meters were selected. According to the available communication network on each case, Modbus RTU or TCP was configured based on respective meters' datasheet instructions and were integrated in the ecoMicrogrid tool and SCADA system.

Environmental sensoring:
Environmental sensors were placed on site in order to evaluate the weather forecasting algorithm and thermal models, as well as to contribute to the showcase in SCADA system. All environmental measuring signals (that is wind speed and direction, solar power and temperatures), were concentrated in a Modular Remote I/O Controller for signal conversion from analogue to digital and then to transmit them via Modbus protocol to our Information system. Wind speed and wind vine sensors were placed on a bracket at the W/T pole, Pyranometer was installed on the roof of the control room and the temperature meters around and inside the building.

Ethernet gateway, Data logger, Modular I/O adapter, Software, etc.:
Various data-handling and communication equipment is used and each of them performs a separate operation.

Ethernet gateway is used in order to give IP address to serial devices. All the site devices that use serial communication protocol such us modbus RTU are gathered via RS485 network to the modbus serial to ethernet Gateway “MGate MB3280”.

Also, for the purpose of including the old equipment of SMA inverters that utilize proprietary communication protocol in our information model, the SMA Data Manager M-EDMM-10 was installed and channeled the respective measurement data to the IP network. Additionally, Data Manager M is configured as an extra, external data logging device for site’s data.

Modular Remote I/O Controller “Moxa iO Thinx 4510”, as mentioned before, plays the role of concentrating and converting all analogue signals to digital and then to transmit them via Modbus TCP protocol to our Information system. The configuration of the I/O Controller is done through the use of additional specific attachable modules for the necessary analogue signals.

ecoMicrogrid PC is an industrial server PC that hosts ecoMicrogrid tool along with all its necessary features. This PC apart from ecoMicrogrid algorithms and services, is also configured with VPN services, SQL server database and Zenon platform as part of the tool Data Concentrator module. Zenon is an industrial platform that allows the programmer to install and choose from among various industrial drivers and protocols to administrate the data. Its role is to collect data from field devices, perform preliminary processing, and register data to an SQL database for further analysis by the tool. Furthermore, it carries out the SCADA operation.

2.3.5 Electrical Connection/Network Diagram

Overview for Kythnos power system:

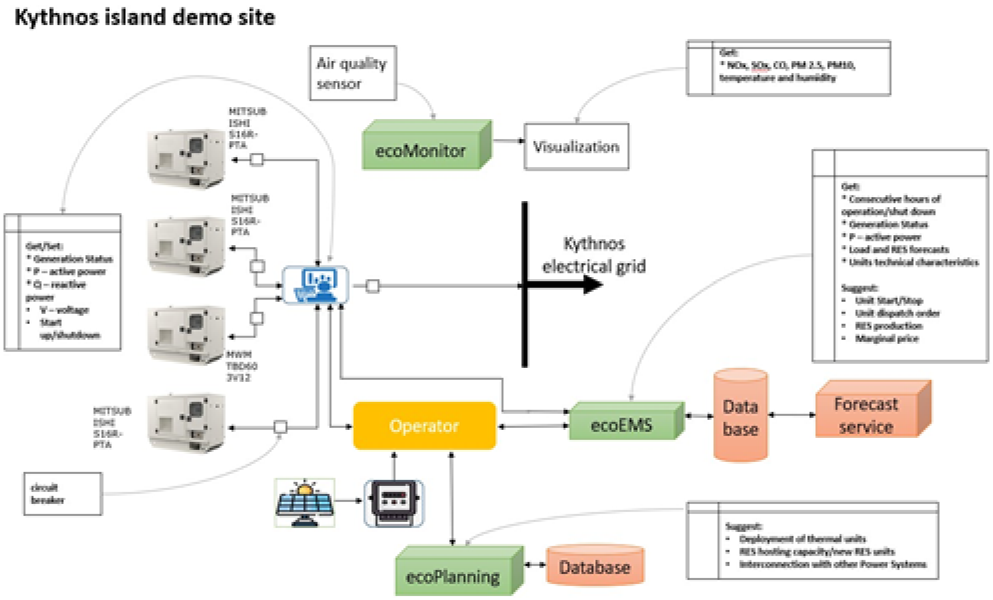


Figure 6: Kythnos power system with ecoTools overview

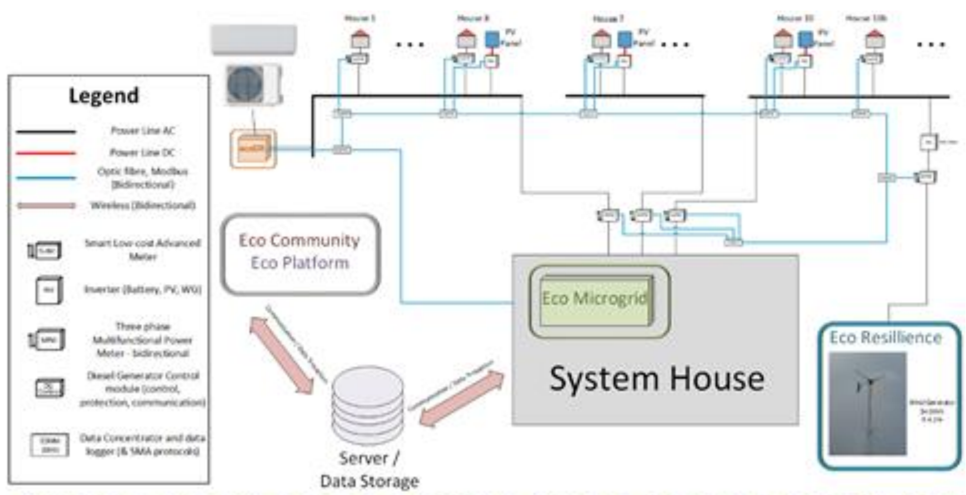


Figure 7: Gaidouromandra microgrid with ecoTools overview

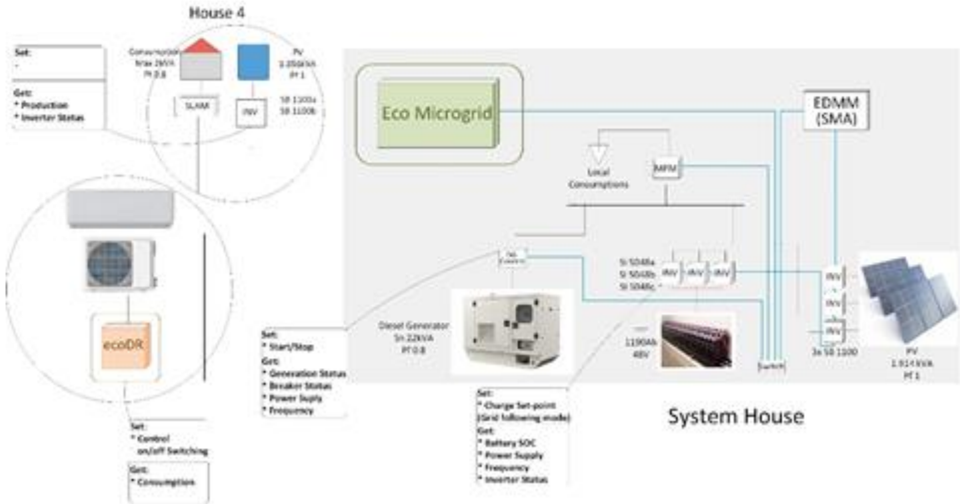


Figure 8: Gaidouromandra microgrid: Crucial microgrid components.

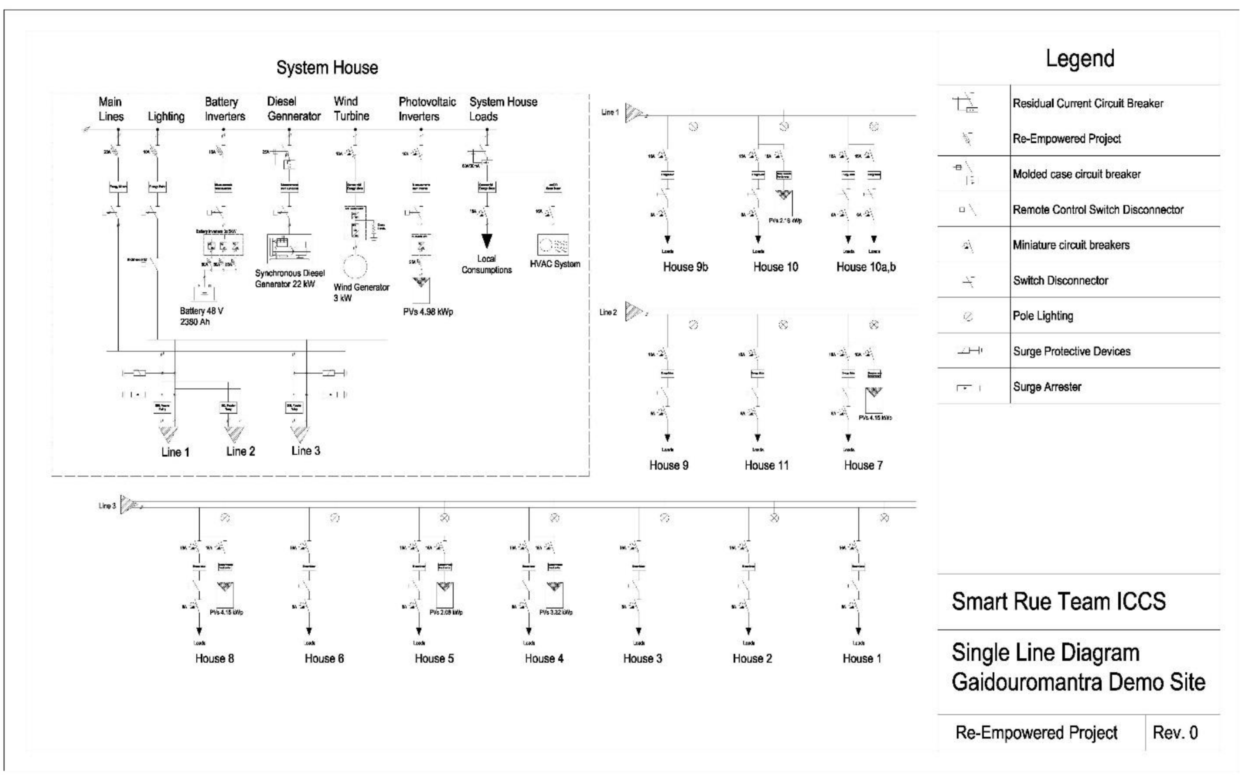


Figure 9: Gaidouromandra microgrid Single Line Diagram

2.3.6 Manuals for the equipment

The following table classifies the available resources like user manuals and technical documents for each piece of equipment, aiding in knowledge sharing and system maintenance.

Table 11: Classifications of manual

A/A	Item Decription	model code	Available Manuals
1	Data logger	SMA Data Manager M-EDMM-10	User, Quick Reference
2	Modbus energy meter	Socomec: Countis E17	Technical
3	Modbus energy meter	Socomec: Countis E03	Technical, Quick Reference
4	VPN Router	Netgate 6100 MAX Security Gateway	Technical
5	Industrial Modbus Serial to Ethernet Gateway	MGate MB3280	User, Technical, Quick Reference
6	MQTT to Ethernet TCP Gateway	MGate 5105-MB-EIP	User, Technical
7	4G Router	Teltonica: RUT 241	Quick Reference
8	EcoMicrogrid PC	Supermicro Server Sys-540A-TR	User, Quick Reference
9	Compact 3-ph Energy Analyser	EM24DINAV23XE1X	User, Technical
10	Anemometer / Transduser	A75-104 SINE Comptus / SIN Freq to 5V	Technical
11	Wind Vine	A75-302 10K Comptus	Technical
12	Pyranometer	Silicon - Cell	Technical
13	Temperature sensors	PT1000 RTD sensors	Technical
14	Modular Remote I/O Controller	MOXA: iO Thinx 4510, 45MK-6600, 45MK-3810	Technical, Quick Reference
15	Ultrasonic Level Measuring Head	Charmeg UM40	Technical
16	Zenon Licence	Edit Licence	User

The manuals have been provided to the demo-site operator. They have not been included in D6.3 report, due to size constraints (available also in MS Teams, only for the RE-EMPOWERED consortium).

2.4 Bornholm

2.4.1 General description about installed energy systems

The overall objective of the installed ecoTools on Bornholm is to demonstrate energy flexibility through sector coupling of the electricity grid and district heating system. The tools allow for control of household district heating units and engage with an electric boiler at the heat plant that produces district heating when the electricity prices favor energy production through electricity.

Installed Equipment

- IoT gateways and district heating consumers for control of district heating units
- Electric heater for ecoDR (control of electric consumption)

2.4.2 Equipment Inventory list

The table details component's model numbers, and deployed unit along with supplier and contact persons details ensuring streamlined resource management and support.

Table 12: IoT Gateway for demand side management

Specifications and model numbers	Product Name: Predator Product Version: 1.40 Product Code: NEOP140-202302
Number of units deployed	8
Name of the supplier	Neogrid Technologies
Contact person	Anders Larsen

2.4.3 RE-EMPOWERED ecoTools deployed at Bornholm

Five of the ten ecoTools are deployed at Bornholm. The tools are listed in Table 13.

- ecoDR (due to regulation and policies, location changed to a laboratory in DTU)
- ecoMonitor (due to regulation and policies, location changed to a laboratory in DTU)

The table provides information about the ecoTools deployed at Bornholm. They describe the purpose of each tool, its developer, and contact persons for technical support or inquiries, to promote smooth tool integration and usage.

Table 13: ecoTools details

ecoTool	Description	Developer	Contact Persons
ecoEMS	Energy management system	George Milionis (ICCS-NTUA)	George Milionis
ecoPlatform	Monitoring and integration platform: Version A	Aysegül Kahraman (DTU)	Aysegül Kahraman

ecoCommunity	Android application	Joseph Thomas (ICL)	Joseph Thomas
ecoDR	Electrical smart meter	Santu Kumar Giri, Anirudh Kumar (CMERI)	Santu Kumar Giri, Anirudh Kumar
ecoMonitor	Air quality meter	Santu Kumar Giri (CMERI)	Santu Kumar Giri

2.4.4 Equipment/ecoTools/software Integration Details

Danfoss ECL Computer and Neogrid IoT Devices:

- IoT Gateway developed by Neogrid integrates through Modbus
- Connection is done by connecting the electrical crimps in the following way:

Table 14: Connection of IoT gateway with crimp

Predator	ECL
RS485 A+	Crimp 34
RS485 B-	Crimp 35

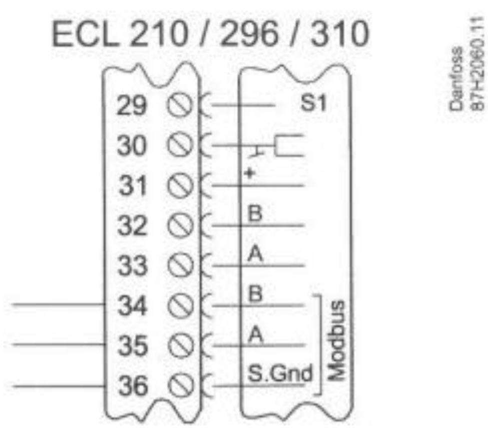


Figure 10: Connection diagram.

All participants have the same Danfoss application key A266.1 meaning the following sensors should be in place:

S1 – Outdoor temperature
S3 – Heating circuit (secondary), supply temperature
S5 – Heating circuit (primary), return temperature
S4 – Domestic Hot Water circuit, tank temperature
S6 – Domestic Hot Water circuit (primary), return temperature
S9 – Domestic Hot Water circuit, circulation temperature (if applicable)

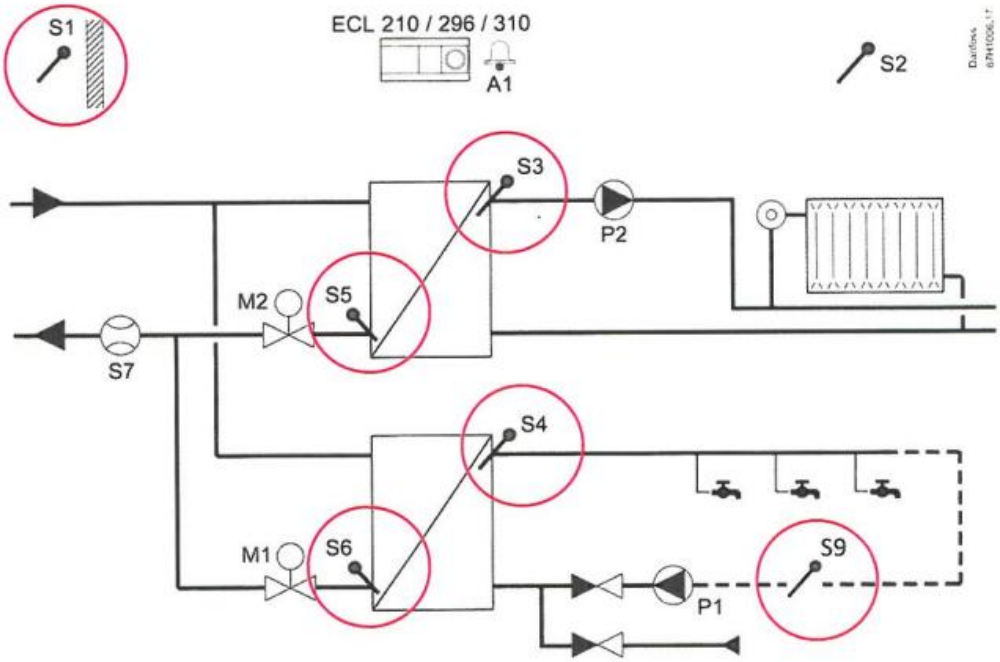


Figure 11: Diagram ECL sensor locations for application key A266.1

2.4.5 Manuals for the equipment

Table 15: Classifications of manual

A/A	Item Decription	model code	Available Manuals
1	IoT Gateways	Product Name: Predator Product Version: 1.40 Product Code: NEOP140-202302	Technical, User, Quick Reference

The demo-site operator has been provided with all necessary manuals. These manuals/materials have not been included in D6.3 report, due to size constraints.

3 RE-EMPOWERED ecoTools user guide and technical manual

This Chapter includes user guides and technical manuals for the RE-EMPOWERED developed ecoTools.

3.1 ecoEMS

3.1.1 Overview

The ecoEMS tool is designed as an Energy Management System aimed at enhancing the operation of power systems in Non-Interconnected Islands (NIIs). It features various optimization algorithms, demand response strategies, and a robust communication framework. With a user-friendly interface, an extensive database of power stations, and strong reporting capabilities, its main objective is to provide a cost-effective 24/7 power supply by effectively utilizing resources from different energy sources, including energy storage, renewable energy sources (RES), and demand forecasting for optimal efficiency. This system, tailored for Non-Interconnected Isolated Island Power Systems (NIIPSs), focuses on reducing operational costs, increasing RES integration, and complying with safety regulations and technical requirements.

Accessible online, ecoEMS accommodates multiple users with different permission levels and supports reporting in .csv format. It employs HighCharts, HTML5, and Javascript for data visualization, aiming for optimal Day Ahead Scheduling (DAS), Economic Dispatch (ED), and support for intraday energy market processes specific to NIIPSs.

The tool has been tested on demo sites in Kythnos and Bornholm, adapted to the unique characteristics of each power system. These tests verified communication protocols, data exchange formats, and the overall performance and interaction of ecoEMS components. In Kythnos, the successful integration of the optimization algorithm was demonstrated, with data seamlessly collected from primary sources and transmitted appropriately. In Bornholm, the co-optimization framework for electricity and heating networks was examined, revealing flawless data exchange and transformation.

Key Features

- Docker / Docker-Compose

Containerization platform allowing the packaging and deployment of applications in isolated containers. Orchestrates and manages the deployment of various services within containers for consistency and scalability.

- Nestjs

A Node.js framework for building scalable and efficient server-side applications. Acts as the Data Server, handling backend logic and providing APIs for communication with the client application.

- Sveltekit

Web framework based on Svelte for building fast, interactive user interfaces. Serves as the Application Layout Server, managing the frontend structure and interactions.

- Keycloak

Open-source identity and access management solution. Functions as the Authentication Server, managing user authentication, authorization, and security.

- SQL Server

Relational database management system for storing and managing structured data. Provides data storage and management capabilities for the application, ensuring data integrity and retrieval.

- Flask

Lightweight Python web framework for building web applications and APIs. Acts as a Python API server, handling data transformations and providing backend support for specific functionalities.

- Crontab

A time-based job scheduler in Unix-like operating systems. Used for scheduling and automating periodic tasks, such as data imports, ensuring timely and efficient data processing.

System Requirements

- Operating System: Linux, macOS, or Windows with Docker support.
- Memory: At least 4GB RAM.
- Storage: Minimum 100GB free disk space.

3.1.2 System Architecture

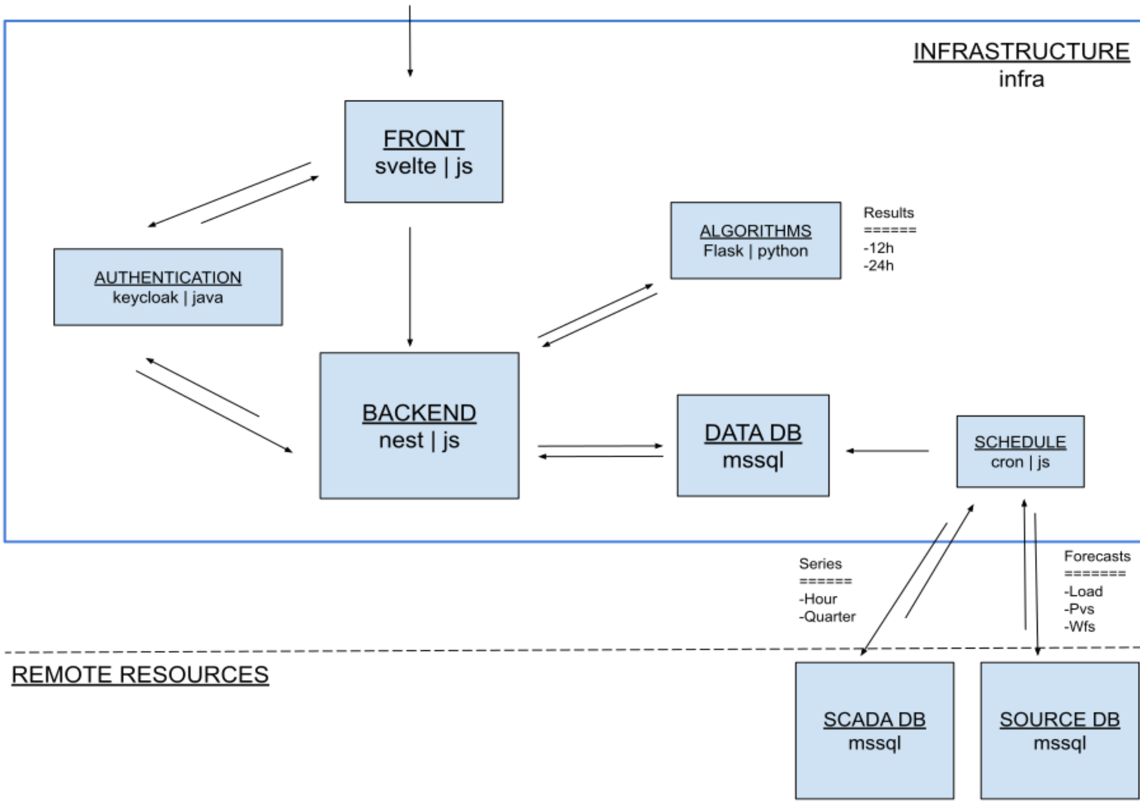


Figure 12: Mapping of system architectures.

Throughout the installation, specific naming conventions will be encountered frequently. Below is an overall mapping of these conventions:

- <INFRA>: Represents the Infrastructure container.
- <NEST>: Refers to the Data Server, also identified as Back / Backend.
- <SVELTE>: Denotes the Layouts (UI) Server, commonly referred to as Front.
- <KEYCLOAK>: Represents the Authentication / Authorization server, also known as Auth.
- <FLASK>: A Backend Service that hosts applicable algorithms, also seen as Algo / Python.
- <CRON>: A Backend Service responsible for collecting and importing data from other remote databases at predefined times, also referred to as Schedule.
- <LOCAL-DB>: The Application Database that stores transformed data in structures that meet application flow requirements.
- <SOURCE-DB>: The Core Remote Database that hosts the raw data required for the application database.

- <SCADA-DB>: A dedicated Remote Database that specifically stores SCADA data in raw formats, also identified as SCADA-Islands.

3.1.3 Installation and Setup

Create the 'Infrastructure' (INFRA) Folder

- Create Folder 'ECOEMS'

Begin by creating the main project folder named ECOEMS.

- Move to 'ECOEMS'

Navigate into the ECOEMS folder.

- Git Clone Repository as 'INFRA'

Execute the following command to clone the repository:

```
git clone git@gitlab.com:manos-zalokostas/ecare.git infra
```

- Move to Newly Created Folder 'INFRA'

Change directory to the newly created INFRA folder

Create "Services" Folders Required by Project

- Move to the Root Folder 'ECOEMS'

Navigate back to the root folder ECOEMS (the project folder that hosts the INFRA folder).

- View All Available Branches in the Repository

Ensure you are in the INFRA folder and view all branches

- Copy Folder 'INFRA' Four Times and Rename

Create four copies of the INFRA folder and rename them as follows:

- Svelte
- Nest
- Cron
- Flask

- Move to Each Folder and Checkout Respective Branch

For each folder, switch to the corresponding branch. The branch names should match the folder names but in uppercase. Repeat the Process for Remaining Folders/Branches

Build and Start the Application + Services

- Set Project Path for Build

Move to the project root folder ECOEMS.

- Move to Folder 'INFRA' and Locate '.env' File

Open the .env file in the INFRA folder.

Locate the entry ENV_DOCROOT=XXXX and replace its value with the copied project root path.
Ensure there is no trailing slash at the end, e.g., /home/ecareuser/ecoems.

- Start the Project with "Docker-Compose"

Ensure you are in the INFRA folder.

```
docker compose up
```

The command will begin downloading required images and building the project. The logs will display progress until the setup is complete.

Configure Authentication Server

- Login as Server Admin ('ECOEMS' User)

Use a browser to navigate to http://192.168.1.42:8080.
This IP address may change depending on your setup.

- Access Administration Console

After logging in, access the Administration Console.

Create a 'Keycloak' Realm

- Add a New Realm

Hover over the 'Master' realm and click Add Realm.
Use the Import file dialog.

- Locate Configuration File

A preconfigured settings file, keycloak-config.json, is located in the INFRA folder under .config/keycloak.
If the file is not accessible, download it to your local environment first.

- Verify Pre-Configured Clients

After importing, navigate to the clients page in Keycloak to ensure CLIENT-ECARE-APP and CLIENT-ECARE-SERVER are listed.

Import Database

- Locate Sample Database Backup

A sample database backup for the Greek project is located in the INFRA folder under .config/mssql.

- Copy Backup to Docker Container

Since the SQL Server runs in a Docker container, first copy the backup file into the container:

```
docker cp ECAREDB.bak mssql:/tmp
```

Prerequisites

Before installing ecoEMS, ensure that your system meets the necessary requirements, including Docker and Docker Compose.

- Installing Docker and Docker Compose
    - Linux: Install Docker using your distribution's package manager and Docker Compose by downloading it from the official Docker website.
    - macOS/Windows: Download Docker Desktop, which includes Docker Compose.

Deploying ecoPlatform B

1. Clone the ecoPlatform B Repository: Obtain the latest version from the repository.
2. Navigate to the Deployment Directory: Access the directory containing the Docker Compose file.
3. Run Docker Compose: Use the command docker-compose up -d to start the deployment. This command will launch all the necessary containers.

Verifying Installation

After deployment, verify that all containers are running and accessible. Check the status using docker ps and ensure that the ESB, Database, API, and Dashboard are operational.

3.1.4 Using ecoEMS

Accessing the dashboard

To access the ecoEMS dashboard, connect with your provided VPN client, open your web browser and navigate to http://192.168.1.42:8080. The ecoEMS will prompt you to log in with your credentials.

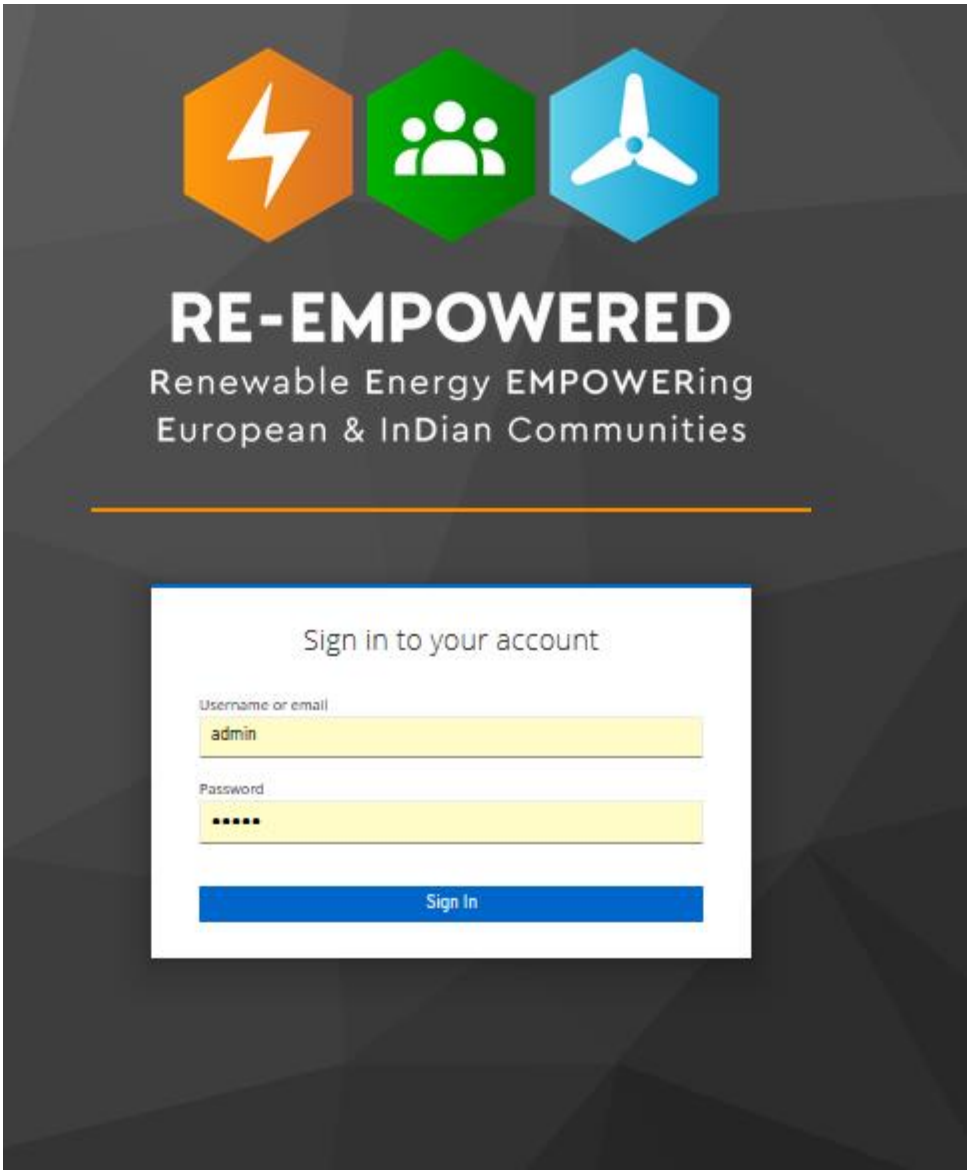


Figure 13: Dashboard interface

Navigating the Interface

- Datafeed Overview

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.

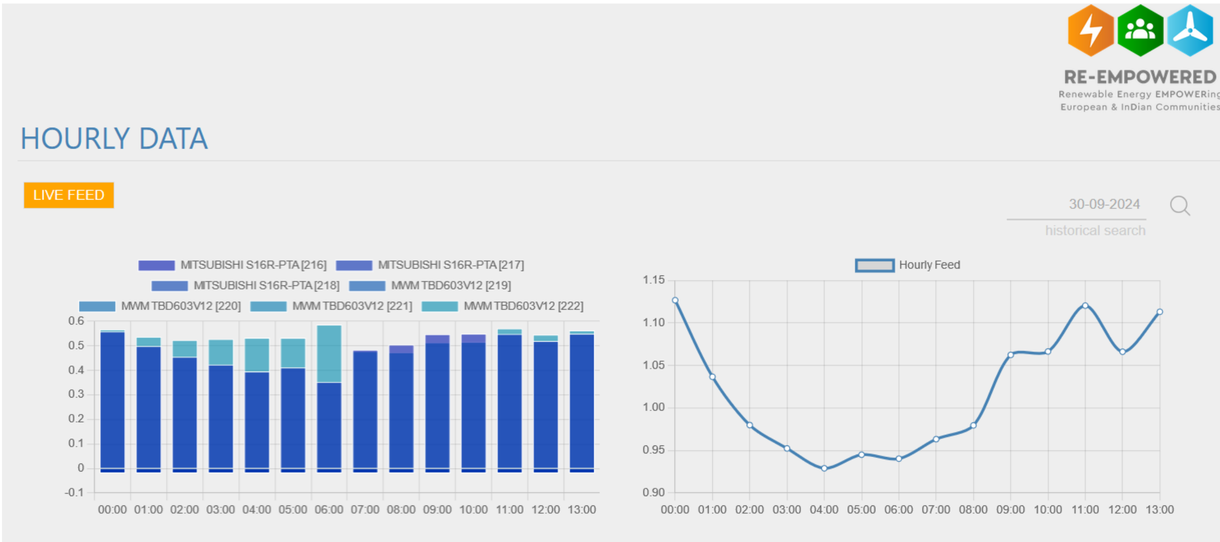


Figure 14: Hourly data feed overview

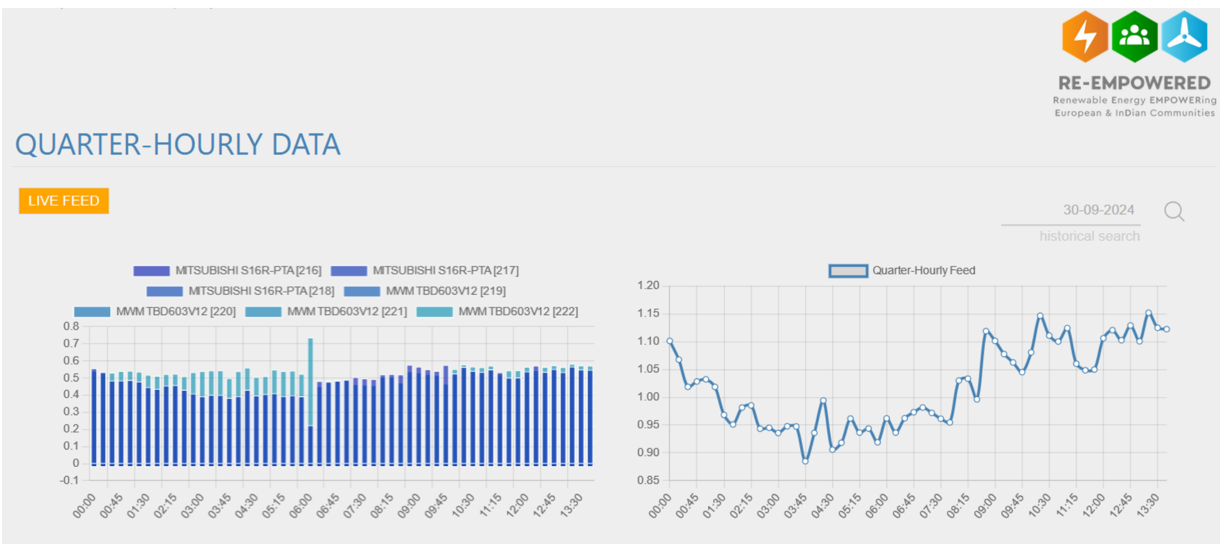


Figure 15: Quarter-hourly data feed overview

- Power Systems Forecasts

In the next two graphs, data referring to forecasts are presented; load and photovoltaic forecasts have been retrieved from the database.

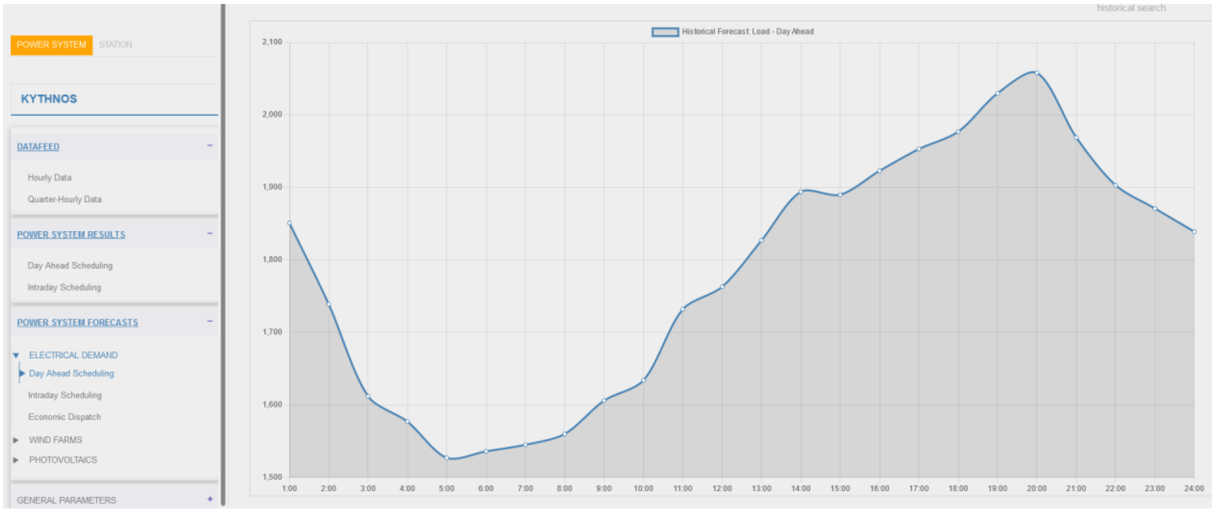


Figure 16: Load forecast

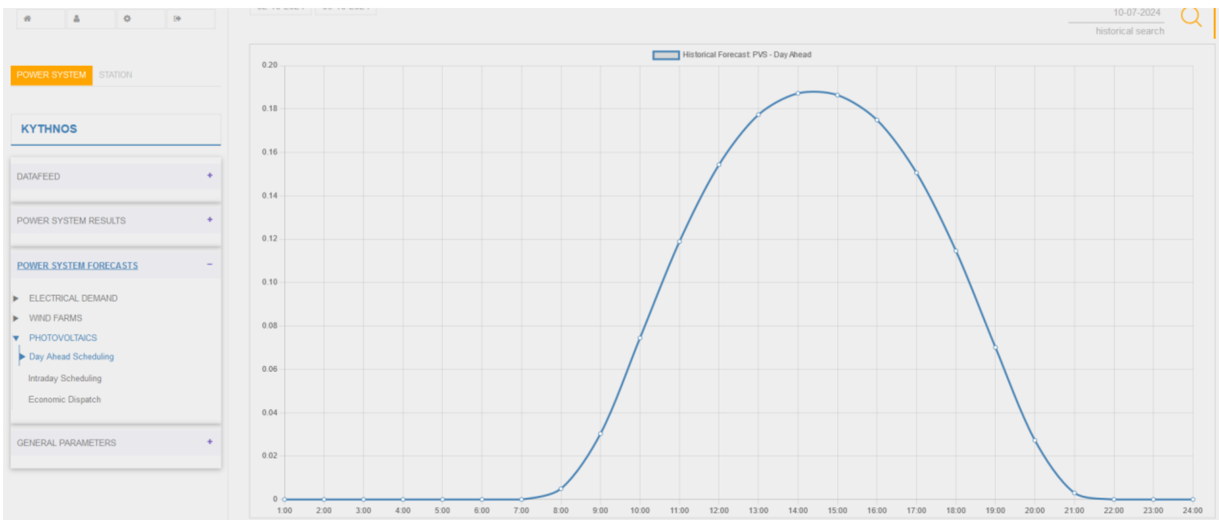


Figure 17: Photovoltaic forecast

Defining and Scheduling

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 CO2 emmissions factors, fuel costs, CO2 emissions allowance, etc.

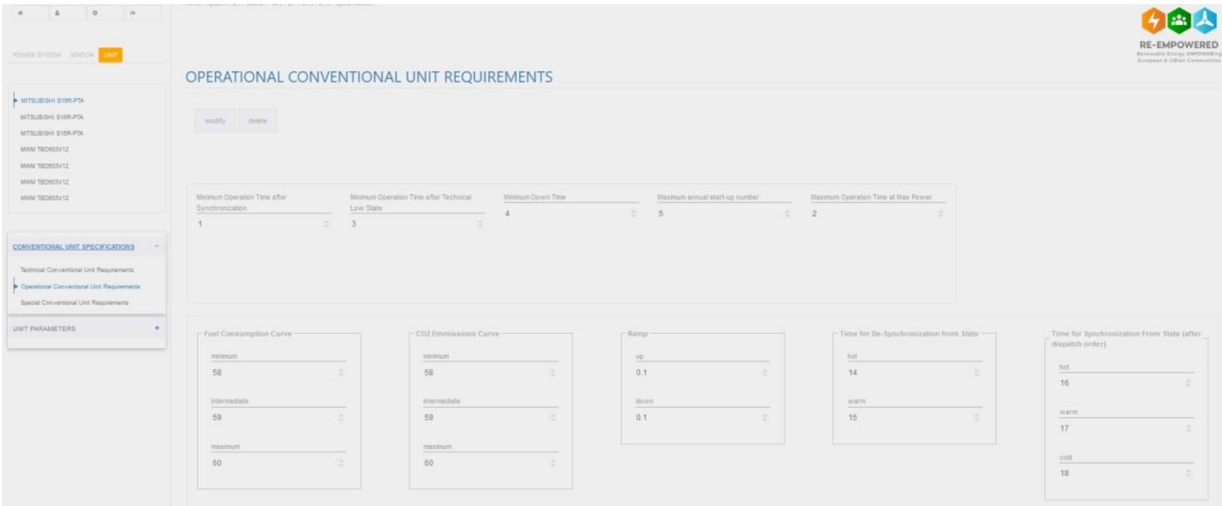


Figure 18: Technical thermal unit data sheet

Figure 19: Financial data sheet

After that, in conjunction with the forecasts and the uncertainties presented in the previous use case, the user can establish the reserve requirements and the merit order for constraint violations. This merit order determines which slack variables will be activated in the algorithm and the sequence in which they will be considered to identify a feasible solution.

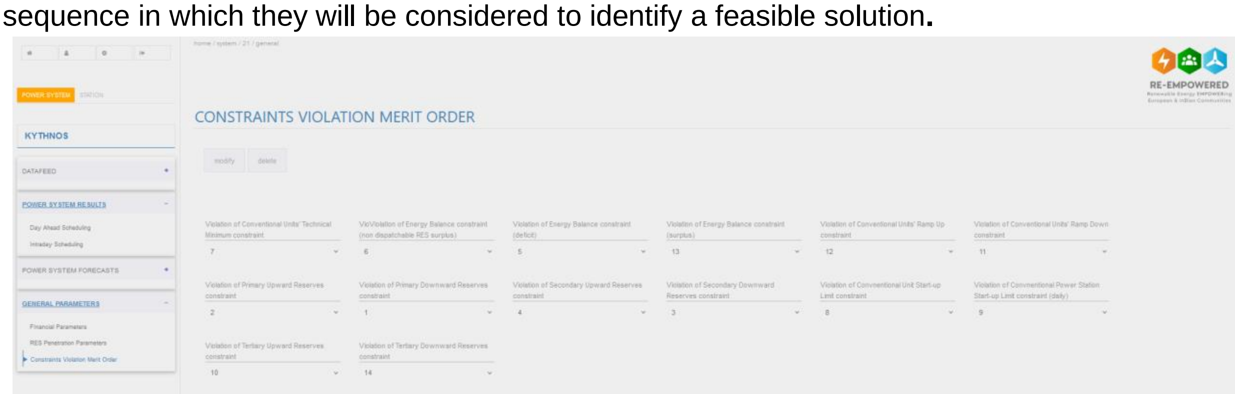


Figure 20: Constraint violation order

In conclusion, the user is prepared to execute the simulation and examine the outcomes. They can modify the Unit Commitment setup and run a new simulation if needed. All simulation results are saved in the database and can be retrieved later. Once the user approves the final result, they can click the “Finalize” button, which stores the final scheduling in a separate table and sends the scheduling orders to the operator of the demo site.

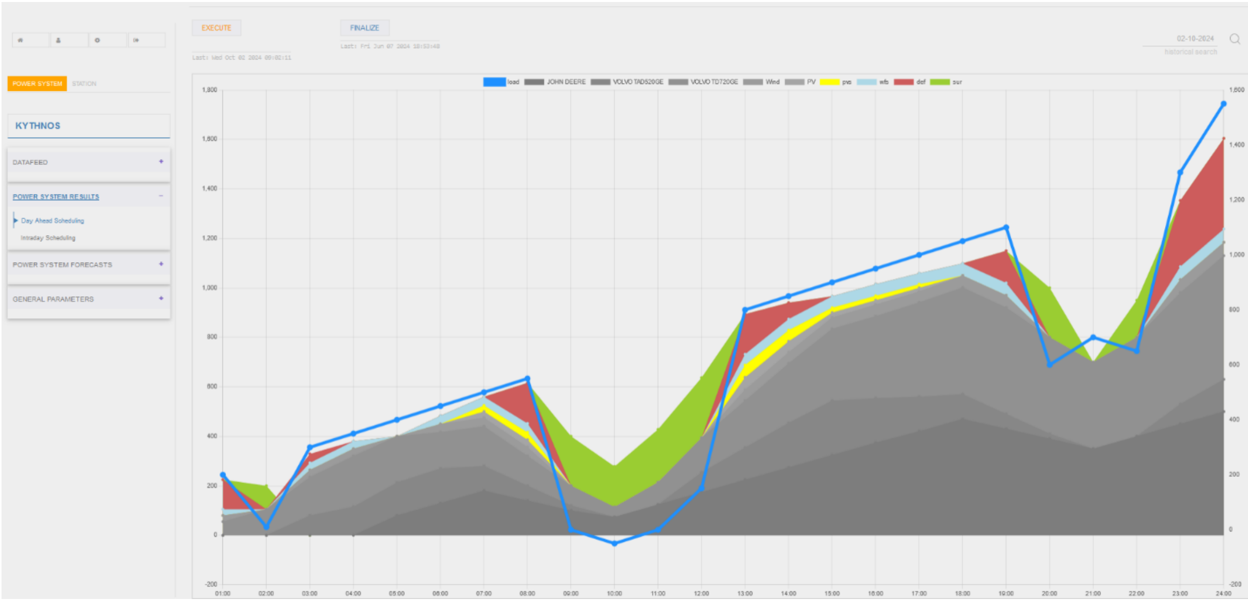


Figure 21: Final result

Interacting with Data

The integrated database is scheduled to receive data from the source database and the ecoPlatform, where are stored at various time intervals, 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.

Since the data have been pulled and transformed in the backend of the application are stored in the integrated database. There are both static tables where 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, 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.

3.2 ecoMicrogrid

EcoMicrogrid is a sophisticated Energy Management System (EMS) designed for microgrids and small off-grid systems. It uses advanced algorithms to optimize performance by leveraging synergies among various energy vectors, including cooling systems. The system continuously monitors all microgrid components and performs necessary actions, such as load shedding, starting or shutting down diesel generators, and curtailing renewable energy sources, to achieve optimal performance. Additionally, EcoMicrogrid coordinates with other ecoTools to engage users in Demand Side Management (DSM) schemes and provide real-time consumption and pricing indicators.

The EcoMicrogrid tool focuses on several key objectives:

- Ensure Reliable and Stable Microgrid Operations: Achieve this through predictive control mechanisms.
- Optimize Storage Devices: Enhance the use and lifespan of storage devices.
- Maximize Cost Savings and Minimize Environmental Impact: Achieve efficient operation to save costs and reduce environmental footprint.
- Promote Sustainable Energy Management: Reduce emissions and support sustainability.
- Maintain Secure Operations: Respect security boundaries to ensure safe operations.
- Enhance Observability: Utilize real-time monitoring and data analysis for improved system visibility.

EcoMicrogrid is offered as an all-in-one solution with low hardware requirements, integrating multiple functionalities into a single hardware device. The software comprises several modules that perform essential functions within its architecture. For detailed module descriptions and architecture, refer to deliverable D4.1. The key system components are illustrated in Figure 22.

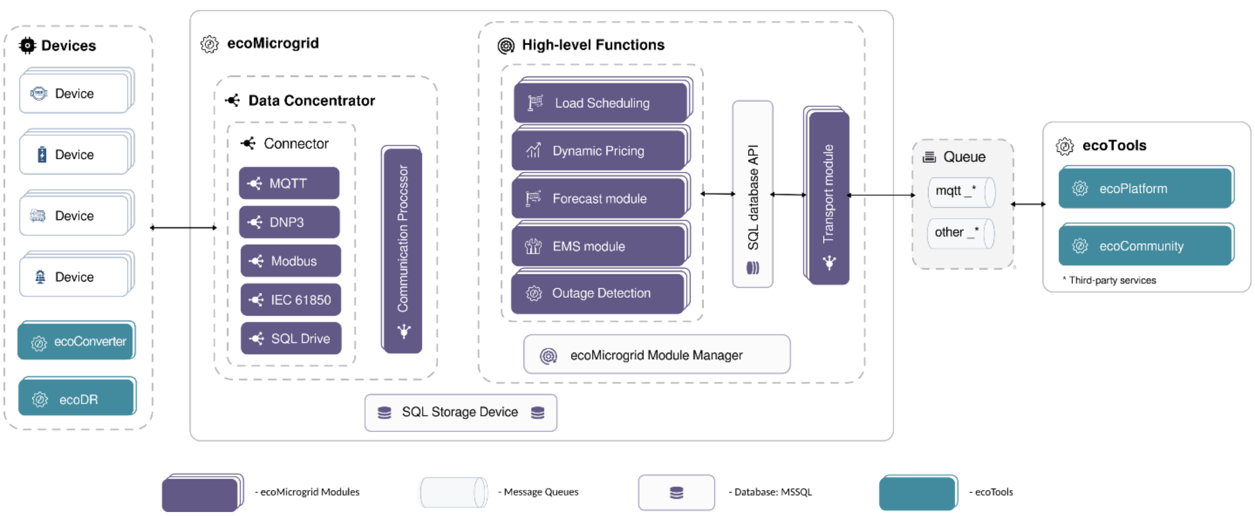


Figure 22: The key system components and architecture of ecoMicrogrid.

The Data Concentrator collects data from field devices and is a proprietary industrial-grade software. It supports over 300 protocols, allowing designers to select the drivers that meet the requirements of each project.

The High-Level Functions ensure the optimal operation of the microgrid. Key components include:

- **EMS Module:** Coordinates control and optimization algorithms to maximize performance.

- **Forecast Module:** Uses meteorological and static data for accurate renewable energy source (RES) forecasts and load forecasting based on historical data.
- **Load Scheduling Module:** Calculates time slots for flexible private loads as part of DSM strategies, optimizing energy utilization.
- **Outage Detection Module:** Detects power outages within the microgrid and identifies their locations for timely response and maintenance.
- **Dynamic Pricing Module:** Calculates the levelized cost of electricity in real-time over a multi-hour horizon, enabling effective pricing strategies.
- **Storage Device:** Manages data storage, serving as an intermediary between the Data Concentrator and High-Level Functions.
- **EcoMicrogrid Manager:** Orchestrates the operation of different modules, ensuring synchronization, coordination, and efficient workflow.
- **Transport Module:** Facilitates communication with external systems, such as ecoCommunity, enhancing interoperability and collaborative functionality.

Each module within the EcoMicrogrid tool functions as a service, providing specific functionalities that can be seamlessly integrated with other modules.

3.2.1 Installation and Configuration

EcoMicrogrid is composed of two main components: the Data Concentrator and the High-Level Functions. Each component plays a crucial role in the system's functionality and has distinct configuration and installation requirements. The Data Concentrator serves as the foundation for data collection and processing, interfacing directly with field devices and supporting a wide array of protocols. On the other hand, the High-Level Functions encompass the sophisticated algorithms and modules that drive the system's optimization capabilities, from energy management to forecasting and pricing.

The following sections provide detailed, step-by-step instructions for the installation and configuration of both the Data Concentrator and the High-Level Functions. These guidelines are designed to facilitate a smooth setup process, enabling system integrators and operators to effectively deploy EcoMicrogrid.

3.2.2 Data Concentrator

The Data Concentrator Module (DCM) is a tool that collects data from field devices. The module consists of a software platform that runs Modbus drivers to acquire the data and then writes these data to an SQL server. The chosen communication protocol is Modbus TCP, which is an open-source and widely used protocol.

The Zenon platform is a flexible platform where the designer can select among many drivers to implement the solution that meets the requirements of each project. The Modbus TCP drivers are configured in a Client-Server architecture by specifying the correct IP address for each device (Figure 23). In this specific project, the devices are energy meters (E.M), where the drivers collect data such as active power, current, and voltage (Figure 24). Moreover, there are other measurements for other auxiliary and balance of plant (BOP) devices, such as the battery storage system, temperature sensors, HVAC, and diesel generator.

In the Modbus protocol, the client requests specific data from the server via polling at a specific address with a constant sampling rate. For example, the current from the energy meter of house number 10 would be requested as slave device 1 address 15 "H10-SEM_CurrentA" variable.
After collecting the measurement data, the application writes the data to an SQL database table. The database source (DSN) is synchronized with Zenon via an ODBC driver, and the designer declares the driver's string to the Zenon application. In Zenon, the variables, after being collected from the Modbus driver, are transformed into SQL variables using the Zenon allocation attribute (Figure 25). Each variable is allocated to an SQL variable that meets the standard for writing it to an SQL table. The writing to the SQL table is done automatically. The data written to the table are accessible for manipulation (statistic analysis, prediction,etc) by the system.
The system has a high level of interoperability, as the Modbus protocol is widely adopted, ensuring that devices from different vendors can communicate effectively. Finally, the scalability of the system can be greatly extended by simply adding new variables to the drivers. Many solutions using Modbus handle tens of thousands of variables.

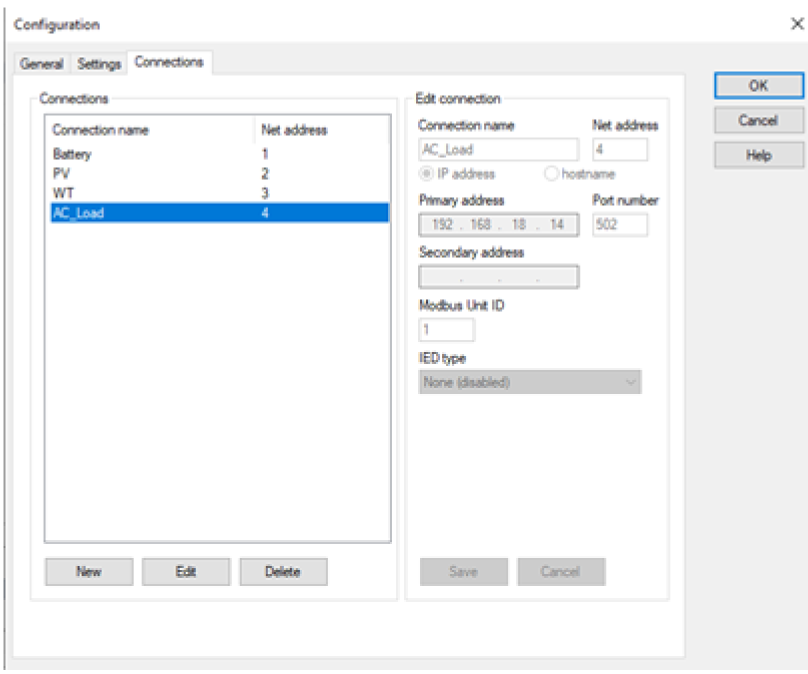


Figure 23: The Variables Registration on DCM

	Project1/Global/CR_BATT_Idc_mdbs_all
	CR-BATT_P
	CR-BATT_Vdc
	CR-BATT_Idc
	Project1/Global/trigger_logic_BATT
	Project1/Global/CR_BATT_SoC_Mdbs_All
	BATT_SOC
Net address : 2 (2 Elements)	
	CR_PV_P_mdbs
	CR_PV_Energy_Exp_mdbs
Net address : 4 (10 Elements)	
	CR_TL_Pa_mdbs
	CR_TL_Pb_mdbs
	CR_TL_Pc_mdbs
	CR_TL_Ptot_mdbs
	CR_TL_Qa_mdbs
	CR_TL_Qb_mdbs
	CR_TL_Qc_mdbs
	CR_TL_Energy_Cons_Grid_Mdbs
	CR_TL_PF_mdbs
	CR_TL_F_mdbs
Net address : 1 (5 Elements)	
	CR_BATT_P_mdbs
	CR_BATT_Vdc_mdbs
	CR_BATT_Idc_mdbs
	CR_BATT_Energy_Cons_Grid_Mdbs
	CR_BATT_Energy_Fed_Grid_Mdbs
Net address : 3 (2 Elements)	
	CR_WT_Energy_Exp_Mdbs
	CR_WT_P_Mdbs
Net address : 5 (2 Elements)	
	test_COMM_ECO_DR
	test_COMM_ECO_DR_1
Net address : 6 (2 Elements)	
	test_Developed_ECO_DR_1
	test_Developed_ECO_DR

Figure 24: The Variables Registration on DCM

Allocation 0		Project1/Global/RHM_TotalActivePower_Mdbs_All	RHM_TotalActivePower
Allocation 1		Project1/Global/CLH_A_Energy_All	CLH-A_Energy
Allocation 2		Project1/Global/CLH_A_TotalActivePower_Mdbs_All	CLH-A_TotalActivePower
Allocation 3		Project1/Global/CR_BATT1_TotalActivePower_Mdbs_All	CR-BATT1_TotalActivePower
Allocation 4		Project1/Global/CLH_B_TotalActivePower_Mdbs_All	CLH-B_TotalActivePower
Allocation 5		Project1/Global/RHM_Energy_Mdbs_All	RHM_Energy
Allocation 6		Project1/Global/CLH_C_TotalActivePower_Mdbs_All	CLH-C_TotalActivePower
Allocation 7		Project1/Global/CLH_B_Energy_Mdbs_All	CLH-B_Energy
Allocation 8		Project1/Global/CLH_D_TotalActivePower_Mdbs_All	CLH-D_TotalActivePower
Allocation 9		Project1/Global/CLH_C_Energy_Mdbs_All	CLH-C_Energy
Allocation 10		Project1/Global/CLH_E_TotalActivePower_Mdbs_All	CLH-E_TotalActivePower
Allocation 11		Project1/Global/CLH_D_Energy_Mdbs_All	CLH-D_Energy
Allocation 12		Project1/Global/CLH_F_TotalActivePower_Mdbs_All	CLH-F_TotalActivePower
Allocation 13		Project1/Global/CLH_E_Energy_Mdbs_All	CLH-E_Energy
Allocation 14		Project1/Global/CLH_G_TotalActivePower_Mdbs_All	CLH-G_TotalActivePower
Allocation 15		Project1/Global/CLH_F_Energy_Mdbs_All	CLH-F_Energy
Allocation 16		Project1/Global/CLH_H_TotalActivePower_Mdbs_All	CLH-H_TotalActivePower
Allocation 17		Project1/Global/CLH_G_Energy_Mdbs_All	CLH-G_Energy
Allocation 18		Project1/Global/CLH_I_TotalActivePower_Mdbs_All	CLH-I_TotalActivePower
Allocation 19		Project1/Global/CLH_H_Energy_Mdbs_All	CLH-H_Energy
Allocation 20		Project1/Global/CLH_J_TotalActivePower_Mdbs_All	CLH-J_TotalActivePower
Allocation 21		Project1/Global/CLH_I_Energy_Mdbs_All	CLH-I_Energy
Allocation 22		Project1/Global/CR_LC_TotalActivePower_Mdbs_All	CR-LC_TotalActivePower
Allocation 23		Project1/Global/CR_BATT1_VoltageDC_Mdbs_All	CR-BATT1_VoltageDC
Allocation 24		Project1/Global/CR_BMG_Status_Mdbs_All	CR-BMG_Status
Allocation 25		Project1/Global/CR_PV1_TotalActivePower_Mdbs_All	CR-PV1_TotalActivePower
Allocation 26		Project1/Global/CR_BATT1_CurrentDC_Mdbs_All	CR-BATT1_CurrentDC
Allocation 27		Project1/Global/CR_ACDL_TotalActivePower_Mdbs_All	CR-ACDL_TotalActivePower
Allocation 28		Project1/Global/CR_ACDL_Energy_Mdbs_All	CR-ACDL_Energy
Allocation 32		Project1/Global/CR_BMG_TotalActivePower_Mdbs_All	CR-BMG_TotalActivePower
Allocation 33		Project1/Global/CR_BATT1_SoC_Mdbs_All	CR-BATT1_SoC

Figure 25: The Variables Allocation from Modbus to SQL.

3.2.3 High-Level Functions

The high-level modules have been mainly developed in Python, and a dedicated GitLab repository was used for collaboration and storage of the project. The repository is private and available [here](https://gitlab.com/smartrue-reempowered/ecomicrogrid). Part of the following instructions is also available there.

3.2.3.1 Overview

The high-level modules of EcoMicrogrid have been primarily developed using Python. These modules constitute the core intelligence of the system, responsible for advanced functionalities such as energy management, forecasting, and optimization.

3.2.3.2 Development and Collaboration

To facilitate collaborative development and version control, a dedicated GitLab repository has been utilized. This repository serves as the central hub for code storage, issue tracking, and project management.

- **Type**: Private GitLab repository
- **Access**: Restricted to authorized team members
- **URL**: https://gitlab.com/smartrue-reempowered/ecomicrogrid

3.2.3.3 Documentation

Detailed instructions for installation, configuration, and usage of the high-level functions are available within the GitLab repository. These instructions cover:

- Environment setup
- Dependency management
- Module configuration
- Integration with the Data Concentrator
- Troubleshooting common issues

3.2.4 Setting up the Code

- **Cloning the Repository**

To clone the repository, ensure you have `git` installed on your machine. Choose the correct distribution for your OS and clone the repository using:

```
git clone https://gitlab.com/smartrue-reempowered/ecomicrogrid/pyemgmanager.git
```

It is also important to initialize the submodules:

```
git submodule init
```

As the repository is private, ensure you have the necessary permissions before attempting to access it. If you require access or have any questions about the high-level functions, please contact the ecoMicrogrid development team. For security reasons, do not share access credentials or repository contents with unauthorized individuals.

- **Setting up Python**

The project requires `Python` to be installed on your machine. The exact version can be found in the `Pipfile` file at the `python_version` property.

- It is highly recommended to use PyEnv[1] as the Python manager regardless of the OS you use (use pyenv-win on Windows[2]).

- **Creating the Virtual Environment**

Although there are many tools for `Python` to create and manage a virtual environment, for this project it is **highly** recommended to use `pipenv` (on Windows, make sure to follow the installation instructions[3]

Once `pipenv` is installed and functional, create a folder named “`.venv`“ in the root directory and use the following command to install all dependencies:

```
pipenv sync
```

- Code Development and Debugging

For code development, Visual Studio Code was chosen as the preferred IDE. Therefore, debugging and other tasks are based on it.

3.2.5 Code Structure

The following provides a generic description of the code structure.

- `docs`: Documentation
- `services`: Register ecoMicrogridManager as a service on Windows.
- `solvers`: Repository for various solvers
- `tools`: Collection of tools to help `compile` or `minify` the project's code (submodule)
- `source`: The source code
    - `dbapi`: Database interaction provider. Also holds the MSSQL project structure needed for DB initialization (submodule)
    - `dynamic pricing`: Dynamic pricing data provider (submodule)
    - `ems`: EMS data provider (submodule)
    - `pv forecast`: PV forecast data provider (submodule)
    - `load forecast`: Load forecast data provider (submodule)
    - `load scheduler`: Load scheduler data provider (submodule)
    - `outage detection`: Outage detection data provider (submodule)
    - `plogging`: Logging provider (submodule)
    - `transport`: Collection of data transporters (submodule)
        - `mqtt`: MQTT client
        - `nwp`: NWP *(Numerical Weather Prediction)* data provider via HTTPS
    - `managers`: Collection of manager classes
        - `config manager`: The configuration (settings and arguments) orchestrator

[1] PyEnv is available at: https://python.land/virtual-environments/pyenv
[2] pyenv-win is available at: https:/github.com/pyenv-win/pyenv-win
[3] Available at: https://pipenv.pypa.io/en/latest/installation.html#preferred-installation-of-pipenv

- `eco microgrid manager`: The main workflow orchestrator
- `services`: Collection of services
    - `abstracts`: Abstraction classes
    - `consumption`: Energy consumption data publisher via MQTT transporter
    - `dsm availability`: DSM availability data publisher via MQTT transporter
    - `dsm booking`: DSM booking data subscriber via MQTT transporter
    - `ems`: EMS workflow service
    - `forecasts data`: Collection of forecast data services
        - `demand`: Energy demand data publisher via MQTT transporter
        - `ems`: EMS data publisher via MQTT transporter
    - `load forecast`: Load forecast workflow service
    - `load scheduler`: Load scheduler workflow service
    - `nwp`: NWP *(Numerical Weather Prediction)* workflow service
    - `outage detection`: Outage detection workflow service
    - `pricer`: Dynamic pricing data publisher via MQTT transporter
    - `pricing`: Dynamic pricing workflow service
    - `pv forecast`: PV forecast workflow service
    - `real time data`: Real time data publisher via MQTT transporter
- `main`: Entry point
- `settings`: The settings configurations needed to run the program
- `version`: Version numbering

3.2.6 Compiling the code

This project is targeting Windows OS due to the requirements of the data concentrator, however compiling for unix based systems is doable. To compile the project to a Windows executable, use:

```
pipenv run package-win
```

If you have chosen not to use pipenv, you can use:

```
python ./tools/package.py ./ecoMicrogridManager.win.spec –log-level=ERROR
```

Ensure you have enabled a virtual environment beforehand. An executable can also be created for Linux by using (untested):

```
pipenv run package_unix
```

3.2.7 Setting up the configuration

Configuration is based on TOML and includes the following sections:

Table 16: GLOBAL section

Property Name	Description
longitude	The site's longitude for NWP data retrieval
latitude	The site's latitude for NWP data retrieval

Table 17: DB section.

Property Name	Description	Note
connection_url	The URL to connect to the database	see SQLAlchemy docs

Table 18: GROUPS section.

Property Name	Description
pv_group_names	The group name of the PVs used in the DB related table
load_group_names	The group name of the loads used in the DB related table
building_group_names	The group name of the buildings used in the DB related table
indoor_temperature_group_names	The group name of the indoor temperature meters used in the DB related table
outdoor_temperature_group_names	The group name of the outdoor temperature meters used in the DB related table
thermal_unit_group_names	The group name of the thermal units used in the DB related table
hvac_unit_group_names	The group name of the HVAC units used in the DB related table
bes_unit_group_names	The group name of the BES units used in the DB related table
feeder_group_names	The group name of the line feeders used in the DB related table

Table 19: ASSETTYPE.NAMES section.

Property Name	Description
pv_type_name	The asset type name of the PVs used in the DB related table
load_type_name	The asset type name of the loads used in the DB related table

building_type_name	The asset type name of the buildings used in the DB related table
indoor_temperature_type_name	The asset type name of the indoor temperature meters used in the DB related table
outdoor_temperature_type_name	The asset type name of the outdoor temperature meters used in the DB related table
thermal_type_name	The asset type name of the thermal units used in the DB related table
hvac_type_name	The asset type name of the HVAC units used in the DB related table
bes_type_name	The asset type name of the BES units used in the DB related table

Table 20: WD.PROVIDER section.

Property Name	**Description**	**Unit**
cron	The interval on which the provider fetches data from the source4 https://en.wikipedia.org/wiki/Cron	
catalog_url	The URL of the NWP provider	
dataset	The query section of URL of the NWP provider	
level	The elevation level for the NWP data	meters
forecast_horizon_hours	The horizon of the forecasting data to fetch	hours

Table 21: WD.PROVIDER.VARIABLES section.

Property Name	**Description**
temperature	The property name used by the NWP provider for temperature
cloud	The property name used by the NWP provider for cloud coverage
windspeed	The property names used by the NWP provider for windspeed

Table 22: PV.FORECAST section.

Property Name	**Description**	**Unit**
wd_lookup_hours	The amount of hours to lookup for weather data	hours
forecast_horizon_hours	The horizon of the forecasting data to fetch	hours
surface_type	Not Used	
altitude	Not Used	

[4] Follows the cron syntax: https://en.wikipedia.org/wiki/Cron.

Table 23: LOAD.FORECAST section.

Property Name	Description	Unit
cron	The interval on which the provider fetches data from the source (cron syntax)	
meas_lookup_hours	The amount of hours to lookup for measurement data	hours
forecast_horizon_hours	The horizon of the forecasting data to fetch	hours
meas_property_name	The property name of the measurement data to fetch	

Table 24: LOAD.SCHEDULER section.

Property Name	Description	Unit
bes_charge_target_percentage	The Battery Energy System charging target	percentage (%)

Table 25: EMS section.

Property Name	Description	Unit
provider_name	The name of the provider class to use	
cron	The interval on which the provider fetches data from the source (cron syntax)	
forecast_horizon_hours	The horizon of the forecasting data to fetch	hours
air_density	The air density	number
earth_temperature	The temperature of the Earth	degrees
solver	The name of the solver to use	
solver_executable_path	The path to the solver executable	
timeout	The amount of time the solver should wait for a calculation to finish	seconds

Table 26: PRICING section.

Property Name	Description	Unit
forecast_horizon_hours	The horizon of the forecasting data to fetch	hours
asset_property_name	The property name of the asset data to fetch	
meas_property_name	The property name of the measurement data to fetch	

Table 27: OUTAGE.DETECTION section.

Property Name	Description
cron	The interval on which the provider fetches data from the source (cron syntax)

meas_property_name	The property name of the measurement data to fetch

Table 28: MQTT section.

Property Name	Description	Note
host	The IPv4 to communicate to	
port	The port to communicate to	
username	The username to log in	
password	The password to log in	
use_ssl	Indicate whether to use SSL or not	True or False
ca_certs	The path to the CA certificate	Only used for SSL
certfile	The path to the client certificate	Only used for SSL
keyfile	The path to the client key file	Only used for SSL

Table 29: DSM.AVAILABILITY section.

Property Name	Description
topic	The name of the MQTT topic to publish to

Table 30: DSM.BOOKING section.

Property Name	Description
cron	The interval on which the provider fetches data from the source (cron syntax)
topic	The name of the MQTT topic to subscribe to

Table 31: PRICER section.

Property Name	Description
topic	The name of the MQTT topic to publish to

Table 32: CONSUMPTION section.

Property Name	Description
cron	The interval on which the provider fetches data from the source (cron syntax)
topic	The name of the MQTT topic to publish to
meas_property_name	The property name of the measurement data to fetch

Table 33: REALTIME section.

Property Name	Description
cron	The interval on which the provider fetches data from the source (cron syntax)
topic	The name of the MQTT topic to publish to
meas_property_name	The property name of the measurement data to fetch

Table 34: DEMAND section.

Property Name	Description	Unit
topic	The name of the MQTT topic to publish to	
forecast_horizon_hours	The horizon of the forecasting data to fetch	hours
meas_property_name	The property name of the measurement data to fetch	

Table 35: FORECASTS section.

Property Name	Description
topic	The name of the MQTT topic to publish to
meas_property_name	The property name of the measurement data to fetch

3.2.8 How to Deploy it

Prerequisites:

- Install MSSQL Server on the target machine.
- Create a deployment folder on the target machine.
- Register the ecoMicrogridManager executable as a service on the target machine.
- Copy the solver executable to the deployment folder on the target machine, on the same path as set in the settings[5].
- Copy the certificates if you are going to use SSL to connect to MQTT on the target machine, on the same path as set in the settings[6].
- Compile the source code.

Deploying via Automation Script:

In order to facilitate and automate as much as possible the deployment, a *deploy* script has been created. Since the project is targeting the `Winodws OS` the script is written in `Powershell`.

In order to use the script, open a `powershell` terminal and type `` `.\deploy.ps1 [options]` `` from the root folder of the project.

[5] See section 3.2.7 Setting up the configuration.
[6] See section 3.2.7 Setting up the configuration.

```
> .\deploy.ps1
Usage: deploy.ps1 [-ip] address [-verbose] [-settings] [-stop] [-start] [-restart]
  -ip                 The ip address of the server
  -p -stop            Only stops the service
  -t -start           Only starts the service
  -o -nostart         Does not starts the service
  -r -restart         Only restarts the service
  -u -uploadonly      Only uploads the files
  -x -noupload        Does not upload the files
  -s -settings        Include settings files in the deployment
  -d -details         Display detailed output
  -v -verbose         Display verbose output
```

3.2.9 Data base Initialization

To initialize the database for use, follow these steps:

1. **Install SQL Server and SSMS**:
   - Download and install MSSQL Server Developer Edition on the target machine.
   - **Note:** During the installation process, make sure to set the Data folder to a drive with a high capacity.
   - Download and install SQL Server Management Studio on the target machine.
2. **Publish the Database Schema**[7]:
   - Uses the `sqlpackage` tool[8].
   - Publish the database schema to the SQL Server on the target machine, using the publish.cmd found in the `dbapi\sqlproject\ecomicrogrid` folder.
   - Replace the path/to/ecomicrogrid.dacpac parameter with the path to the ecomicrogrid.dacpac, which can be found in the `dbapi\sqlproject\ecomicrogrid\Release` folder.
   - Replace the *servername parameter* (you can use the IP of the server).
   - Replace the *username* parameter.
   - Replace the *password* parameter.

1. **Initialize the Static Data**
   - Populate the static data csv files found in the `dbapi\sqlproject\ecomicrogrid\staticdata` folder (these are template files) with the data for the site[9].
   - Copy the populated *csv* files to the target machine, in the same folder where you have the Data folder of the MSSQL installation.
   - Copy the *sql* scripts found in `dbapi\sqlproject\ecomicrogrid\scripts` to the target machine, in the same folder where you have the Data folder of the MSSQL installation. This is **important** to execute the static data initialization scripts.
   - Open the SSMS (SQL Server Management Studio) on the target machine and load the `MasterScript.sql` file.

[7] This command requires *admin* privileges to the SQL Server.
[8] If it's not already installed, you can find it here.
[9] The data should be separated with semicolons (;).

- Before executing the script, replace the `scriptRootDir` and `staticDataRootDir` parameters with the actual path of the scripts folder and the actual path of the static data folder.
- Execute the `MasterScript.sql`.

3.3 ecoPlatform

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

3.3.1 Functionalities

The objective is to establish the ecoPlatform as a cloud-based service running on a local server with a service bus to support communication with other digital services. Its primary functions are as follows:

- Communication and data exchange between different tools
- Data storage and governance
- User interface to visualizing data streams
- Communication and asset status monitoring
- Alarms and notifications related to system operations
- Interface to incorporate data pre-processing algorithms

Two versions of ecoPlatform have been developed: ecoPlatfrom-A and ecoPlatform-B. Both versions feature a user interface, MQQT, cloud support, and HTTP API, making them versatile tools tailored for their specific use cases and demo sites. EcoPlatform-A is designed specifically for the Bornholm demo site to facilitate communication with corresponding tools.

3.3.2 The Architecture of ecoPlatform-A

The architecture of ecoPlatform integrates various roles, including operators, data providers, consumers, instance administrators, users, platform developers, system administrators, demo-site leaders, and ecoTool leaders. This structure enables these stakeholders to make informed decisions and promote sustainable energy practices.

• **System administrators** handle all Linux server-side tasks necessary for installing and running an instance of the platform.

• **Platform developers** are responsible for enhancing or expanding the platform's functionality after its initial release.

• **Instance administrators** manage the web application component of ecoPlatform. They have specific responsibilities and privileges within the system.

• **Users** are individuals with a user account on an ecoPlatform instance. They can create new datasets, becoming the owner of those datasets and managing their datastreams. Users can also invite others to become co-owners of their datasets.
• **Data providers** and consumers are the individuals and programs that use the ecoPlatform API to supply or consume data through the platform.

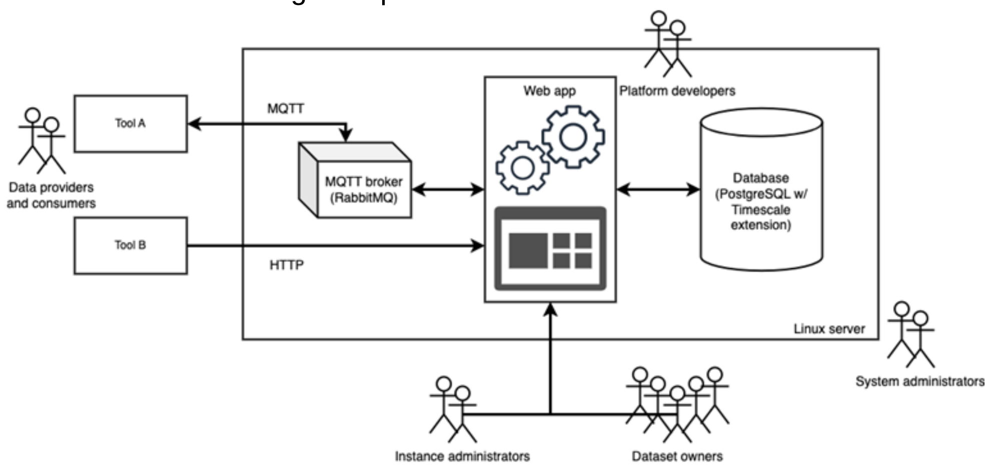


Figure 26: Platform services integrated with the Linux server

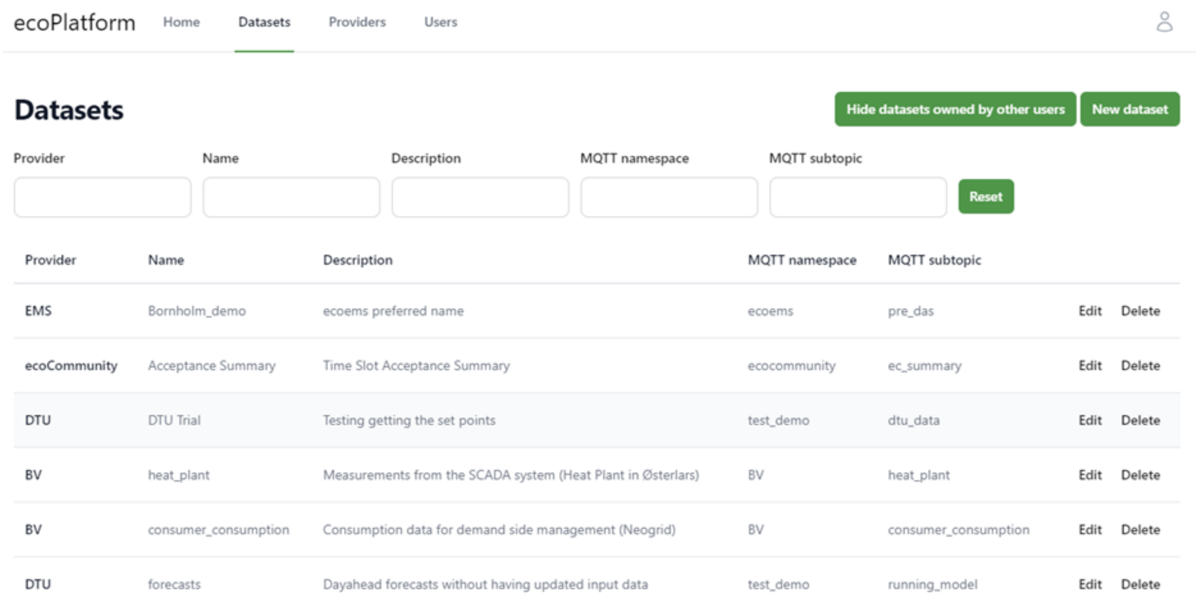
The platform includes an **MQTT API** that allows providers to publish data, and consumers to subscribe it. This API is ideal for cases where consumers need to be immediately notified when new data is published by a provider. Additionally, the platform includes an **HTTP API** that enables providers to import data and consumers to export data. This API is suitable for situations where bulk data import and export are needed, and immediate notification of data arrival is not required.

3.3.3 Interactions with Other ecoTools

The ecoPlatform at the Bornholm demo site interacts with various ecoTools, each serving a specific purpose and contributing to the overall functionality of the ecoPlatform ecosystem:
• **ecoEMS:** Provides suggestions for the efficient operation of the Østerlars District Heating Network (DHN), such as the optimal dispatch of electrical boilers in conjunction with a straw-fueled boiler.
• **ecoDR:** Creates flexibility in the electrical grid using demand-response techniques.
• **ecoMonitor:** Consists of sensors that monitor air quality at the District Heating (DH) plant.
• **ecoCommunity**: An Android mobile app for monitoring heat consumption, managing flexibility, and engaging the community.
• **ecoPlatform**: Collects and stores data from the District Heating plant and consumers, facilitating interaction with other tools.

3.3.4 User Registration and Operations on ecoPlatform

The system administrator is responsible for adding new users and sending them a registration link for the platform at https://reempowered-ecoplatform.dk/. Users can create their own login credentials by following this link. Before creating datasets and datastreams, users must first create a provider. Then, the user decides on a dataset name along with an MQTT subtopic, which is sent to the system administrators. With the provided MQTT subtopic and dataset name, the system administrator generates and sends the user API credentials, including an API Key and API Secret. These credentials allow users to submit data and subscribe to data streams.



Provider	Name	Description	MQTT namespace	MQTT subtopic		
EMS	Bornholm_demo	ecoems preferred name	ecoems	pre_das	Edit	Delete
ecoCommunity	Acceptance Summary	Time Slot Acceptance Summary	ecocommunity	ec_summary	Edit	Delete
DTU	DTU Trial	Testing getting the set points	test_demo	dtu_data	Edit	Delete
BV	heat_plant	Measurements from the SCADA system (Heat Plant in Østerlars)	BV	heat_plant	Edit	Delete
BV	consumer_consumption	Consumption data for demand side management (Neogrid)	BV	consumer_consumption	Edit	Delete
DTU	forecasts	Dayahead forecasts without having updated input data	test_demo	running_model	Edit	Delete

Figure 27: Datasets on ecoPlatform created and uploaded by users.

3.3.5 Introduction to ecoPlatform B

Overview

ecoPlatform B is an advanced integration tool designed to enable seamless communication and data exchange between various ecoTools within a demo site. Built on a Dockerized architecture, it ensures modularity, security, and ease of deployment across diverse environments.

Purpose of ecoPlatform-B

The primary purpose of ecoPlatform B is to unify the operation of multiple ecoTools, enabling them to work together efficiently. It standardizes data exchange protocols and offers robust storage and visualization capabilities to enhance the operational efficiency and data management practices of sustainability initiatives.

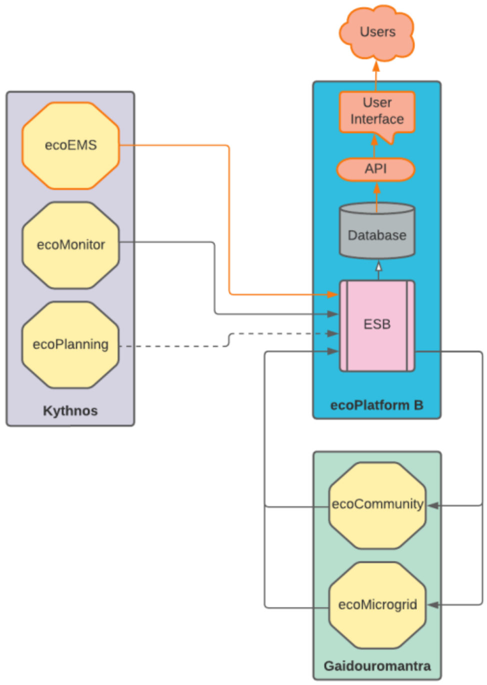


Figure 28: Example of the architecture of an ecoPlatform B instance

Key Features

- **Enterprise Service Bus (ESB):** Central communication hub based on RabbitMQ and MQTT protocols.
- **Database:** Dockerized MySQL for centralized data storage.
- **Storage Microservice:** Manages the data flow between ESB and Database.
- **API:** Facilitates data retrieval and interaction.
- **Front-end Dashboard:** User-friendly interface for data visualization.

System Requirements

- **Operating System:** Linux, macOS, or Windows with Docker support.
- **Memory:** At least 2GB RAM.
- **Storage:** Minimum 20GB free disk space.

System Architecture

General Description

ecoPlatform B is composed of several interconnected subsystems that work together to manage and visualize data from various ecoTools. The platform is designed to be flexible and scalable, adapting to the needs of different demo sites.

Subsystems Overview

Enterprise Service Bus (ESB)

The ESB is the core communication infrastructure of ecoPlatform B, enabling real-time data exchange between ecoTools. It uses RabbitMQ for message brokering and the MQTT protocol for lightweight messaging.

Database

The Database subsystem, implemented using MySQL, serves as the central repository for storing data received from ecoTools. Each demo site operates its instance of the database to ensure data isolation and security.

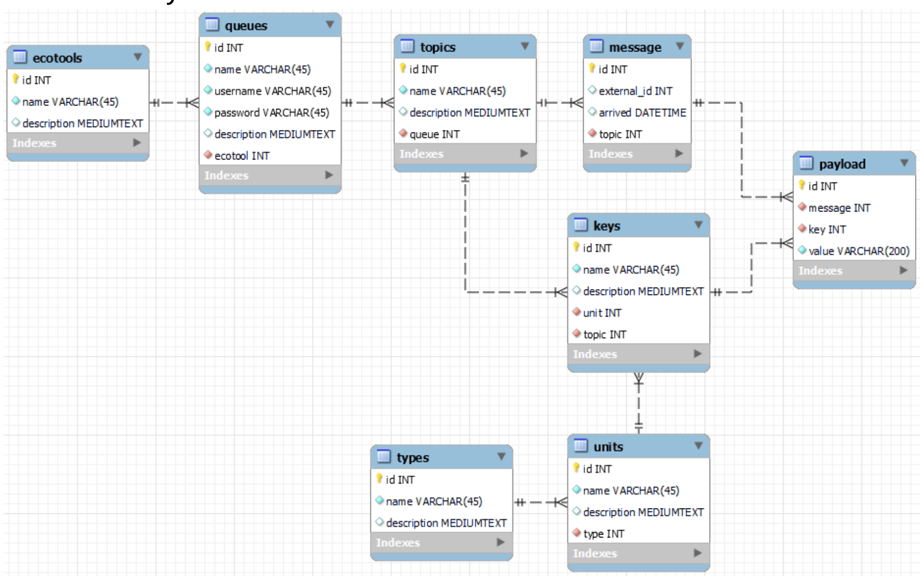


Figure 29: ecoPlatform's DB Shema

Storage Microservice

This microservice acts as an intermediary between the ESB and the Database. It processes incoming messages from the ESB and stores the relevant data in the database, ensuring data accuracy and integrity.

API for Data Visualization

The API subsystem provides endpoints for querying and retrieving data stored in the Database. It is essential for enabling the Front-end Dashboard to visualize real-time data.

Front-end Dashboard

The Dashboard is a web-based interface that allows users to interact with data in real-time. It is built using Angular and chart.js and is designed to be intuitive and responsive.

Installation and Setup

Prerequisites

Before installing ecoPlatform B, ensure that your system meets the necessary requirements, including Docker and Docker Compose.

Installing Docker and Docker Compose

- **Linux:** Install Docker using your distribution's package manager and Docker Compose by downloading it from the official Docker website.
- **macOS/Windows:** Download Docker Desktop, which includes Docker Compose.

Deploying ecoPlatform B

1. **Clone the ecoPlatform B Repository:** Obtain the latest version from the repository.
2. **Navigate to the Deployment Directory:** Access the directory containing the Docker Compose file.
3. **Run Docker Compose:** Use the command docker-compose up -d to start the deployment. This command will launch all the necessary containers.

Verifying Installation

After deployment, verify that all containers are running and accessible. Check the status using docker ps and ensure that the ESB, Database, API, and Dashboard are operational.

Using ecoPlatform B

Accessing the Dashboard

To access the ecoPlatform B Dashboard, open your web browser and navigate to http://83.212.170.163:8888/dashboard.html. The Dashboard will prompt you to log in with your credentials.

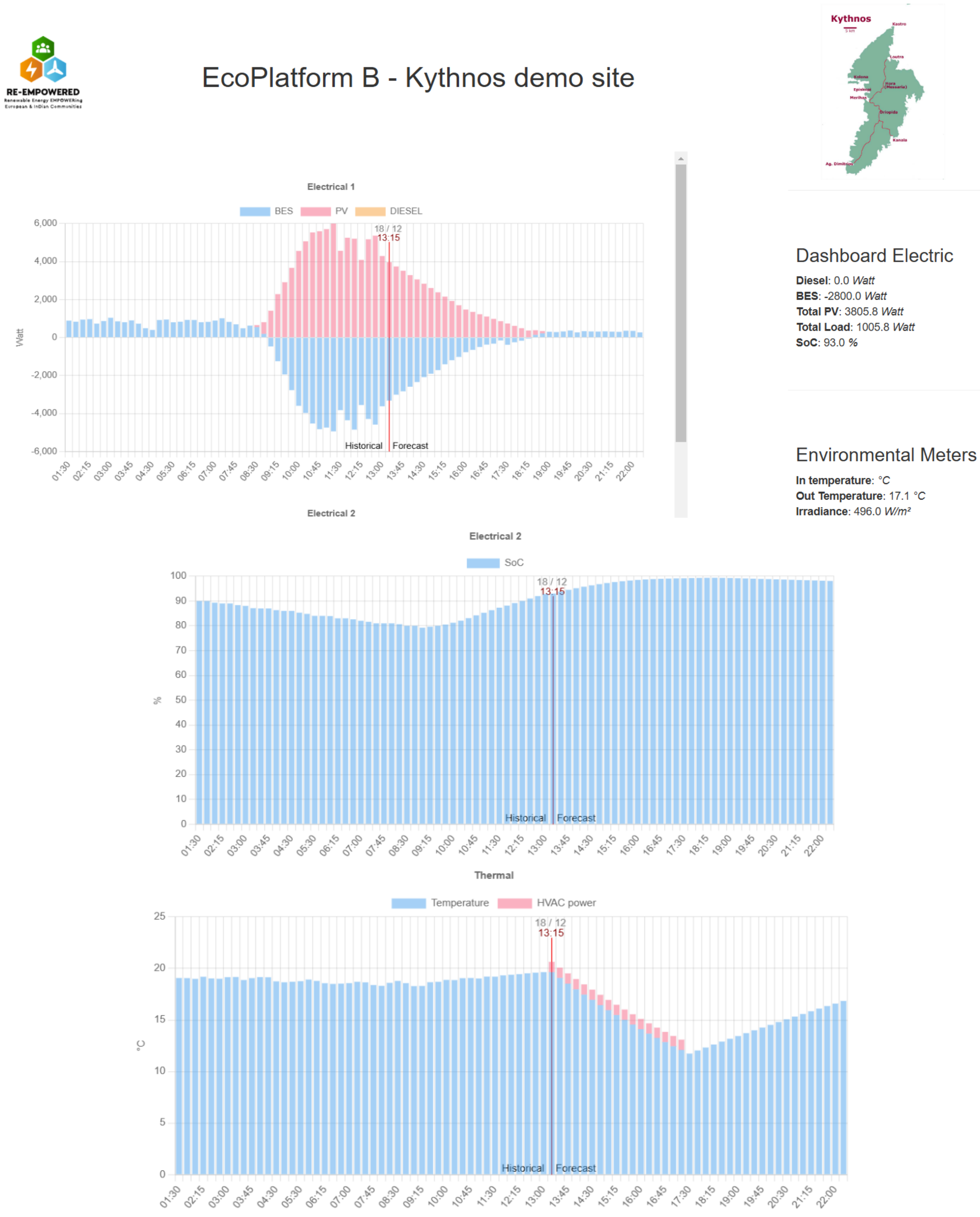


Figure 30: Examples of ecoPlatform's B views.

Navigating the Interface

Dashboard Overview

The Dashboard's homepage provides an overview of system status, including active ecoTools, data flow, and performance metrics.

Data Tables

View detailed data tables that show raw data from the ecoTools. You can filter, sort, and export data as needed.

Charts and Graphs

Visualize data trends and patterns using the Dashboard's charting tools. Customize graphs based on specific ecoTool data or time frames.

Interacting with Data

Querying Data via API

Use the API endpoints to query specific data from the Database. Endpoints are available for accessing ecoTool information, data queues, and more.

The API is listening at: http://83.212.170.163:7777

Real-time Data Monitoring

Monitor real-time data flow and system performance directly through the Dashboard. This feature is critical for live assessments of ecoTool operations.

Managing ecoTools

Integrating New ecoTools

To integrate a new ecoTool, configure its communication settings in the ESB and update the API as needed.

Monitoring ecoTool Performance

Use the Dashboard to monitor the performance of integrated ecoTools to ensure optimal operation.

3.4 ecoPlanning

Description: ecoPlanning is a tool applied in non-interconnected islands, for the decision-making process of deploying new electricity generation units. The studies to be conducted by the tool are: 7-year energy planning for the assessment of the conventional power units deployment plan;

analysis of the RES hosting capacity; interconnection assessment through steady-state simulations to evaluate the interconnection gains.
Contact Information: George M. Milionis

3.4.1 Introduction

The section presents the user interface through which the following actions can be performed: demand/peak estimations, and formulation of ES Models.
All Demand/Peak Models and ES Models are saved and can be edited according to the user preferences. The combination of one Demand/Peak Model with an ES Model defines a scenario that can be used in order to simulate the operation of the ES on an hourly basis either for 7-Year Energy Planning studies (the simulation runs for at least one year and maximum seven years), for RES Hosting Capacity studies (simulation per scenario), for Monthly Energy Balance studies (one-year simulation) or for Interconnections Study.
This section presents the step-by-step procedure for formulating the models and executing the scenarios (For more detail, please refer to Deliverable 3.4 [4]).

3.4.2 Initial Screen

After logging in (Figure 31), the dashboard appears, where the user can select the ES using the drop- down menu (Figure 32). Accordingly, two lists appear: one with the saved Demand/Peak Models and one with the saved ES Models for the specific electric system (Figure 33).

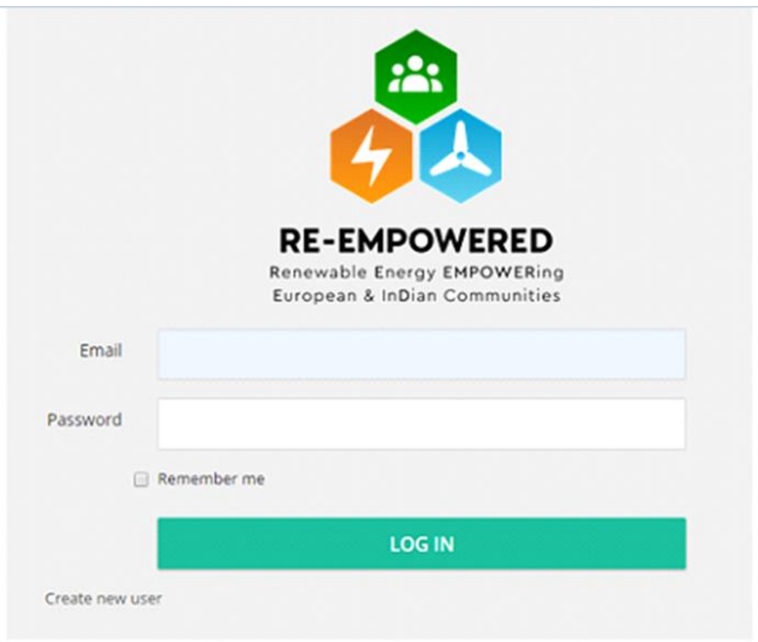


Figure 31: Log-in screen

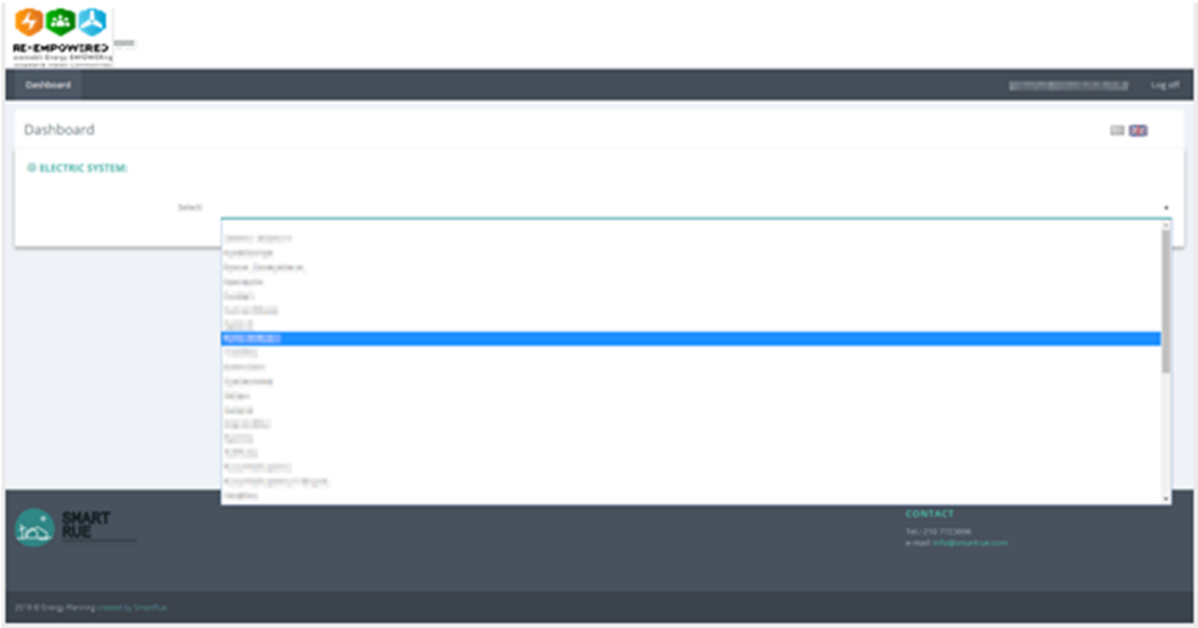


Figure 32: ES selection.

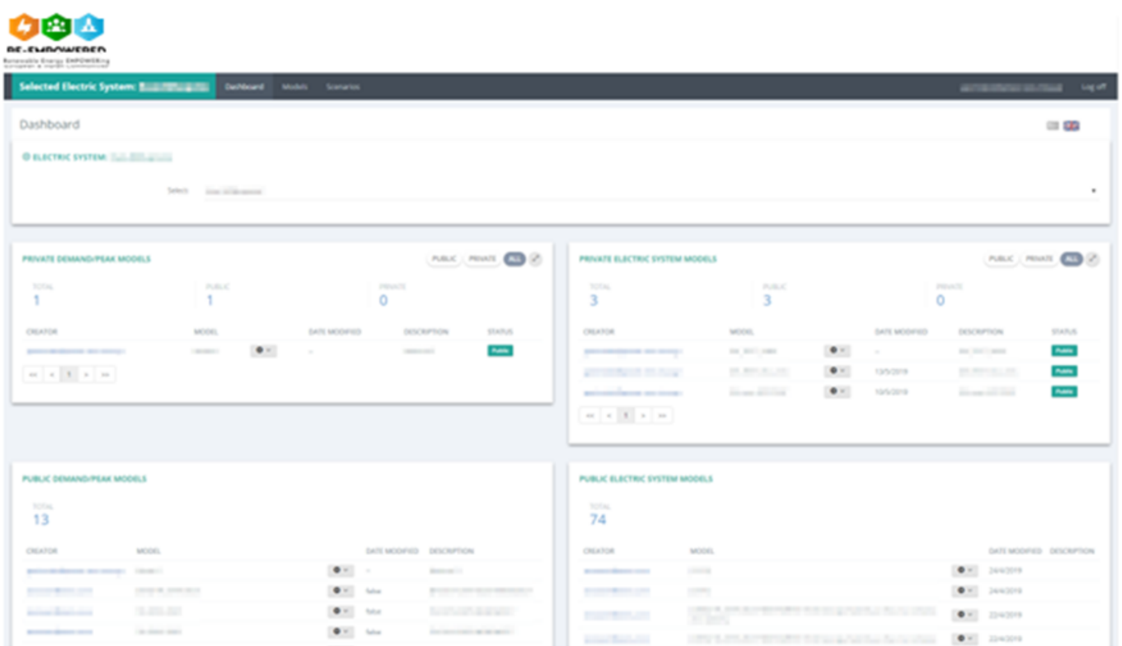


Figure 33: Initial selection screen for ES, Demand/Peak Model and ES Model.

The menu on the top of the screen (Figure 33) allows browsing the various sections of the Application:

- Single click on button "Dashboard" causes the initial screen to appear (Figure 34).

The menu "Models" (Figure 35), includes two sub-menus for managing the Demand/Peak and ES Models separately.

- ➢ Single click on button "New Model" under "Demand/Peak Models" opens the page for creating a new Demand/Peak Model.
- ➢ Single click on button "New Model" under "Electric System Models" opens the page for creating a new ES Model.

The menu "Scenarios" (Figure 36), opens the page for selecting the combination of Demand/Peak and ES Model as well as the type of simulation (7-Year Energy Planning or RES Hosting Capacity) and initiating the simulation.

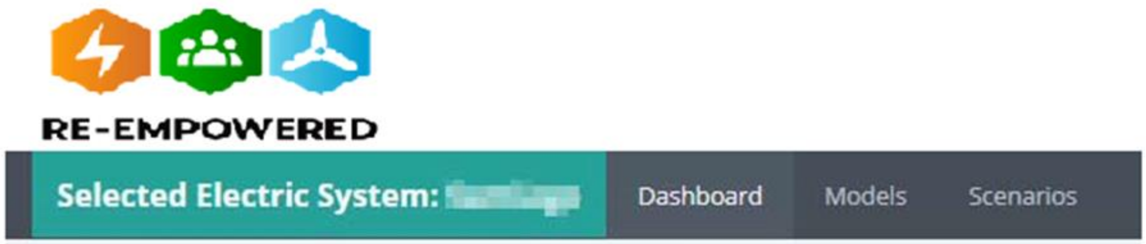


Figure 34: Main menu.

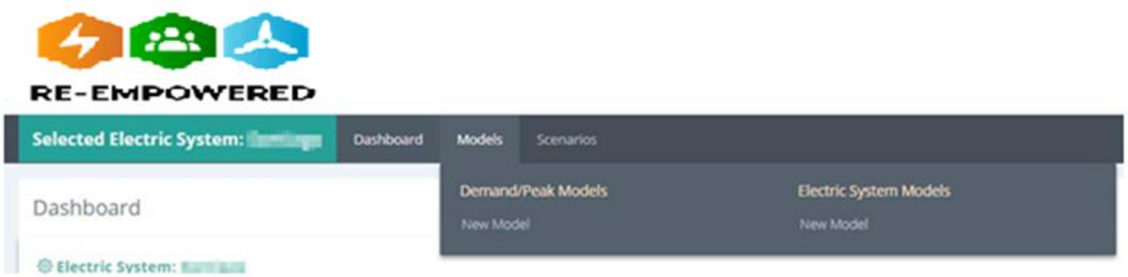


Figure 35: "Models" menu.

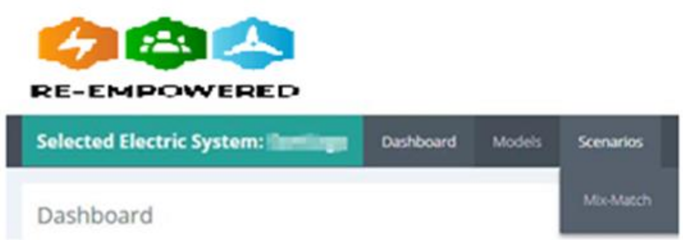


Figure 36: "Scenarios" menu.

At the bottom of the page, the Demand/Peak and ES Models appear. The models are of one of two types: public models can be viewed and edited by all users; private models can be viewed and edited only by the user that created them. For each type of model two lists appear: first the models created by the user (with the appropriate label indicating the type) (Figure 37) and, next, the public models (Figure 38). The user can navigate through the lists using the available buttons "<<", "<", ">" and ">>" or selecting a specific page number (Figure 39).

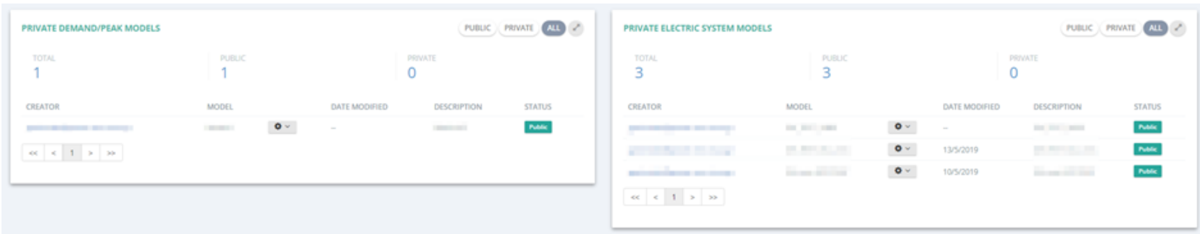


Figure 37: Demand/Peak and ES Models created by the user.

Figure 38: Public Demand/Peak and ES Models.

Figure 39:Available buttons for navigation through the Demand/Peak and ES Models lists.

The lists containing the Models created by the user can be filtered using the appropriate selection "PUBLIC"/"PRIVATE"/"ALL" (Figure 40). Single click on the button and then on button "Edit" (Figure 41) allows modifying the specific model. Selecting "Delete" (Figure 41), the user can delete one or more models created by himself.

Figure 40: Filters for models created by the user.

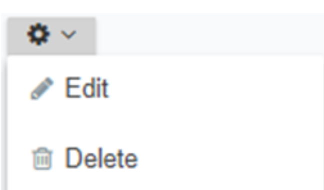


Figure 41: Edit and delete Demand/Peak or ES Model.

Single click on "Delete" causes a dialog box to appear, containing a list of all models created by the user (Figure 42). The user may choose to delete one or more models by single click on the checkbox next to each model and by selecting "Delete". Accordingly, the user is notified that the selected scenarios will be permanently deleted (Figure 43). Single click on "Delete Permanently" deletes all selected models and the user is notified accordingly (Figure 44 and Figure 45).

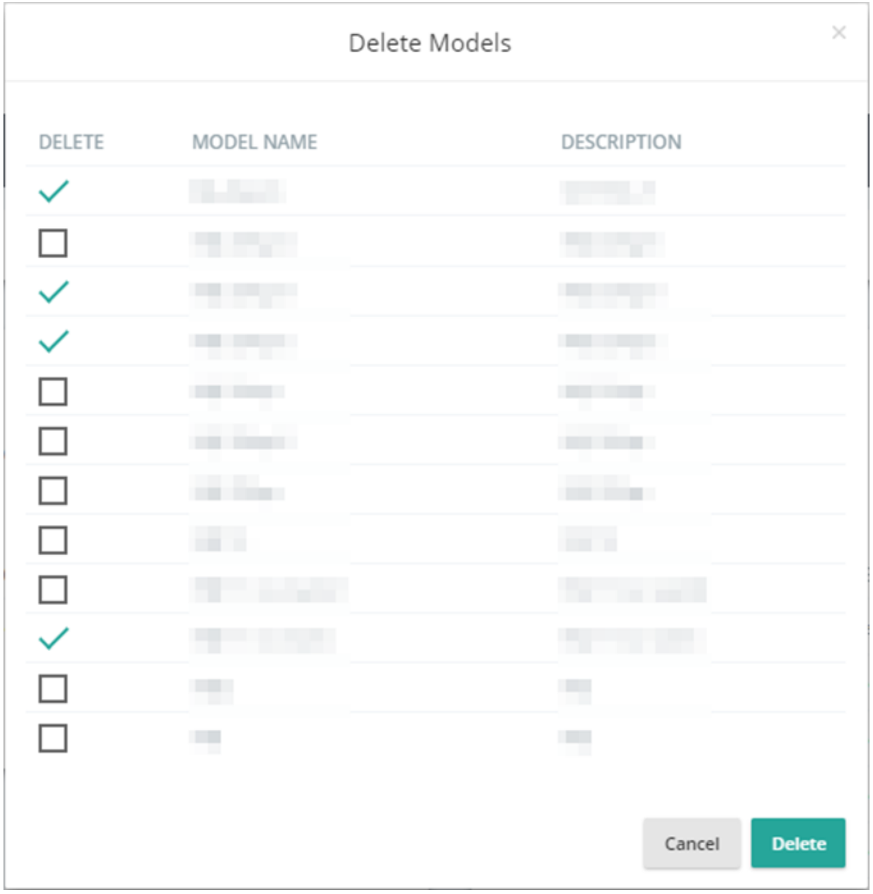


Figure 42: Delete private models.

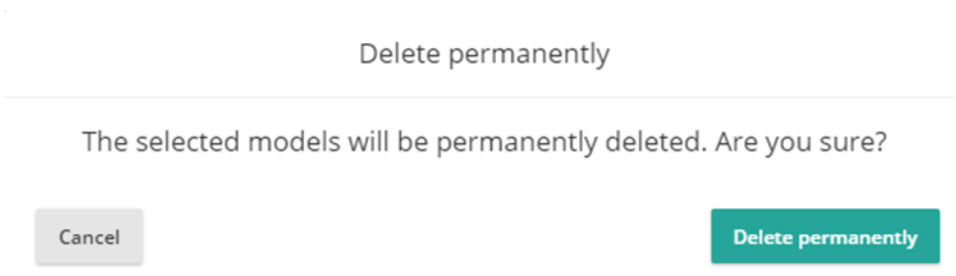


Figure 43: Notification message for permanent deletion of selected models.

Figure 44: Notification message for successful deletion of Demand/Peak Models.

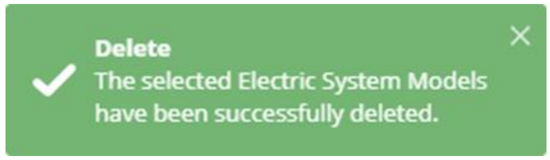


Figure 45: Notification message for successful deletion of ES Models.

3.4.3 Demand/Peak Model

By selecting “New Model” from the menu “Demand/Peak Models”, the user can create a new Demand/Peak Model or modify an existing one through proper selection of the demand/peak estimation method and its parameters (Figure 46).

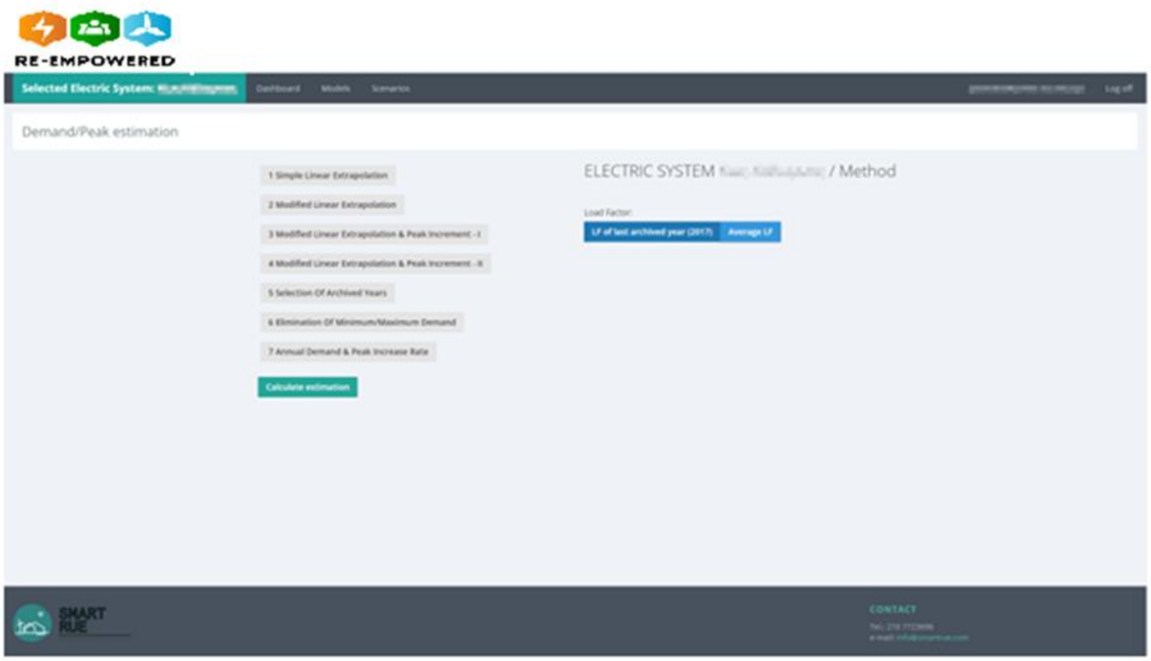


Figure 46: Initial screen for selection of method and parameters for the demand/peak estimation.

The results of the demand/peak estimation can be exported in .csv file by single click on button "CSV file" (Figure 47).

Figure 47:Button for exporting the results of the demand/peak estimation in .csv file.

Subsequently, given the available choices (Figure 46), the user can:

- perform a new estimation by clicking the button “New Estimation” (this action prompts the initial screen for selection of method and parameters for the demand/peak estimation to appear – Figure 48),
- initiate the calculations for the assessment of the system adequacy and view the respective report by clicking the button “Report”,

save the results of the estimation as a new Demand/Peak Model by clicking the button “Save”.

Figure 48: Available choices for management of demand/peak estimation results.

Save a Demand/Peak Model

The user can save the Demand/Peak Model by selecting an appropriate name and – optionally – a short description (Figure 49). During this process the user may define the type of the model as either “Public” or “Private”. The public models can be accessed by all users, while the private models can be accessed only by the user who created them. Single click on "Save" concludes the saving process, after which, the use is notified through a relevant message (Figure 50).

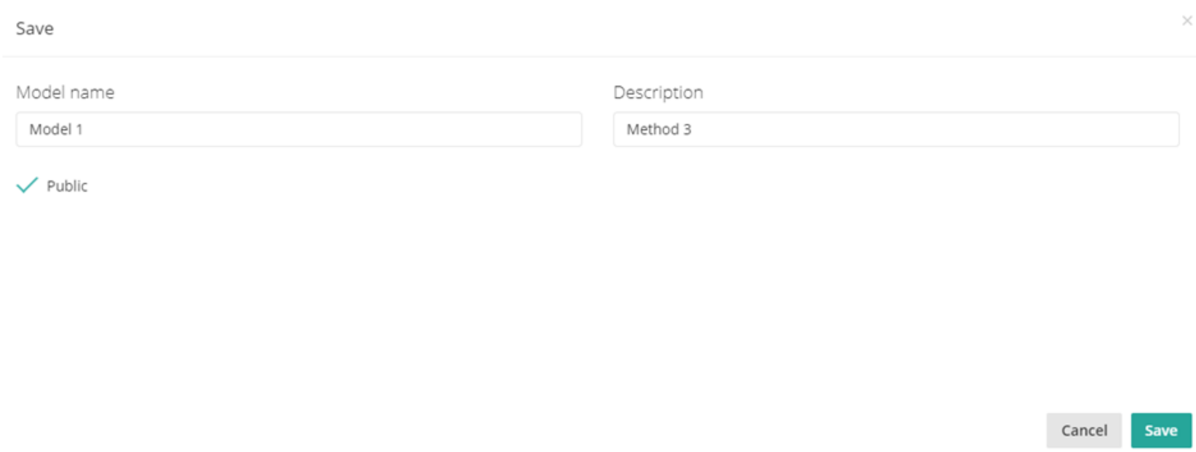


Figure 49: Save a Demand/Peak Model.

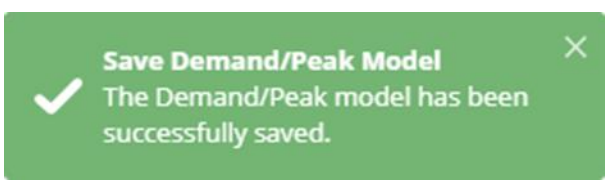


Figure 50: Notification message for successful saving of Demand/Peak Model.

The maintenance schedule is inserted separately for each conventional production unit (Figure 51). Single-click on the button “Add Maintenance” causes a pair of fields to appear name “From” and “To” (Figure 52), where the user can insert the period during which each conventional production unit will be considered to be on maintenance in the form dd/MM. Single click on the button removes the respective pair of dates.

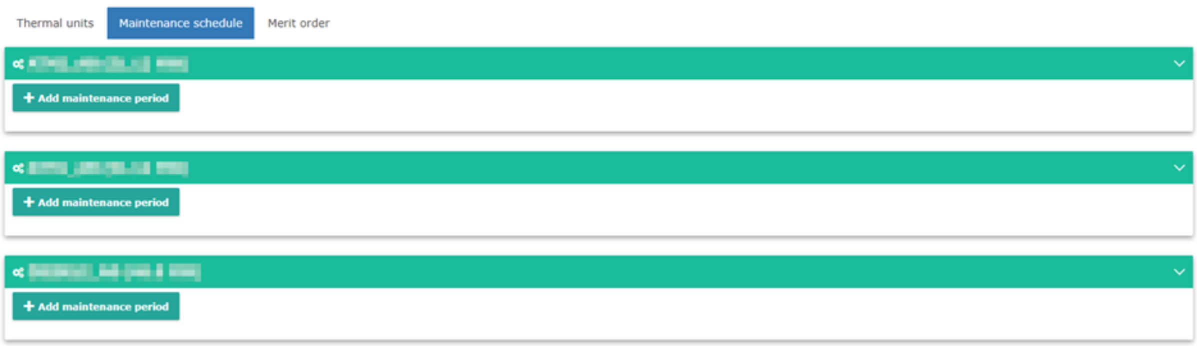


Figure 51: Initial screen for defining the maintenance schedule per conventional production unit.

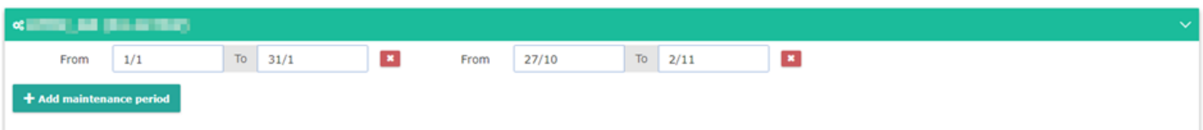


Figure 52: Maintenance schedule of conventional production units.

Two methods for defining the per month commitment priority of the conventional production units are available:

The priority per conventional production unit is defined by filling in the field of the respective month with the appropriate positive integer (Figure 53). In case the checkbox “Enable autocomplete” is checked, the fields corresponding to subsequent months are automatically filled-in with the value inserted in the current field.

The priority per conventional production unit is defined by repeating the following three steps as many times as necessary (Figure 54): a. single click on the boxes next to each month for selecting one or more months, b. rearrange the order of the conventional units in the list (drag and drop) and c. single click on the button “Apply” (assigns the appropriate priority only for the selected months).

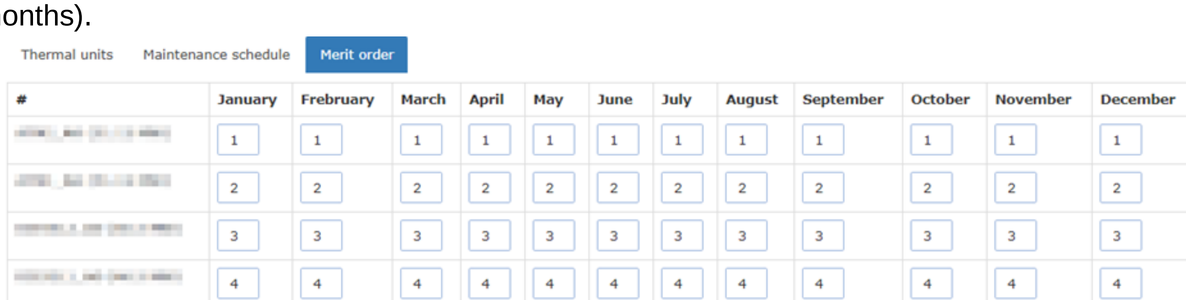


Figure 53: Commitment priority of conventional production units (1st method).

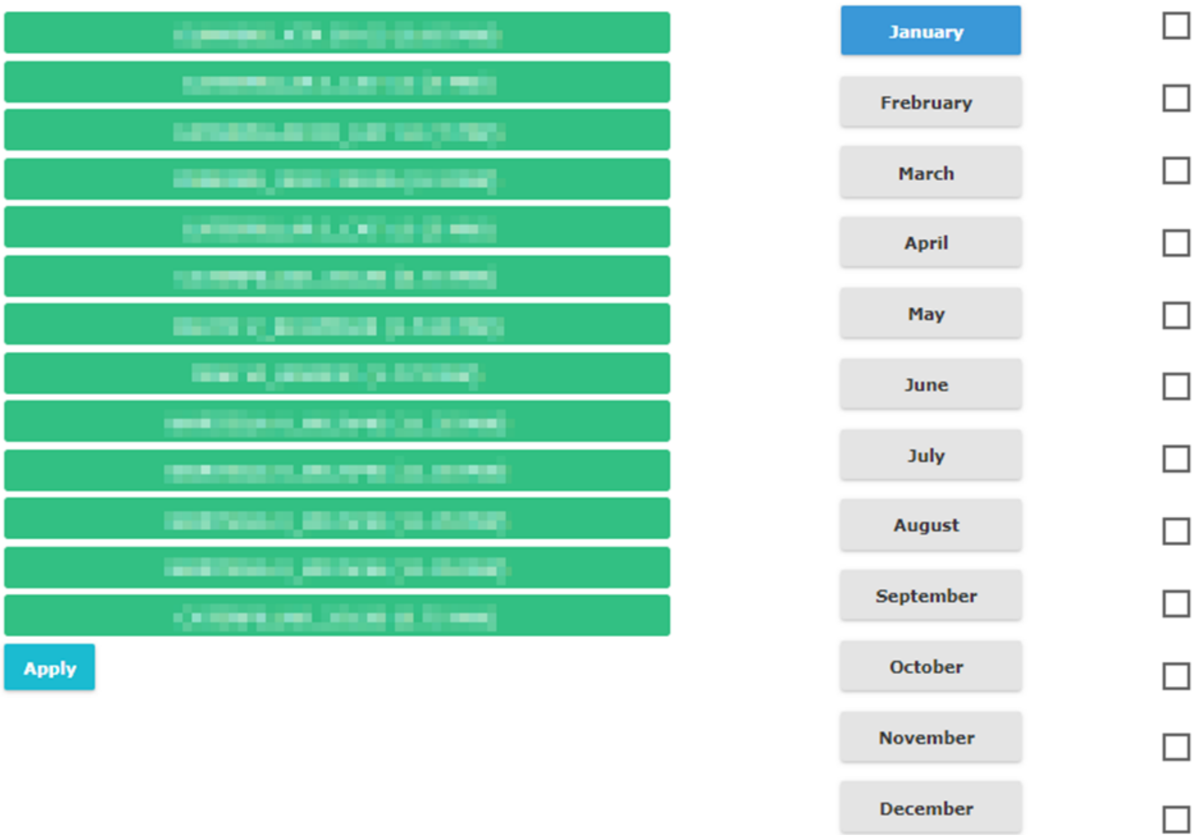


Figure 54: Commitment priority of conventional production units (2nd method).

Save an Electric System Model

The formulated ES Model is saved when the user clicks the button “Save Model”. In the appearing window the user can provide an appropriate name and – optionally – a short description. During this process the user may define the type of the model as either “Public” or “Private”. The public models can be accessed by all users, while the private models can be accessed only by the user who created them.

In case the selected name coincides with an existing ES Model, the user is notified that by proceeding, the existing model will be replaced by the new one. In case a different name is selected, a new ES Model is created. Single click on button "Save" concludes the procedure and the user is notified accordingly.

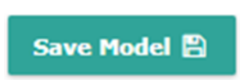


Figure 55: Button for saving an ES Model.

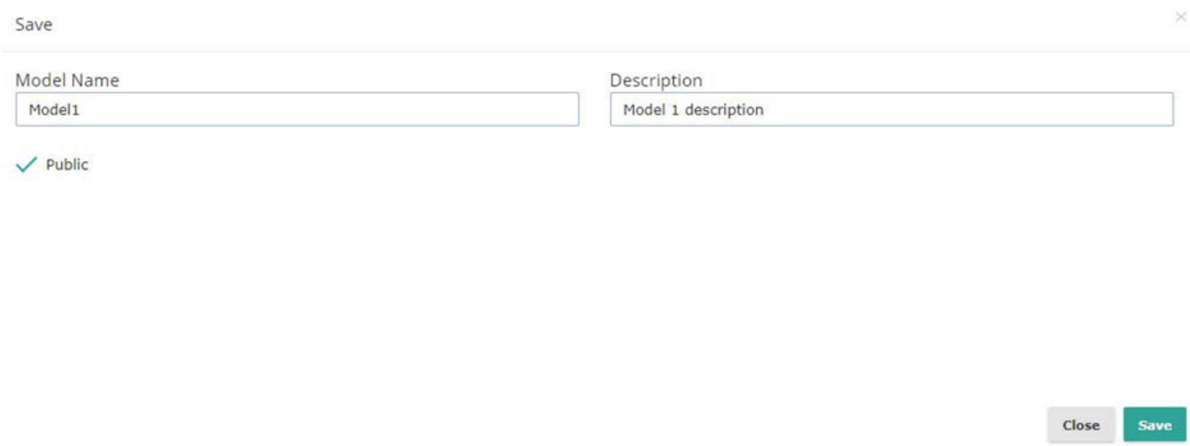


Figure 56: Save an ES Model.

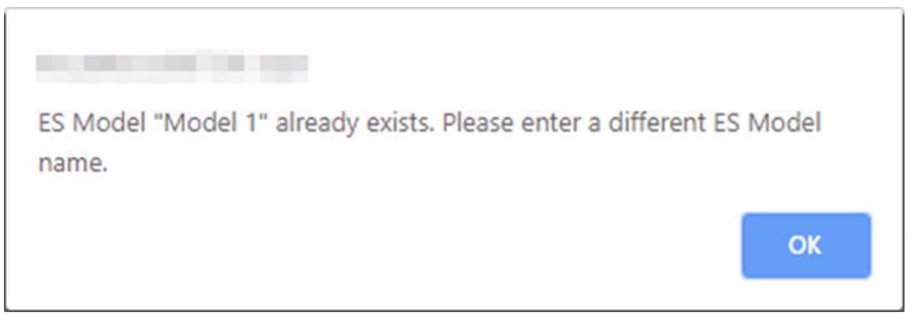


Figure 57: Message informing the user that the selected ES Model name already exists and that the user should select a different one.

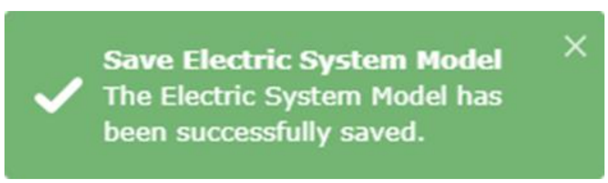


Figure 58: Notification message for successful saving of ES Model.

3.5 ecoConverter

Description: ecoConverter deals with the development of several power electronic converters and their control to form a multi-source microgrid. In the scope of this tool, a DC/DC partial power converter (PPC) for multi-string PV architecture, an Intelligent Power Module (IPM) based inverter, a power quality conditioner (STATCOM), a load flow controller, a SiC based DC/DC converter and an FPGA (Field Programmable Gate Array) based digital control platform are being developed. The purpose of these converters is to form a local microgrid and extract the maximum power from PV panels under partial shading conditions. The converters will be modular, plug-andplay, reliable and compact with functions like built-in communication, protection, remote control, and display option. The preparation of a user guide is in progress by the Indian partner IIT KGP.

3.6 ecoDR

Description: ecoDR is an advanced metering infrastructure (AMI) containing load control and protection functionalities. The tool will communicate with ecoMicrogrid to foster demand-side management and implement the control schedule of non-critical loads. ecoDR will additionally serve as a measurement tool of household energy consumption.

3.6.1 Installation

- Before installing or removing the meter, the power must be turned off.
- Only competent and qualified personnel must carry out the installation in compliance with national regulations.

For service and technical support information, please contact: Siddheswar Sen, Dr.Santu Kumar Giri.

3.6.2 Operation

- Do not take off the meter cover while the meter is in use.
- The open circuits and parts could cause harm to the meter
- The operational voltage of the meter should not exceed 120% of the nominal voltage (230 V) and the current draw should not exceed 120% of the maximum current.
- Prolonged exposure to high voltage and excessive loads can cause harm to the meter.
- Avoid using the meter when your hands are wet.

3.6.3 General Description:

Different views of the ecoDR tool are shown in the below figures.

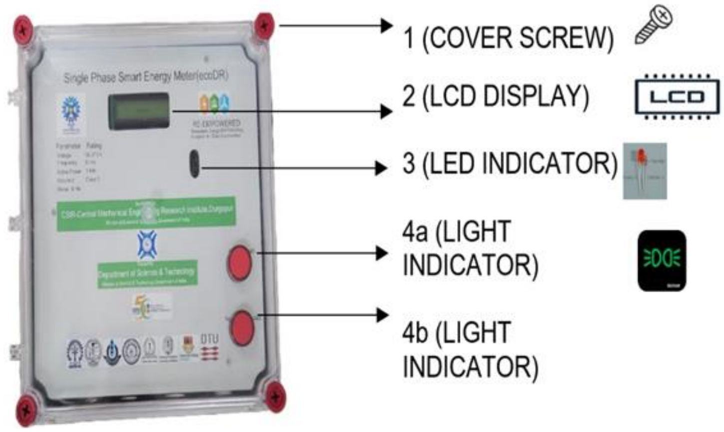


Figure 59: Front view of ecoDR

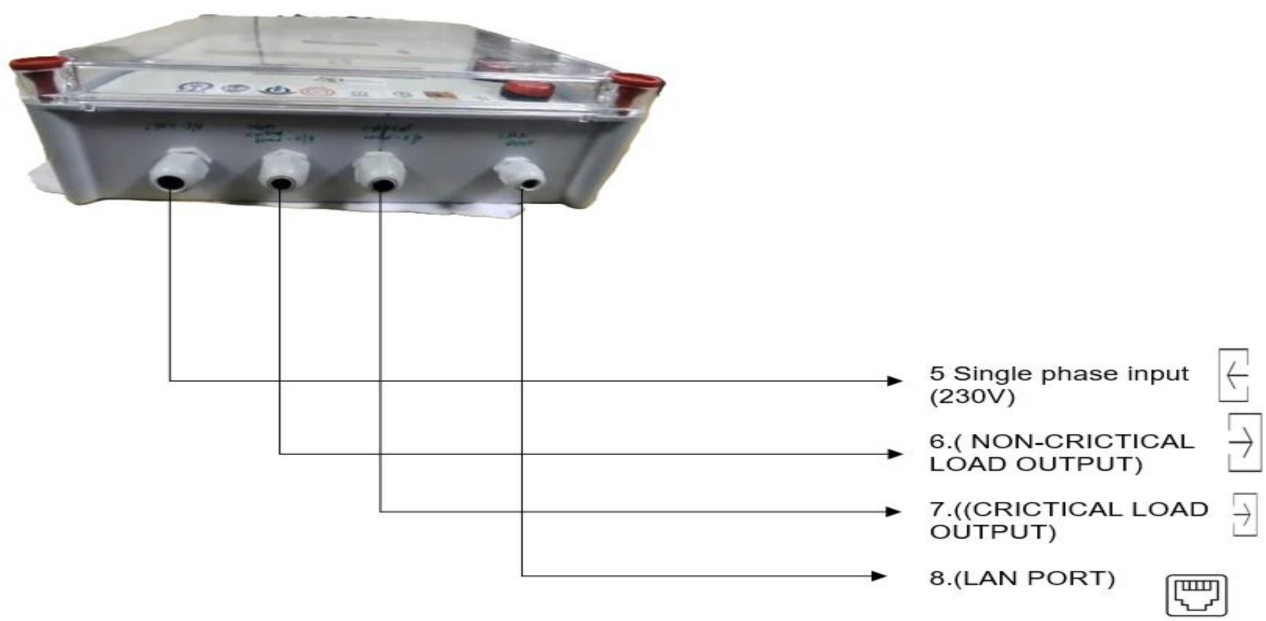


Figure 60: Sideview of ecoDR

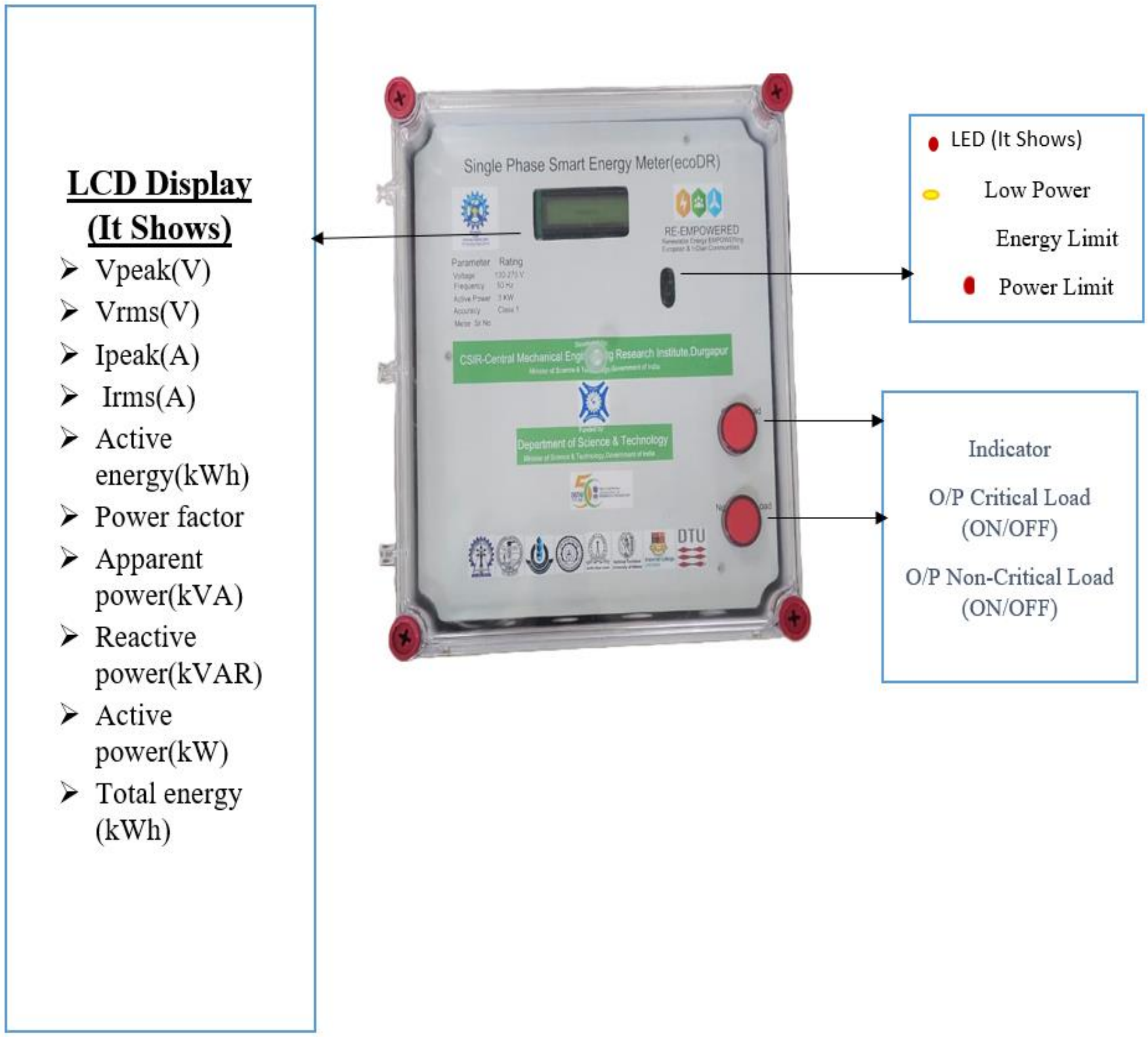


Figure 61: Nomenclature and marking

3.6.4 Measurement System:

The developed ecoDR has been facilitated with most of the electrical parameters for reading purpose which are listed below

- Vpeak(V), Vrms(V)
- Ipeak(A), Irms(A)
- Active energy(kWh)
- Power factor
- apparent power(kVA)
- Reactive power(kVAR)
- Active power(kW)
- Total energy (kWH)

Table 36: Features List/Technical Specifications:

Input voltage:	230 AC, 50Hz
Current Rating:	1-50A
Reference Temperature:	300C
Operational temperature: -	10 to 500C
Maximum load:	3kW
Accuracy Class:	1.0
A static single phase, two wire energy meter	
Available parameters like Irms, Vrms, active energy, power factor, apparent power, and load	
Visible indicator for poor power factor	
LCD for display	
Support MODBUS communication protocol	
Two output ports for critical and non-critical loads.	
Programmable energy and load limit feature	
Variable cut-off delay time after overload event.	
Load scheduling by management of non-critical loads	

3.6.5 Features of meter enclosure:

- There is cable gland to tie the wire tightly
- The case can be sealed after use.
- The name plate is printed on vinyl paper.
- There is cable gland to tie the wire tightly.
- The case can be sealed after use.

3.6.6 Wiring diagram:

The figure below presents a basic wiring diagram of the meter presenting the available output connections for critical and non-critical loads.

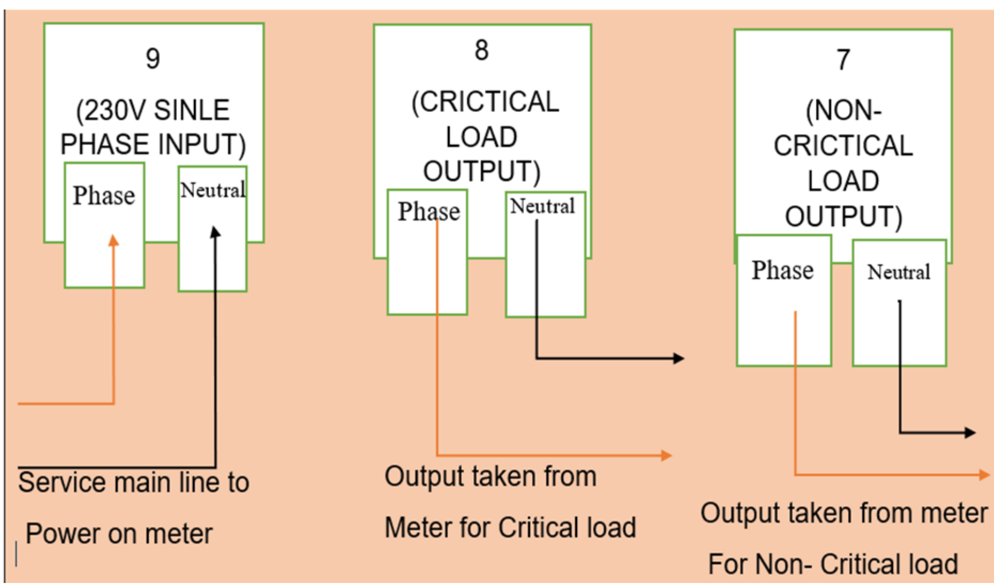


Figure 62: Basic Layout_Wiring_Diagram

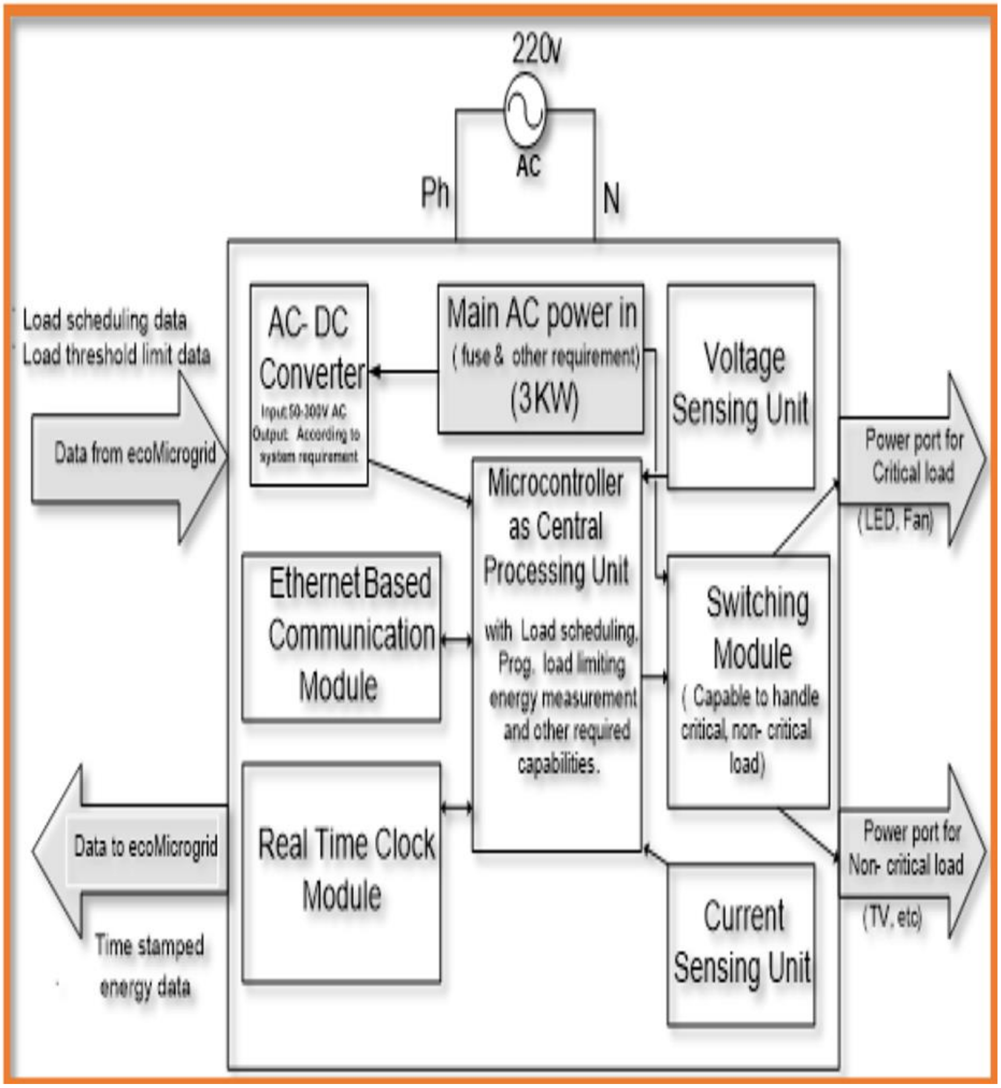


Figure 63: Basic layout

Figure 64: Display Mode

3.6.7 Communication Interfaces and Communication:

- On PC2 (for emulating Role Of ecoMicrogrid): MBAXP Modbus ActiveX Control Client
- Client and Server were Connected via Ethernet cable
- Protocol used: MODBUS (MBAP)
- Developed meter (EcoDR) is MODBUS SERVER (IP - 192. 168………)

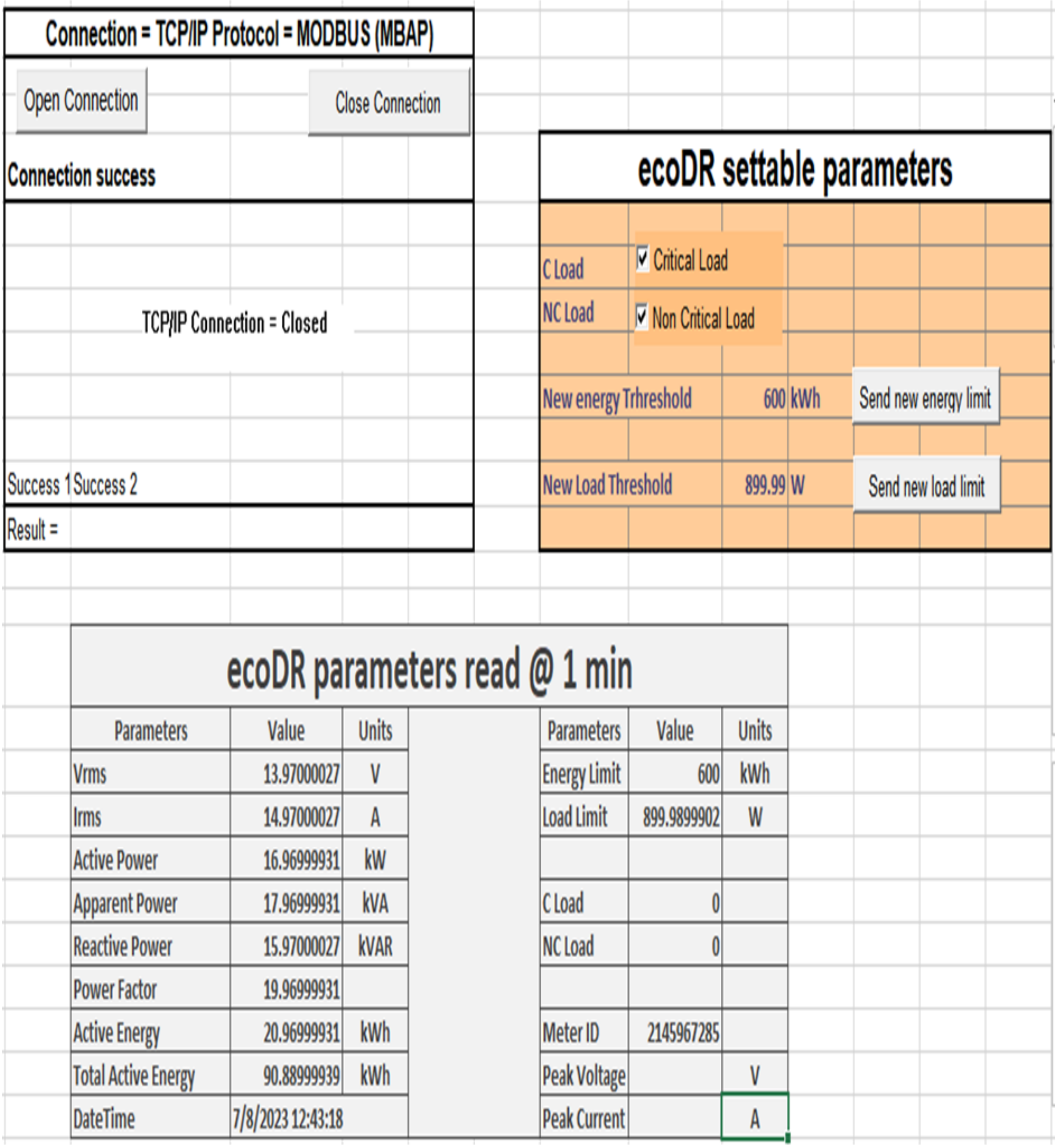


Figure 65: ecoDR parameters data

Table 37: MODBUS commands for Communication:

	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

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

3.6.8 ecoDR-Demand Response:

- Firmware development for communication with Eco Tools.
- Tested firmware and hardware
- Tested for communication with MODBUS
- Tested for all connections.
- All Quality checked passed

3.7 EcoMonitor

3.7.1 Overview

ecoMonitor is equipped with multiple sensors for real time monitoring of the local air quality parameters and deployed as a portable digital control platform. The collected data is transmitted to the adequate ecoTools for visualization/analysis.

For service and technical support information, please contact: Dr. Santu Kr. Giri

This section introduces the main instructions that users shall follow during the receiving, storage, handling, installation, wiring, operation, inspection and disposal of the products.

3.7.2 Input requirements

- The input power of the ecoMonitor is 12V DC. Otherwise, there may be personnel injuries and mechanical failure.
- Do not make any alterations to this product. Only qualified/designated persons can configure, dismantle or repair this product.
- Otherwise, there may be personnel injuries, mechanical failure or fire.

3.7.3 Storing and Transporting

The product should be stored or used in the below environment:(Otherwise, there may be fire, electric shocks or machinery breakdown.)

- Should be stored in outdoor environment, so that the sensors would be able to calibrate the data;
- It should be stored in a shed so that it can be protected from water.
- Please do not transport the, product by grasping the sensors or display. Otherwise, there may be a machine breakdown.

3.7.4 Installations:

- Please do not block the air inlet and outlet and prevent alien matters entering the product.

- Otherwise, the inner components may be aged and cause failure or fire.
- Please install at correct directions.
- Otherwise, there may be failure.

3.7.5 General Description:

ecoMonitor is an Outdoor Air Quality Monitoring device, which monitors pollutants like NO2, SO2, CO, and O3. It also monitors particulate matters like PM 2.5 and PM 10, along with temperature and humidity. This eco tool display the calibrated data through the LCD display and send the data using MODBUS communication.

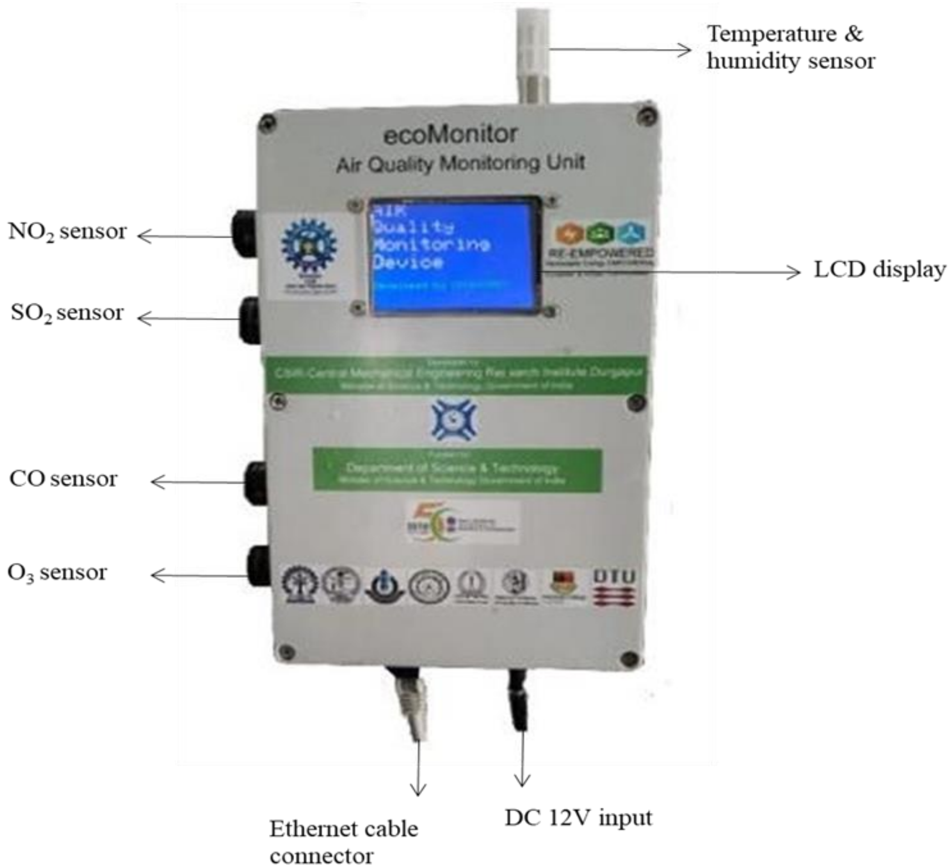


Figure 66: ecoMonitor display

Figure 67: enclosure

3.7.6 DC 12 V Input-

- The power input of the ecoMonitor uses 12V DC supply. The male input port of the DC adaptor to be attached to the female port attached to the ecoMonitor.
- The dimension of the input port of the DC input- Figure 69 shows the 12V DC input male and female port. The LAN port connector is provided at the ecoMonitor to connect the LAN cable.
- The LAN connector & the LAN cable-

Figure 68: Input port dimension and male female

3.7.7 Measurement System:

The ecoMonitor is designed to measure air pollutants- NO2, SO2, CO, O3, and PM 2.5 and PM 10 along with temperature and humidity from the surrounding environment. This eco tool collects the data in analog signal and calibrates the data in digital value using the sensors.

Table 38: ecotool measures the data in the following units:

Name	Units
NO2	ppm
SO2	ppm
CO	ppm
O3	ppm
PM 2.5	ug/m3
PM 10	ug/m3
Temperature	°C
Humidity	%RH

3.7.8 Features List/Specifications:

Table 39: The key features of the enclosure box

Sl. No.	Factors	
1.	Material	Acrylonitrile Butadiene Styrene (ABS)
2.	Size	160 x 250 x 90 mm
3.	Color	RAL 7035

4.	IP Rating	IP65
5.	Surface Finishing	Glossy
6.	Thickness	3.5 mm

3.7.9 Sensors:

The key features of the Gas sensors are mentioned below:

Table 40: Nitrogen dioxide (NO2)

Sl. No.	**Factors**	
1.	Type	NO_2
2.	Resolution	0.1 ppm
3.	V0 (V Output Range)	(2 - 0) V
4.	Vout1	1.2 V @ 10 ppm
5.	Detection Range	(0 - 20) ppm
6.	Response Time	≤ 30s

Table 41: Sulphur dioxide (SO2)

Sl. No.	**Factors**	
1.	Type	SO_2
2.	Resolution	0.1 ppm
3.	V0 (V Output Range)	(0.6 – 2.4) V
4.	Vout1	1.5 V @ 10 ppm
5.	Detection Range	(0 - 20) ppm
6.	Response Time	≤ 30s

Table 42: Carbon mono oxide (CO)

Sl. No.	**Factors**	
1.	Type	CO
2.	Resolution	1 ppm
3.	V0 (V Output Range)	(0.6 - 3) V
4.	Vout1	0.9 V @ 200 ppm
5.	Detection Range	(0 - 1000) ppm
6.	Response Time	≤ 30s

Table 43: Ozone

Sl. No.	**Factors**	
1.	Type	O_3

2.	Resolution	0.1 ppm
3.	V0 (V Output Range)	(2 – 0.7) V
4.	Vout1	1.3 V @ 5 ppm
5.	Detection Range	(0 - 10) ppm
6.	Response Time	≤ 120s

Table 44: PM sensor

Sl. No.	**Factors**	
1.	Type	PM 2.5, PM 10
2.	Resolution	1 ug/m3
3.	Working Voltage	(3.3 – 5.0) V
4.	Standard Volume	0.1 L
5.	Particle Measurement Range	(0.3 – 10) µm
6.	Response Time	≤ 10s

Table 45: Temperature and Humidity sensor

Sl. No.	**Factors**	
1.	Type	Temperature & Humidity
2.	Working Voltage	(3.3 – 5.0) V
3.	Measurement Range	(-40 – 125) °C & (0 - 100) %RH
4.	Response Time	≤ 8s

3.7.10 Display:

Table 46: The key features of the display screen

Sl. No.	**Factors**	
1.	Type	Thin Film Transistor (TFT)
2.	Working Voltage	(3.3 – 5.0) V
3.	Display Color	RGB 65K color
4.	Resolution	(320 * 240) Pixel
5.	Active Area	(43.2 x 57.6) mm
6.	Driver IC	ILI9341

3.7.11 Communication Interfaces and Communication:

Table 47: The ecoMonitor with a single communication interface

Interface	**Purpose**	**Baud Rate**	**Protocol**

LAN	Local communication	115200 bps	MODBUS

This LAN port is used to monitor the data of the ecoMonitor locally. In general, PC software is used to communicate with the monitor using the LAN port.

3.8 ecoResilience

This tool deals with the development of cyclone resilient support structures for ground-mounted solar photovoltaic (PV) arrays and wind turbine systems. It also targets the development of a small wind turbine system with locally available materials and tools and its fabrication, and installation at the demo site.

For service and technical support information, please contact:

Dr. Murugan Thangadurai, CSIR-CMERI (Resilient support structures)
Dr. Kostas Latoufis, ICCS-NTUA (For locally made wind turbines)

3.8.1 Overview

Conventional ground-mounted solar photovoltaic systems have rigid support structures (Figure 69). When these systems are exposed to severe cyclones such as Fani, Amphan, etc., at the Ghoramara site, the aerodynamic forces acting on the support structures are huge as the local wind velocity would be in the order of 150 to 200 kmph, and they need strong support structures and foundation. Here, an innovative passive structure is attached to the solar PV frame, which helps in reducing the angle of movable solar photovoltaic panels at the designed critical velocity for reducing the aerodynamic forces.

Figure 69: Conventional PV support structures

Similar to the ground-mounted solar PVs, small wind turbines attached to support structures (Figure 70) also experience huge aerodynamic loads due to the larger frontal area of the blades (Increases with an increase in diameter of the blades). These support structures are designed based on the size & power rating of the wind turbines, such as constant cross-section area monopole, variable area monopole, simple truss structure, and hybrid tower. These wind turbine installations need large spaces for installation & maintenance. The availability of space for the installation of wind turbines at the demo site is minimal, and the demo site's approachability is also challenging as it is difficult to transport fabricated towers. Hence, we must design resilient support structures considering these demo site constraints.

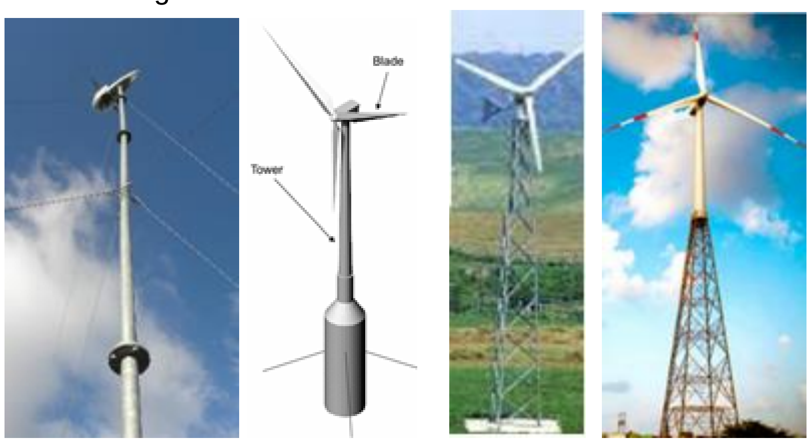


Figure 70: Conventional support structures for small wind turbine systems

The most vulnerable part of the wind turbine system to higher wind velocities is its moving part, i.e., the blades. Though the support structure (tower) can be made rigid to avoid damage, the blades experience massive loads during severe cyclones, which damages them. Further, the intensities of wind speed increase with an increase in height. The wind turbines are usually kept at the height at which they receive undisturbed wind (Kept at a height higher than buildings & trees). Since the demo site location is surrounded by buildings & trees, the wind turbines are installed at a height of 18 m.

Figure 71: Fabrication of small wind turbine at CSIR-CMERI Durgapur collaborating with ICCS-NTUA

Conventionally, many variants of tilt-up towers are used for the installation of small wind turbines up to 5 kW due to their low cost, simplicity and ease of tilt-up and tilt-down operations during maintenance. However, the tilt-up tower needs sufficient working area for placing guy wires and tilt-up and down operations of the tower during maintenance and adverse environmental conditions. Hence, hybrid support structures having a monopole upper part and a truss at the bottom are preferred over monopole tilt-up towers for installing commercial wind turbines. Further, the top monopole structure is made movable, i.e., it 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.

One small wind turbine with a capacity of 2.5 k W was also manufactured at CSIR-CMERI, Durgapur, using locally available materials involving students, entrepreneurs, technical staff of CSIR-CMERI and support from ICCS-NTUA staff (Figure 71).

3.8.2 Components/subsystems of ecoResilience

The following are the main components of the ground-mounted solar PV support structure:

Solar panel frame: Solar panel (2277 mm x 1133 mm) is attached to a galvanized MS hollow square box (Size:25 mm x 25 mm x 2 mm) with bolts and fixed on galvanized MS horizontal hollow rectangular section (Size:60 mm x 40 mm x 2 mm) to connect with ball bearing -2 Nos.

Bottom attachment for solar panel frame: Galvanized MS semi-circular section (Size: Diameter 100 mm, Length 1260 mm, Thickness 3 mm) with attachments – 1 No.

Top attachment for solar panel frame: Galvanized MS flat plate (Size: 1000 mm x 170 mm x 5 mm) having two galvanized MS double-sided buckets (Size:100 mm x 100 mm x 2 mm) at its ends and two galvanized MS flat plates to support with solar panel frame (Size:88 mm x 200 x 10 mm) – 1 No.

Bearing for solar panel frame: Pillow block ball bearing (Size: Inside diameter 30 mm, center height 42.9 mm, length-175 mm) attach solar panel frame with vertical support – 02 Nos.

Vertical support: A galvanized MS vertical hollow square section (Size:100 mm x 100 mm x 5 mm) having a length of 1524 mm where a galvanized MS base plate (Size:300 mm x 300 mm x 10 mm) with stiffeners is attached at the bottom and a C-Section (Size:150 mm x 100 mm, collar height 100 mm) to hold bearing bolt is welded -02 Nos.

Stoppers for solar panel frame: the front stopper (Size:100 mm x 200 mm) helps in fixing the solar panel's incident angle, and the back stopper (Size:100 mm x 225 mm) limits the movement of the solar panel frame up to the horizontal plane -2 Nos

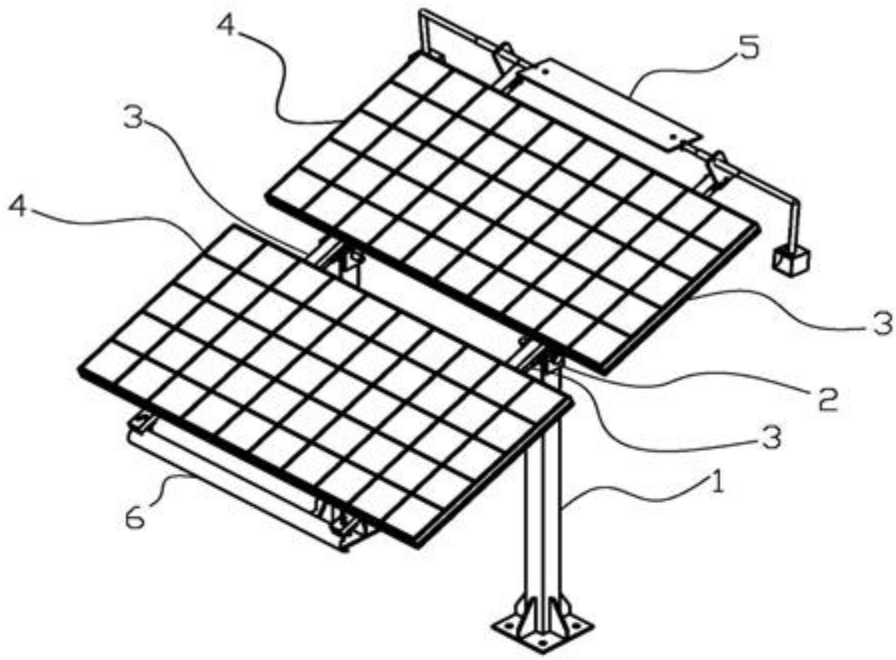


Figure 72: The designed Resilient ground-mounted PV system with its components

The proposed resilient ground-mounted PV system (Figure 72) has a movable solar panel frame and add-on aerodynamic surfaces at its end compared to the conventional ground-mounted PV system with a rigid support structure without any add-on surfaces. It has a central rigid support (1) with arrangements to connect pillow block bearings (2) on top and a plate with stiffeners at the bottom. Bearings provide free movement to the PV panel frame in case of uneven loads on the bottom and top sides of the panel. However, the stoppers on the central vertical support limit the free movement of the PV panel frame. Depending on the geographical location, the front stopper is kept at a solar incident angle. The back-stopper stops the movement of the PV panel frame when the frame becomes parallel to the ground surface.

The solar panel frame (3) is attached with pillow block bearings using nuts & bolts, and it supports the commercially available PV panels (4). A flat plate with double-sided buckets at its end is attached to the PV panel frame's top side. A semi-circular cylinder (6) is attached to the bottom side of the solar PV panel frame. 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. It is important to remember that the add-on aerodynamic surface on the solar panel frame has to align with the wind irrespective of wind direction such as head or tailwind. 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.

After establishing analytical calculations, CAD model of the resilient ground-mounted PV system is developed and meshed in ICEM CFD software. Numerical simulations were performed in ANSYS Fluent for different free stream velocities to examine forces and moments on solar panel PV frame. After optimizing the geometry for the designed wind velocity of 30 m/s, a 1:10 scale-down model is prepared through 3D printing to perform wind tunnel testing. Wind tunnel experiments are performed with the developed model to calculate aerodynamic loads. It was observed that the proposed add-on components generate lesser aerodynamic forces compared to the fixed ground-mounted PV systems. A maximum of 60% reduction in drag force and more than 70% reduction lift force is noticed.

The solar panel PV frame (3) is a movable structure and it stands on two vertical hollow square columns (1). Four ribs (triangular plates) and a base plate are welded at the bottom of the vertical column to transfer loads on the civil foundation (the foundation is decided according to static and dynamic stress analysis). A C-section is welded on the top of each vertical column. A pillow block ball bearing (2) is connected with each vertical column through the C-section with the help of a 30 mm bolt. The base of the pillow block ball bearing is attached to the solar PV panel frame (3) through bolts, which allows free movement of the solar PV panel frame. It is important to note that the exact location of the pillow block ball bearing placement depends on the designed critical velocity (the exact offset distance is finalized through numerical simulations and wind tunnel experiments) to allow free movement of the PV panel frame and its geographical location.

PV panels (4), one at the bottom & other at the top side of the vertical column) are fitted over the PV panel frame with the help of bolts. The top attachment, having a flat plate & double-sided bucket arrangement (5), is attached with a PV panel frame with the help of two flat plates. The bottom attachment, having an MS semi-circular cylinder (6), is fitted on the PV panel frame with the help of four bolts. The required inclination angle (depending on the geographical location) for the solar panel frame is maintained with the help of a front stopper fitted on each vertical column. The back stoppers attached to the vertical column prevent movement of the PV panel frame beyond the horizontal position.

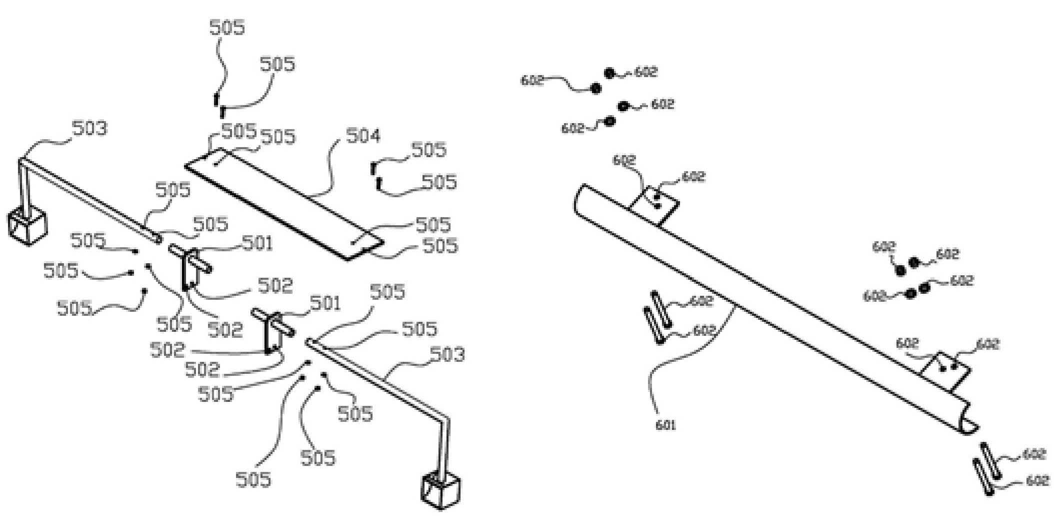


Figure 73: Top and bottom add-on components for the movement of the PV panel frame

Figure 73 shows the detailed drawing of the top and bottom attachments (add-on aerodynamic components) used for the movement of the solar PV panel frame. The shape and size were optimized through analytical calculations and wind tunnel experiments. When the wind flows perpendicular to the panels (both left and right), the movement of the double-sided bucket causes the flat plate to move against the wind to produce a downward force to move the panel along the flow direction.

The top attachment is enough to produce sufficient downward force to move the solar panel frame if the offset distance is minimized and the minimum velocity to activate movement is reduced. However, the acceleration of wind over PV panels when the wind comes from the front side (headwind) compared to the constant wind velocity when the wind comes from the backside (tail-wind) demands a concave surface at the bottom of the solar panel frame. The variation drag coefficients of concave & convex surfaces help in maintaining a similar hinge moment at the vertical support when the wind comes from both the front and back sides of the solar PV panels.

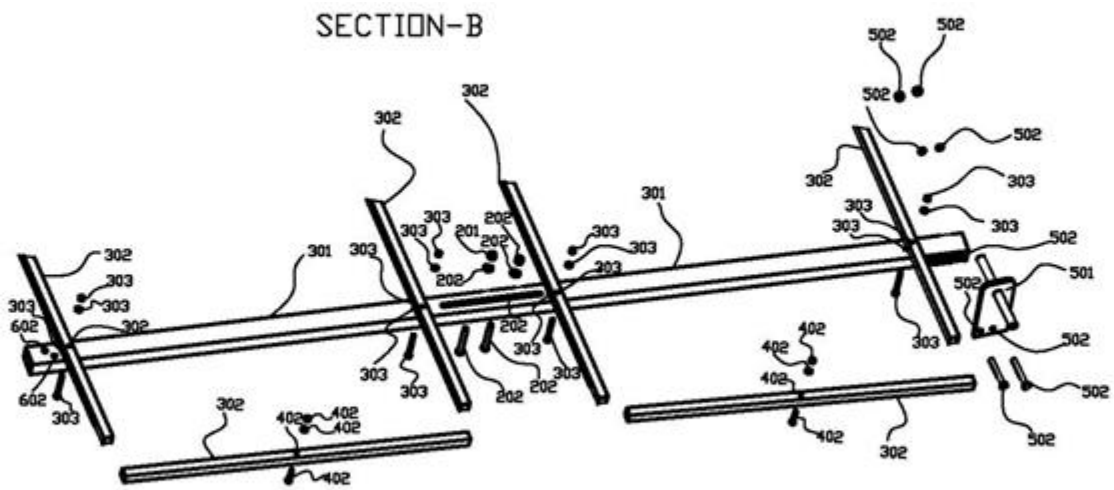


Figure 74: The solar PV panel frame with slits in the middle to attach the bearing

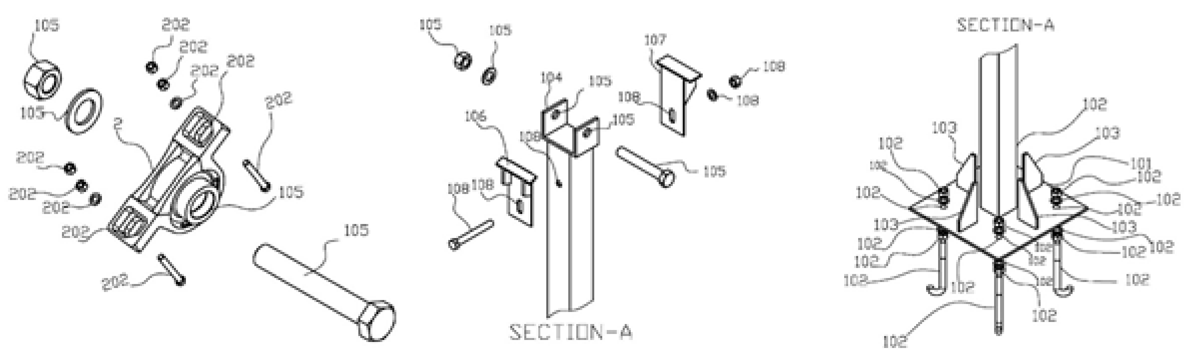


Figure 75: Vertical support with stoppers and pillow block ball bearing at top and a base plate with stiffeners at bottom to attach with civil foundation

The cut section view of the solar PV panel frame is shown in Figure 74. A rectangular frame is made with a box structure to attach PV panels at multiple locations which gives rigidity to the PV panels. It is attached with horizontal frames through nuts & bolts. A slit having a length of 400 mm is provided in the middle of the horizontal frame. This helps in attaching the ball bearing at the required offset location based on the designed minimum velocity to move the panel and geographical location. Figure 75 shows the schematic of the vertical support (1) with other attachments needed for attaching it to the civil foundation and solar PV panel frame. It has a base plate with holes to attach with a civil foundation at the bottom. A vertical box structure with stiffeners is welded on the base plate. Front and back stoppers are placed close to the top section to limit the movement of the solar panel frame. A pillow block ball bearing is attached on top of the vertical support with the help of bolts. It is connected to the solar PV panel frame with nuts and bolts to provide free vertical movement during heavy wind velocity scenarios such as storms and cyclones.

Working of Resilient Ground-mounted PV module support structure:

In normal circumstances, the solar PV panel frame rests on the front stopper to have the highest efficiency from solar PV panels. When there is an adverse environmental condition with heavy wind velocities, the PV panel frame is aligned with the wind direction to minimize the aerodynamic loads on the panel. It is achieved with the help of add-on aerodynamic surfaces. When the wind comes from left to right, the deflection of the double-sided bucket along the wind direction helps the flat plate to incline against the wind, which creates a downward force on the flat plate. This helps the solar panel frame to align with the wind direction. Similarly, when the wind comes from the right to left (behind the panel), the deflection of the double-sided bucket along the wind direction helps the flat plate to incline against the wind, which again creates a downward force on the flat plate. This helps the solar panel frame to align with the wind direction to reduce the aerodynamic load. The concave section at the bottom of the solar panel frame also gives upward force to align along the wind direction. Hence, these added aerodynamic surfaces help reduce forces.

Similar to the ground-mounted PV systems, the following are the main components of the wind turbine support structure:

Wind turbine & its components: The wind turbines with a power capacity of 5.1 kW with a charge controller in IP 55 enclosure surge suppressor, switchgear, dump load, and tower top adaptor are installed over the monopole tower. It will be connected with a 480 VDC Microgrid using a 192 V to 480 V booster converter developed by VNIT Nagpur. The cabling from Tower top to bottom & up to the control room is also done – 2 Nos.

Top Monopole structure & Guywires: It has a length of 6 m with a nominal diameter of 88.9 mm and thickness of 7 mm. The wind turbine is attached over the monopole using an adaptor. The top of the monopole is connected with the truss structure platform through 8 guy wires having a thickness of 12 mm – 2 Nos.

Bottom truss structure: The main loading carrying structures (4 Nos) are made from L sections having a dimensions of 75 mm x 75 mm x 5 mm. All cross structures are made with a dimensions of 75 mm x 75 mm x 5 mm. A base with box section having a dimensions of 70 mm x 70 mm x 5 mm is given at 1 m below the top of truss structure to fix the monopole on truss structure to harness wind energy. Another base is given at 4.5 m from top of truss structure to place the bottom of monopole during maintenance & repair.

Ladder & platform to approach wind turbine: The ladder is made using L sections having dimensions of 50 mm x 50 mm x 5 mm. It is cover with 8 mm diameter rods for additional safety. The platform on top of truss section is made with a plate having a thickness of 5 mm. It is also attached with truss tower at locations using angle section (50 mm x 50 mm x 5 mm). A barricade having a height of 1 m is also made using angle section (50 mm x 50 mm x 5 mm).

Movable base plate & its attachment: A sliding plate is made with the dimensions of 360 mm x 200 mm x 10 mm) which reside on the box structure. The top monopole is attached with this plate using a flange through eight number of 12 mm nuts & bolts. It is moved away while bringing the top monopole down.

Chain block & its support: A chain block having a capacity of 1 ton is attached at the bottom of the platform and connected with the hook given at the bottom of monopole through a chain having a thickness of 8 mm. During bringing the tower down, the chain block slightly lift the monopole (after removing the nuts & bolts) to move the bottom plate sideways to allow the monopole to move down. After repairing and maintenance is done, the monopole is lifted using the chain block and fixed at its original place.

Top annular support/guide pipe & its attachments: On top of the truss structure, a guide pipe having a thickness of 5 mm and length of 1 m is attached at the middle of the platform. It provides additional support for the monopole other than guywires.

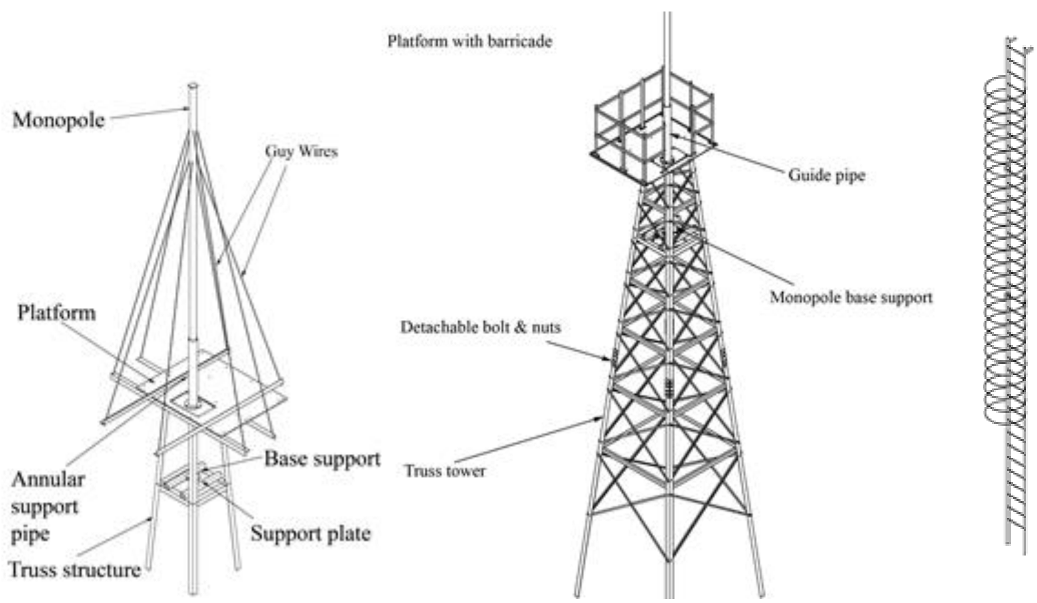


Figure 76: Different components of the wind turbine hybrid support structure (a)top monopole with guy wires, (b) truss structure with platform (c) ladder to reach top of truss structures, I.e., platform

Figure 76 shows different components of the designed hybrid support structure for the commercially procured 5 kW wind turbines. The designed truss-monopole hybrid support tower has many advantages and innovative features compared to the commercially available support structures. It has a fixed truss and movable monopole structures. The monopole structure can be brought down to remove the wind turbine blades easily by removing a few nuts & bolts and sliding a base plate. The truss structure is fabricated using small pieces of L-sections and connected using nuts and bolts for easy transport and installation at remote places. A removable chain hoist with a long chain is used to lower/uplift the monopole structure. Sufficient rigidity of the monopole over the truss is ensured using a 1 m annular guide pipe and eight guy wires attached on top of the truss structure. A platform is provided on top of the truss structure for easy access to remove blades. The detailed isometric views of the tower are given in Figure 77.

Figure 77: Isometric view of the hybrid tower

Figure 78: Scale-down model of the support structure with PV panels

The monopole structure is easily brought down using a winch and few persons as it is usually installed with gin-pole arrangement. A maintenance manual for “Piggott“ based designed small wind turbines (SWT), is developed by Wind Empowerment (WE) association (http://www.windempowerment.org). Founded in Senegal in 2011, Wind Empowerment is involved in the development of locally manufactured small wind turbines for sustainable rural electrification around the world. A training was given to the locals of Ghoramara during tilting down the mono pole of the damaged wind turbine. The existing monopole tower structure is brought down by CSIR-CMERI staff and Ghoramara locals to remove the damaged wind turbine systems (Figure 79).The monopole is brought down gradually on to the cyclone building as the direction of tilt down was lying on the cyclone tower and then it is brought to the floor.

Figure 79: Dismantling of existing monopole tower with damaged wind turbine

3.9 ecoCommunity

3.9.1 Overview

The ecoCommunity is a community engagement tool which aims to provide a digital platform for the members of an energy community (microgrids) through which they are able to access their consumption data, pricing data in case of variable pricing tariffs, coordinate and manage communal and flexible load usage, reporting problems, interacting with the energy community through forum, as well as provide access to digital help and support materials like manual, FAQ etc.

3.9.2 Architecture

The tool utilises an Android mobile application as the engagement platform for the community members. The energy community comprises of administrator, manager and consumer users who will be able to login to application using the supplied credentials (username and password). The administrator user is designated to manage all the tool users, help and support materials as well as addressing to reported problems and maintain the communication with other ecoTools. For the proper operation of the tool, it is important that at least on administrator user is always active.
The tool utilises a cloud database to synchronise and manage the data associated with the energy consumption, user inputs and help materials.

3.9.3 Installation & Login

The tool is installed using the APK file associated with each demo site. Each APK is developed considering the module requirements of each demo site and is programmed to link with the cloud database of that demo site.
To install the tool, follow the following steps.

1. **Download** the android application APK on your android mobile phone:
2. Open your **Android device's file explorer app**. Locate the APK file in the file explorer. (Fig. 66a)
3. Tap on the file. The APK installer pop-up will appear - tap '**Install**' (Fig. 66b)
4. Allow time for the app to install.
5. Tap '**Open'** once the installation is complete. (Fig. 66c)

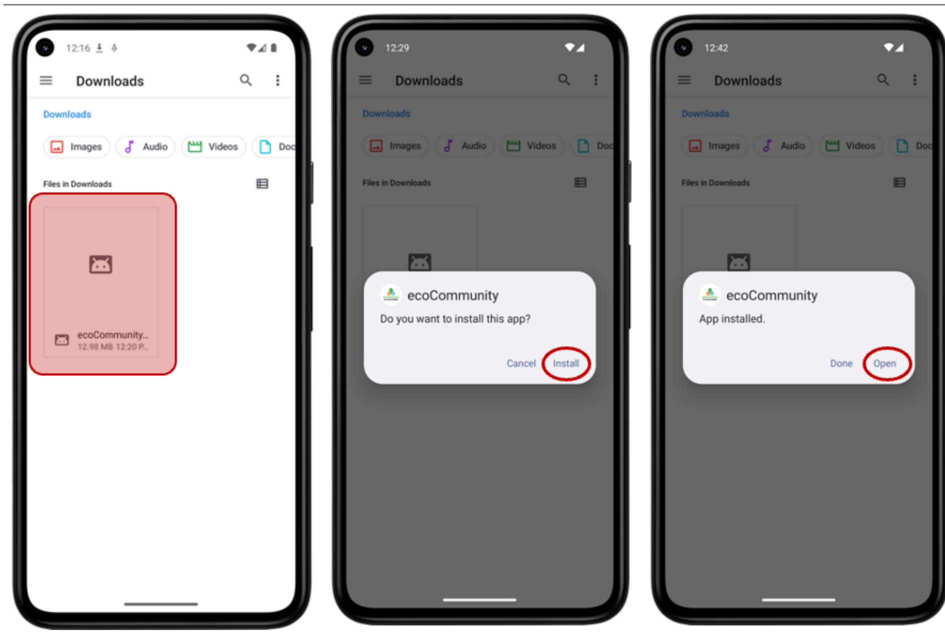


Fig a *Fig b* *Fig. c*

Figure 80: ecoCommunity interface

Once installed, follow the following steps to login to the application.

1. **Open** the application from the app drawer. (Fig. 67a)
2. **Tap** on the language dropdown to **select** the desired user interface language. (Fig. 67b)
3. **Enter your username and password** and tap '**Login'**. (Fig. 67c)
4. Read through and sign. the information sheet and consent form when logging in for the first time. (Fig. 67 d and e)
5. Explore the various modules in the home menu of the application. (Fig. 67f)

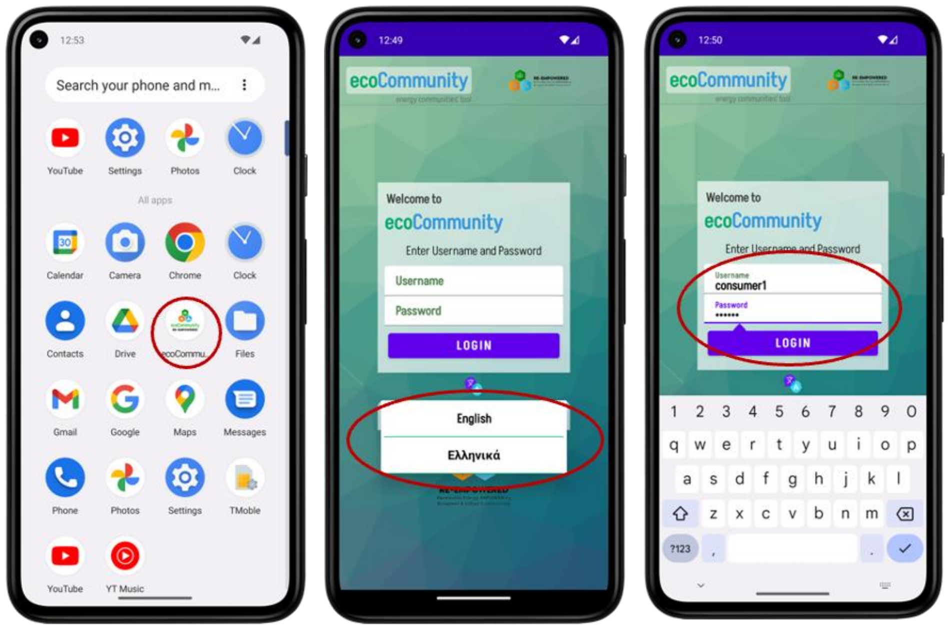


Fig a *Fig b* *Fig. c*

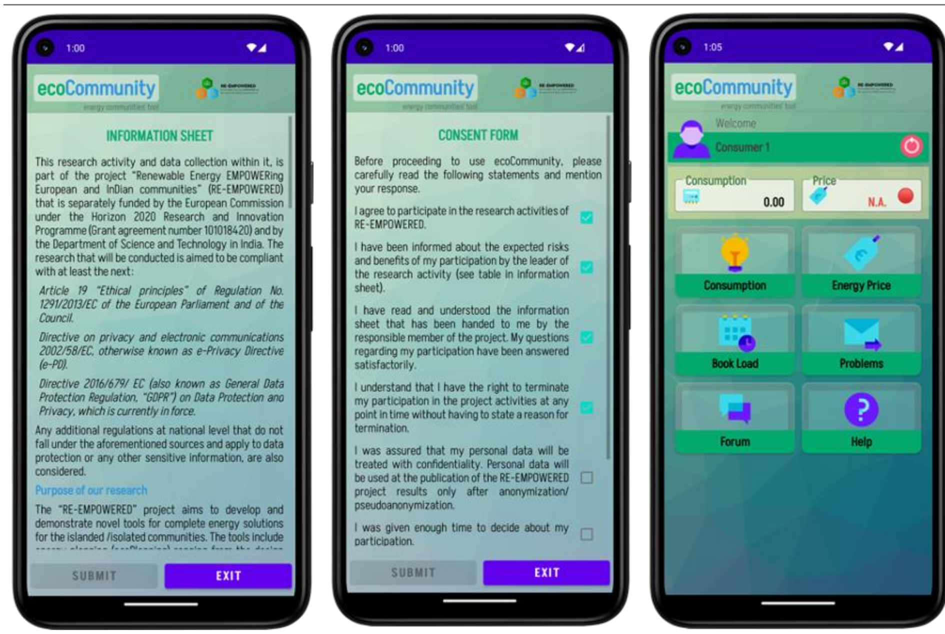


Fig d	*Fig e*	*Fig. f*

Figure 81: Installation procedure

3.9.4 Tool Modules

The tool modules are preprogrammed based on the system and requirements of each demo site. Once the user logins to the tool, they will be able to access and interact with the modules without any further inputs or configurations.

3.9.5 Administrator Level Configuration

The administrator user can configure or manage the following details of the tool.

1. Tool Users: The User module can be utilised to add or update the tool users. Administrator can configure the energy meter and energy scale associated with each consumer user as well as assign the manger for the users.
2. Help & Support Documents: Administrator can add or update the help and support documents associated with the demo site.

4 Conclusion

The RE-EMPOWERED project has successfully developed and deployed the ecoToolset. This deliverable serves as complementary documentation, providing detailed information on technical guides, user manuals, and related materials. These resources are crucial for ensuring the sustainable operation of the four demo sites following the project's completion. Moreover, proper documentation promotes the potential of integrating innovative renewable energy solutions to address local energy challenges in diverse geographic and socio-economic contexts, providing valuable insights and learnings for future activities. By implementing advanced sustainable energy systems, the project has significantly improved energy access, sustainability, and community participation.

This document serves as a comprehensive resource for project's stakeholders, detailing technical specifications, equipment integration processes, and operational guidelines. It underscores the project's commitment to sustainability, resilience, and collaboration, aiming to offer a replicable framework for deploying renewable energy systems in diverse settings.

It should be noted that guidance documents for community engagement were fully covered in "D6.1 Engagement Status Report" [2] (Task 6.1) and are not repeated in this document. These include the stakeholders' engagement guide, as well as a guide for the creation of an energy community. Moreover, a detailed report on training activities, including awareness material for local citizens is included in "D6.2 Training activities report" [3].

References

[1] RE-EMPOWERED, "Deliverable 7.3/7.2b: Report on deployment of RE-EMPOWERED solutions," 2024.
[2] RE-EMPOWERED, "Deliverable D6.1: Engagement Status Report," 2024.
[3] RE-EMPOWERED, "Deliverable D6.2: Training Activities Report," 2024.
[4] RE-EMPOWERED, "Deliverable 3.4: ecoPlanning Tool," 2022.