Renewable Energy STORage planning model for islandic energy systems

Deliverable 3.2

Data Collection & Data-driven Analysis of End-user Energy Profile

Work Package 3

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Executive Summary

Deliverable D3.2 presents the outcomes of Task 3.2 of the RESTOR project, focusing on the collection, structuring, and initial analysis of end-user energy data across the four pilot sites: Aran Islands (Ireland), Gotland (Sweden), La Réunion (France), and Remanso (Brazil). The objective of this task was to establish a consistent and reliable data foundation to support modelling, simulation, and decision-support activities in subsequent work packages.

Given the diversity of the pilot contexts and data maturity levels, a unified but flexible data collection methodology was developed. A structured, multi-layer data framework was applied to characterise facilities, energy assets, measurement systems, and data flows across all pilots. Close engagement with pilot partners ensured alignment between data requirements and local capabilities, while allowing for site-specific constraints.

The deliverable provides a consolidated overview of the energy systems and ICT architectures at each pilot, alongside an assessment of data availability, resolution, and quality. Common challenges identified include data gaps, heterogeneous data sources, limited historical records, and restricted access to grid-level measurements. Mitigation strategies were defined to address these issues and ensure the usability of the datasets for RESTOR's technical developments.

Initial analyses highlight significant flexibility potential across all pilots, driven by mismatches between renewable generation and consumption, seasonal effects, and underutilised storage and controllable loads. These findings confirm the relevance of the selected pilot sites for the project objectives.

Overall, Deliverable 3.2 provides the basis that directly enables the development of digital twins, forecasting and control algorithms, and multi-criteria assessments in later work packages, thus supporting RESTOR's overarching goal of improved renewable energy storage planning for island energy systems.

Contents

Abbreviations

AHP	Analytic Hierarchy Process
AIT	Austrian Institute of Technology (Austria)
ASHP	Air Source Heat Pump
BESS	Battery Energy Storage System
CT	Current Transformers
DER	Distributed Energy Resource
DHW	Domestic Hot Water
DMP	Data Management Plan
DSO	Distribution System Operator
DT	Digital Twin
D3.2	Deliverable 3.2
EDF	Électricité de France
ENTSO-E	European Network of Transmission System Operators for Electricity
EV	Electric Vehicles
FAIR	Findable, Accessible, Interoperable, Reusable
G2V	Grid to Vehicle
GDPR	General Data Protection Regulation (EU)
GEAB	Gotlands Energi AB
GSHP	Ground Source Heat Pump
ICT	Information and Communication Technology
IoT	Internet of Things
IRUSE	Informatics Research Unit for Sustainable Engineering
LV/MV	Low Voltage / Medium Voltage
MCDA	Multi-Criteria Decision Analysis
MQTT	Message Queuing Telemetry Transport
OSM	OpenStreetMap
OT	Operational Technology
PMU	Phasor Measurement Units
POC	Point of Connection
PPE	Programmation Pluriannuelle de l’Énergie
PT	Potential Transformers
PV	Photovoltaic
RES	Renewable Energy Sources
RG	Region Gotland (Sweden)
RMS	Root Mean Square
SAGE	Système d’Aide à la Gestion de l’Énergie
SCADA	Supervisory Control and Data Acquisition
SE3	Swedish Electricity Bidding Zone 3

SEI	Systèmes Énergétiques Insulaires
SQL	Structured Query Language
TSO	Transmission System Operator
UG	University of Galway (Ireland)
UPS	Uninterruptible Power Supply
UR	Université de La Réunion (France)
UU	Uppsala University (Sweden) – Project Coordinator (RESTOR)
V2G	Vehicle to Grid
VAR	Volt-Ampere Reactive
VFD	Variable Frequency Drive
WP	Work Package
WSHP	Water Source Heat Pump
ZNI	Zones Non Interconnectées (Non-Interconnected Zones)

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1 Introduction

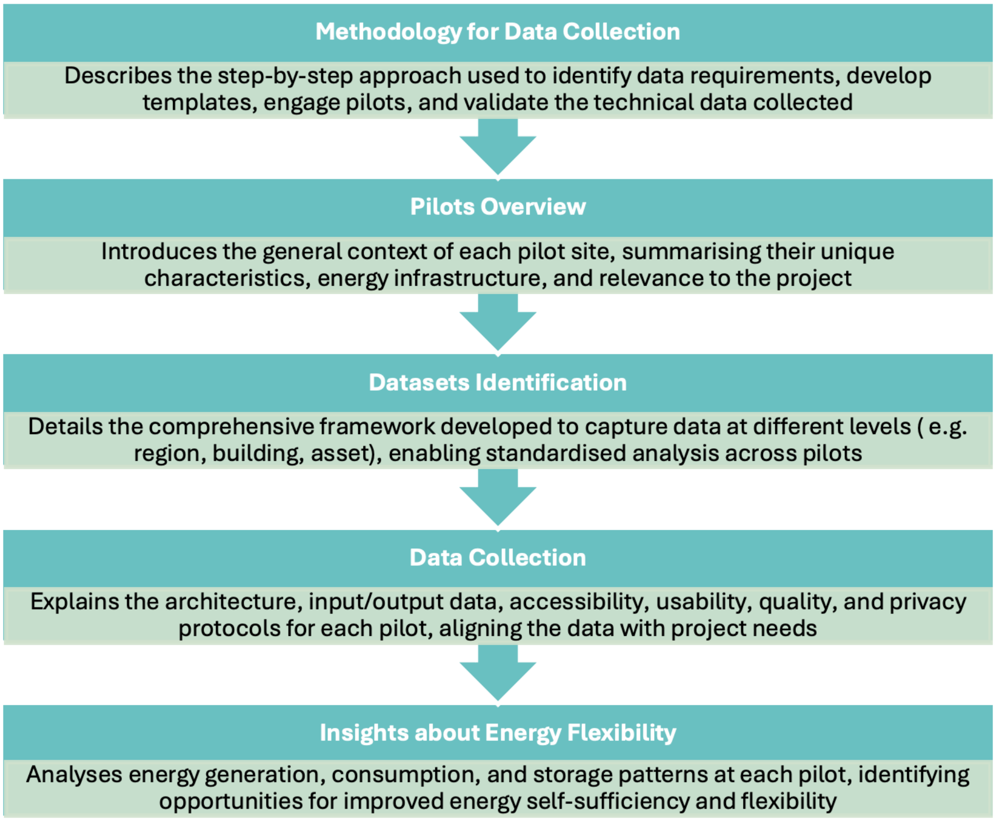
1.1 Scope

Deliverable 3.2 – Data collection & data-driven analysis of end-user energy profile – presents the outcomes of Task 3.2 of the RESTOR project, which focused on gathering, structuring, and assessing data related energy systems across the four pilot sites: Aran Islands (Ireland), Gotland (Sweden), La Reunion (France), and Remanso (Brazil). This task supports the development of the RESTOR's models by providing a technical foundation for data-driven models and simulations.

Task 3.2 description:

This task will gather information about the existing ICT architecture for data collection and processing at each pilot site. An analysis of the data quality and availability will be performed, and techniques to mitigate data gaps will be used where necessary. The collected data will be used for different purposes. First, it will be used in a data-driven quantitative analysis of the end-user behaviour in terms of consumption patterns and the available assets. Second, data will be used as input for the simulation tasks and the development of the multi-criteria model.

Although pilots have different their own specificities, a unified process has been created to ensure future replicability and scalability:



Methodology for Data Collection

Describes the step-by-step approach used to identify data requirements, develop templates, engage pilots, and validate the technical data collected

Pilots Overview

Introduces the general context of each pilot site, summarising their unique characteristics, energy infrastructure, and relevance to the project

Datasets Identification

Details the comprehensive framework developed to capture data at different levels (e.g. region, building, asset), enabling standardised analysis across pilots

Data Collection

Explains the architecture, input/output data, accessibility, usability, quality, and privacy protocols for each pilot, aligning the data with project needs

Insights about Energy Flexibility

Analyses energy generation, consumption, and storage patterns at each pilot, identifying opportunities for improved energy self-sufficiency and flexibility

Figure 1 - Deliverable 3.2 process

2 Methodology

This section outlines the methodology adopted for this deliverable, detailing the processes and tools applied throughout its execution. It describes the approach used for data collection, analysis, and validation, as well as the technical procedures and decision-making criteria guiding this task. The objective is to provide a transparent and replicable method, ensuring consistency with the project's objectives.

2.1 Data Collection and Analysis process

The methodology adopted for this task was designed to ensure a systematic data collection, and refinement of technical information across each of the four pilot sites. The process involved several coordinated steps, combining structured data collection tools with iterative engagement with pilot representatives and technical partners. The following stages were carried out:

a. **Identification of required information**
The first step involved identifying the categories of technical and operational information required for the subsequent stages of the project. This process was guided by the objectives of the deliverable and the requirements of the later technical tasks. The identification was aligned with the inputs expected in the forthcoming stages, particularly those related to pilot overviews and system specifications. This stage also provided an opportunity for all technical partners to request the information needed for the development of their tools and simulations.

b. **Development of a data collection template**
Based on the identified requirements, a structured spreadsheet was designed to support the standardised collection of information from all pilot sites. It was developed to ensure consistency across the diverse pilot contexts while allowing flexibility for site-specific characteristics. The fields included information on facilities, assets, data collection infrastructure, and measurement points.

c. **Pilot engagement and template validation**
Dedicated meetings were held with the pilot managers and technical leads of each site to introduce the proposed data collection template. These interactions aimed to clarify the rationale behind each section of the spreadsheet, address any ambiguities, and gather feedback on potential gaps or necessary customisations. This participatory approach ensured alignment between data requirements and the capabilities of each pilot.

d. **Data submission, review, and clarification**
Following the initial engagement, the designated pilot representatives completed the forms, which were then subject to a preliminary review by the Task 3.2 leader to ensure standardisation across pilots.

e. Identification of additional datasets

To support the technical development in later stages, the pilots were asked to identify additional data sources, such as census data, TSO/DSO data on energy production and consumption, energy mix information, weather data, and other open-source sources.

f. Data analysis and insights

The analysis of the collected data provided valuable insights into pilot configurations, energy usage patterns, and system capabilities. The high-level architecture of each pilot, gathered during this activity includes key system components and technology interactions, supported by additional external datasets. These insights ensure consistency across project outputs and form a foundation for modelling, tool development, and comparative analysis in upcoming technical stages.

3 Structured Pilot Site Data Framework

To support a comprehensive and structured characterisation of the RESTOR pilot sites, a multi-layer spreadsheet has been developed, based on an adapted version of work conducted by UG in the INTELLIGENT project (INTELLIGENT Consortium, 2026), and considering RESTOR's assessment needs. This living document, accessible only to project partners due to its confidential nature, is designed to gather detailed information in a progressive and hierarchical manner, moving from high-level contextual data to highly granular technical details. The structure begins with an overview of each pilot at regional level, followed by specific facility-level information and a breakdown of the energy infrastructure. Subsequent layers provide detailed asset specifications, including thermal loads, electric vehicles, renewable generation, and storage systems. The final sections address data measurement architecture and key input/output parameters. This layered approach ensures a consistent, scalable methodology for data collection across pilots, facilitating technical readiness assessments and enabling alignment with the broader system architecture and platform integration needs. Some pilots will be able to complete all layers due to the granular information available, while others will only have a high-level view of their energy systems.

Pilot general information

This section provides a high-level overview of each pilot site. It includes common fields such as pilot description, main challenges, and key technological innovations. Partners are encouraged to update any information as needed to ensure accuracy. In order to avoid data protection procedures, individual coordinates (latitude and longitud) of pilot participants will not be collected by the RESTOR consortium. Instead, a representative value per pilot site will be used (e.g.: island centroid).

The information is segregated in the spreadsheet file as follows:

- *Pilot*
- *Involved Partners*
- *Name*
- *Description*
- *Main challenges*
- *Technological innovation*
- *Latitude*
- *Longitude*
- *Pilot extension*
- *Composition (buildings) - According to the main purpose of utilisation*
    - *Options: Residential, Commercial, Industrial, Public, Others*
- *Market mechanism data (Type of trading allowed if any)*
- *Information about CO_2 emissions on the power grid mix*

Facility general information

This section captures an inventory of all facilities associated with each pilot (not all pilots have information about individual facilities). A facility is defined as any individual building participating in the pilot, including residential units, commercial premises, or public infrastructure. The goal is to document the total number of facilities and collect relevant attributes such as type of occupancy, installed energy systems, renewable generation, and thermal loads, providing a foundation for asset-level analysis and system planning. The information is segregated in the spreadsheet file as follows:

- *Facility general information*
    - *Facility (identification)*
    - *Facility category (**Options**: Residential; Commercial; Industrial; Public building; Others)*
- *Energy infrastructure*
    - *Does the household have a Smart Meter? (**Options**: Yes; No; No info available)*
- *Thermal load*
    - *Does the facility have a Heat Pump? (**Options**: Yes; No; No info available)*
    - *Does the facility have an Electric Boiler? (**Options**: Yes; No; No info available)*
    - *Does the facility have District Heating? (**Options**: Yes; No; No info available*
    - *Does the facility have significant Plug Loads (Options: Yes; No; No info available)*
- *Electrical Vehicles (EV)*
    - *Does the facility have EVs? (**Options**: Yes; No; No info available)*
    - *Does the facility have EV Chargers? (**Options**: Yes; No; No info available)*
- *Renewable Generation*
    - *Does the facility have Photovoltaic generation? (**Options**: Yes; No; No info available)*
- *Storage*
    - *Does the facility have a battery system? (**Options**: Yes; No; No info available)*
- *Occupancy*
    - *Does the facility have occupancy sensors? (**Options**: Yes; No; No info available)*

Energy infrastructure

This section gathers essential information on the broader energy system context of each pilot site. It includes details on grid topology configuration, applicable tariffs and market participation mechanisms, network parameters, and available metering infrastructure. Additional fields address the existence of validation procedures, and the environmental impact of local energy systems. The information is segregated in the spreadsheet file as follows:

- *Grid topology and Grid market price*
    - *Phase allocation (Options: Single-phase; Three-phase)*
        - *Is there an energy profile available? (e.g. 15-min time series)*
        - *If yes, what is the time resolution? (Options: 1-min; 5-min; 15-min; 30-min; 1-hour; Other)*
        - *Is electricity export permitted? (Options: Yes; No; No info available)*
        - *If yes, what is the export rate? (value in EUR/kWh or local currency)*

        - *What is the electricity purchase rate? (value in EUR/kWh or local currency)*
        - *What is the tariff structure? (Options: Flat rate; Time-of-use; Tiered; Dynamic; Other)*
    - *Grid infrastructure*
        - *Is there a grid diagram identification? (**Options:** Yes; No; No info available)*
            - *Note: If yes please include in the folder*
        - *Is there validation data available? (**Options:** Yes; No; No info available)*
        - *Is there information about Cable types and Length or equivalent circuit parameters, Transformer datasheet, POC Short Circuit power? (**Options:** Yes; No; No info available)*
        - *Location of Potential Transformers (PTs), Current Transformers (CTs), and Phasor Measurement Units (PMUs). (**Options:** Yes; No; No info available)*
    - *Grid costs: Do you have the Grid tariffs / network costs available?*

Thermal Load - Heat Pump

This section is designed to collect technical and operational data on heat pump systems. It includes specifications such as model type, power capacity, thermal storage integration, and operation modes. The section also records available datasets, supported communication protocols, and control capabilities. These inputs are necessary to assess the flexibility potential and integration of heat pumps into decentralised energy optimisation and demand response strategies. The information is segregated in the spreadsheet file as follows. If possible, data should refer to in relevant European performance standards, including EN 14511 (performance and capacity testing at fixed conditions), EN 14825 (seasonal coefficient of performance across variable load conditions), and EN 16147 (sanitary hot water production efficiency).:

- *Heat Pump*
    - *General Heat Pump information*
        - *Heat Pump Brand*
        - *Heat Pump model*
        - *Heat Source Type (**Options:** Air Source Heat Pump (ASHP); Ground Source Heat Pump (GSHP); Water Source Heat Pump (WSHP))*
        - *In what mode does this heat pump operate? (**Options:** Only Heating; Only Cooling; Heating and Cooling)*

        - *What is the rated thermal capacity in kW*
        - *What is the rated electrical input power in kW*
        - *Is the heat pump used for DHW? (**Options**: Yes; No; No info available)*
        - *What is the volume of the thermal storage tank (if applicable)?*
    - *Available data*
        - *Heat demand of the homes/building in kWh per time interval*
        - *Energy consumption per time interval (timeseries), in kWh*
        - *Heat pump water tank temperature (time series profile)*
        - *Ambient temperature profile (timeseries) to configure the heat pump performance*
    - *Communication*

Supported protocols
Analog signals
Digital signals
What is the compressor type? (Options: Fixed speed; Variable speed; Staged; No info available)
Control logic specification (Outdoor temperature, flow-return temepratures, tank temperatures, delta T, Other control logic, No information available).
Is electrical consumption measured (yes, no, no information provided)
Is thermal production measured (yes, no, no information available)

Thermal load - Electric Boiler

This section documents technical characteristics of electric boilers present within the pilot facilities. Data collected includes energy consumption profiles, nominal power ratings, and storage volumes. The aim is to assess the role of electric boilers as thermal loads within the local energy ecosystem and their potential contribution to flexibility and optimisation efforts. The information is segregated in the spreadsheet file as follows:

- *Electric Boiler*
  Energy consumption in kW
  Volume in litres to be provided
  Water tank temperature (timeseries profile)
  Is there any available data related to the consumption of this boiler?
  Is this boiler controllable?

Significant Plug Loads

This section documents technical characteristics of significant plug loads present within the pilot facilities that are individually sub-metered. Data collected includes energy consumption profiles, nominal power ratings, and usage patterns. The aim is to assess the role of significant plug loads within the local energy ecosystem and their potential contribution to flexibility and optimisation efforts. The information is segregated in the spreadsheet file as follows:

- *Significant Plug Loads*
  What is the plug load type?
  What is the rated electrical power in kW?
  Energy consumption per time interval (timeseries) in kWh
  Is there any available data related to the consumption of this load?
  Is this load controllable?

Thermal load - District Heating

This section gathers detailed information about district heating systems where applicable. It includes data on system topology, flow and return temperatures, water flow rates, and any pressure readings available over time. Additional fields cover the presence of booster heat pumps, control strategies, and measurement points across the network. This information supports modelling of thermal energy flows and evaluation of system responsiveness.

The information is segregated in the spreadsheet file as follows:

- *District heating*
    - *System pressure (timeseries)*
    - *Supply temperature (timeseries)*
    - *Return temperature (timeseries)*
    - *Water flow (*m^3/h*) (timeseries)*
    - *Availability of booster heat pumps (**Options**: Yes; No; No info available)*
    - *Topology*
        - *Topology*
        - *Topology lengths*
        - *Topology line diameters*
        - *Pipe Cross Section (U value – Materials)*
    - *Availability measurement systems*
    - *Location of measurement systems*
    - *Thermal storage? (**Options**: Yes; No; No info available)*

Electric Vehicles (EV)

This section collects data on electric vehicle infrastructure and usage at the pilot sites. It includes charger specifications (e.g. power capacity, metering capabilities), communication protocols, and control features. It also records contextual data such as the presence of EVs, charging behaviours, and typical state-of-charge patterns. These data are critical for evaluating EVs as flexible energy consumers or storage assets. The information is segregated in the spreadsheet file as follows:

- *EV Charger*
    - *Capacity (kWh)*
    - *EV Charging Net Metering (kW, timeseries)*
    - *Min/Max discharge rate*
    - *State of Charge (percent, timeseries)*
    - *Min/Max State of Charge*
    - *Charging connector standard*
    - Charging powerflow capability (bidirectional (V2G) or unidirectional (G2V) charging) *(**Options**: V2G; G2V)*
    - *Communication protocols*
    - *Power ramp rates*
    - *Reactive power demand*
    - *Is there a sensor to verify if the EV is connected? (**Options**: Yes; No; No info available)*

Renewable Generation

This section documents information on renewable energy generation, with a focus on photovoltaic (PV) systems. It includes specifications such as panel orientation, tilt, model type, installed capacity, and energy production. Data on inverters, including type, number of MPPTs, and communication capabilities, are also collected. These inputs support generation forecasting and system-level optimisation. The information is segregated in the spreadsheet file as follows:

- *Photovoltaic panel information*
    - *Model*
    - *Is there an energy produced profile per time interval in kWh? (**Options**: Yes; No; No info)*
    - *Orientation (tilt and azimuth)*
    - *Altitude*
    - *Max power (or PV peak) kW*
- *Inverter details*
    - *Inverter Type*
    - *Inverter details*
    - *Is the inverter's datasheet available? (**Options**: Yes; No; No info available)*
    - *Communication protocols? (**Options**: Yes; No; No info available)*
    - *Inverter available communication protocols*
    - *Fixed vs 1 Axis Tracker vs 2 Axis Tracker*

Storage

This section gathers technical information on electrical energy storage systems. It includes storage type (e.g., lithium-ion, flow battery), rated capacity, efficiency, and operational profiles. Additional fields cover charge/discharge rates, variation in state of charge over time, and available communication and control interfaces. These data enable assessment of storage flexibility and integration into market services or self-consumption schemes. The information is segregated in the spreadsheet file as follows:

- *Electricity storage*
    - *Storage type*
    - *Is the battery controllable? (**Options**: Yes; No; No info available)*
    - *Capacity in kWh*
    - *Charge power in kW (time series)*
    - *Discharge power in kW (time series)*
    - *Maximum charge power in kW*
    - *Minimum charge power in kW*
    - *Maximum discharge power in kW*
    - *Minimum discharge power in kW*
    - *Minimum SoC in %*
    - *Actual SoC in time series*
    - *Communication protocols*
    - *Power ramp rate*
    - *Is the inverter for the storage the same one used for the PV? (**Options**: Yes; No; No info)*

Facility Usage

This section records information on occupancy and user preferences related to thermal comfort. Data fields include the number of occupants, typical occupancy schedules (e.g., working hours, seasonal variations), and preferred temperature ranges. These inputs are used to assess energy demand profiles, model user behaviour, and inform adaptive control strategies that balance comfort with energy efficiency. The information is segregated in the spreadsheet file as follows:

- *Occupancy*
    Occupancy - Number of people that use the facility
    Occupancy profile
- *Thermal Comfort Information*
    What is the minimum comfort temperature (°C)?
    What is the maximum comfort temperature (°C)?

Measurement Points

This section compiles detailed information about the measurement infrastructure deployed across the pilot sites. It aims to capture what is being measured, where, and how. For each device, the following attributes are recorded: the type of measurement (e.g., voltage, current, power, temperature), the corresponding unit, and whether the data is raw or metadata. Additionally, it includes information on the type of access available (e.g., real-time, delayed, aggregated), the temporal resolution of the data (e.g., 1-minute, 15-minute, hourly), and the data format (e.g., JSON, CSV, API-based). This structured overview helps assess the quality, granularity, and usability of the data, and supports decisions on simulation capabilities, validation processes, and system interoperability. The information is segregated in the spreadsheet file as follows:

Measurement device
Measurement
UNIT
*DATA / METADATA (**Options:** Metadata; Data; Metadata/Data)*
*TYPE OF ACCESS (**Options:** Read; Write; Read/Write)*
DATA RESOLUTION
DATA FORMAT

Other

This section will be kept as a living document to provide space for any additional information relevant to understanding the pilot site and its associated facilities. It can include qualitative observations, contextual notes, special constraints, or site-specific innovations not captured in the previous sections. Partners are encouraged to use this section during the project to share insights that may support technical analysis, replication, or cross-site comparisons.

4 Pilots

4.1 Aran Islands (Ireland)

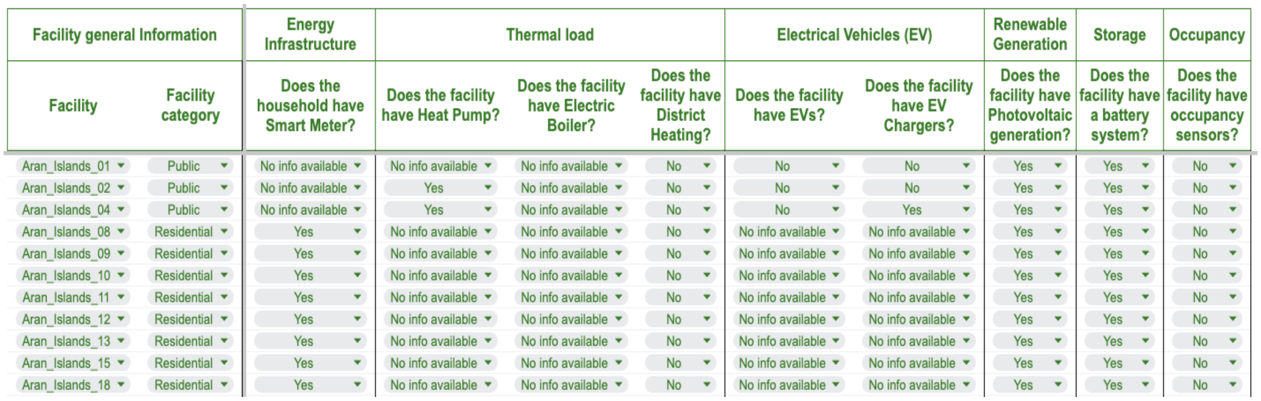
4.1.1 Pilot overview

The Aran Islands pilot, located on Inis Mór (Ireland), includes 11 buildings (8 residential, and 3 public). The renewables aggregated installed capacity accounts for 45.9 kW from PV Panels with a total storage battery capacity of 101 kWh. These energy assets and the infrastructure for data collections were initially deployed through a previous Horizon 2020 REACT (REACT, 2019) project. After an initial assessment, a total of 11 are currently active and were pre-selected to be part of the tests (with potential others to join). While some systems remain operational, several are offline or unmonitored. A criterion for selection, among others, was the availability of heat pump data. Data gaps, particularly regarding grid measurements, and inconsistent asset monitoring present key challenges. Nonetheless, past demand response use cases offer a valuable knowledge base for further control and optimisation. Participant willingness to keep participating in Horizon projects was also a key factor when selecting these buildings.

Figure 2 - Aran Islands pilot

4.1.2 Pilot’s energy asset facility summary

This section presents a consolidated overview of the Aran Islands pilot facilities included in the project, detailing the key energy infrastructure, thermal loads, electrical vehicle readiness, renewable generation assets, storage capabilities, and occupancy monitoring systems. The summaries provide a high-level snapshot of the existing conditions in the pilot site, supporting the identification of technological readiness, potential integration points for new solutions, and opportunities for optimisation.



Facility general Information		Energy Infrastructure	Thermal load			Electrical Vehicles (EV)		Renewable Generation	Storage	Occupancy
Facility	Facility category	Does the household have Smart Meter?	Does the facility have Heat Pump?	Does the facility have Electric Boiler?	Does the facility have District Heating?	Does the facility have EVs?	Does the facility have EV Chargers?	Does the facility have Photovoltaic generation?	Does the facility have a battery system?	Does the facility have occupancy sensors?
Aran_Islands_01	Public	No info available	No info available	No info available	No	No	No	Yes	Yes	No
Aran_Islands_02	Public	No info available	Yes	No info available	No	No	No	Yes	Yes	No
Aran_Islands_04	Public	No info available	Yes	No info available	No	No	Yes	Yes	Yes	No
Aran_Islands_08	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_09	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_10	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_11	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_12	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_13	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_15	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No
Aran_Islands_18	Residential	Yes	No info available	No info available	No	No info available	No info available	Yes	Yes	No

Figure 3 - Irish pilot spreadsheet summary.

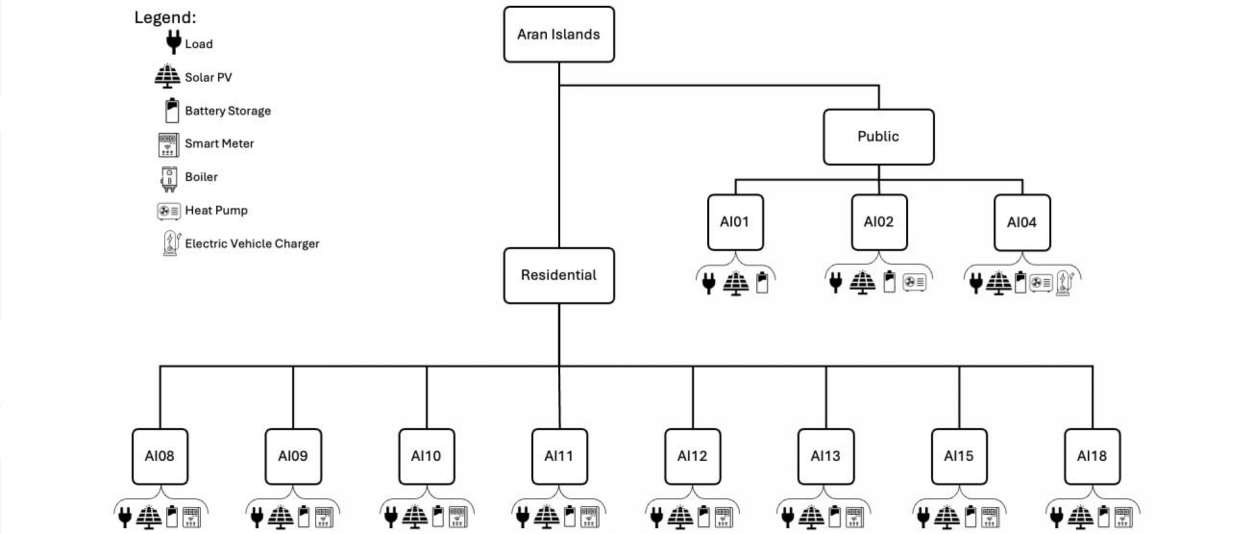


Figure 4 - Irish pilot general structure.

4.1.3 Architecture for data collection

In the Irish pilot, data is gathered in stored in a InfluxDB server. At the field level, various assets generate data, including renewable energy sources assets, common assets, and meters/IoT sensors. These connect to an energy gateway, which acts as the primary interface for transmitting data to higher-level systems. The Middleware MQTT Broker serves as the central communication hub, managing real-time data exchange between the field, storage systems, analytical tools, and external services. Data is stored either as historical data in a time series InfluxDB database or as semantic data in a semantic repository. Both datasets are available for visualisation through a web dashboard and for use in the RESTOR technical tasks. Connections to external systems (such as aggregators or weather forecasting services) are facilitated via an external adapter, while cloud adapters enable integration with specific manufacturer clouds for electric vehicles, RES assets, and other devices.

4.1.3.1 SMA Portal

PV data from public buildings can also be collected and visualised directly in the manufacturer’s cloud platform. In this case, the manufacturer is SMA (SMA Solar Technology AG, n.d.), and the monitoring environment is the Sunny Portal. While this setup creates some redundancy compared to the main InfluxDB-based architecture, it offers the advantage of centralised asset management within the manufacturer’s ecosystem. However, the Sunny Portal provides lower data resolution and involves a less user-friendly, largely manual process for extracting information. A notable benefit is its integrated dashboard, which offers a clear, real-time view of the installation’s status. As shown in the example, the dashboard displays key performance indicators such as installed PV capacity, nominal battery capacity, date of commissioning, and current operating mode. It also visualises energy flows between PV generation, battery storage, and consumption points, alongside performance ratios, self-sufficiency levels, and PV surplus. Additional panels provide insights into daily and monthly energy yields, battery state of charge, CO_2 avoidance, weather conditions, wind speed, module and ambient temperatures, and solar irradiation levels, offering a comprehensive operational overview, as can be seen in Figure 5.

Figure 5 - SMA Sunny portal dashboard.

4.1.3.2 Victron Energy Portal

Similarly to public buildings, data from residential buildings can also be accessed and managed through the manufacturer's cloud portal. In this case, the system is provided by Victron Energy (Victron Energy, n.d.), which offers an online platform for real-time monitoring and control of household energy assets. The dashboard allows users to view grid import/export, PV generation, battery charge status, and load consumption, alongside key electrical parameters such as voltage, current, and temperature. Historical data is visualised through detailed charts showing consumption patterns, solar production, and battery usage over time, enabling better understanding of daily energy flows. While this manufacturer-specific interface provides valuable operational insights and direct system management capabilities, its data extraction process, like the Sunny Portal, does not match the flexibility, data resolution, and integration possibilities offered by InfluxDB-based solutions. Figures 6 and 7 show an example of the Victron's dashboard in the portal.

Figure 6 - Victron's connection dashboard.

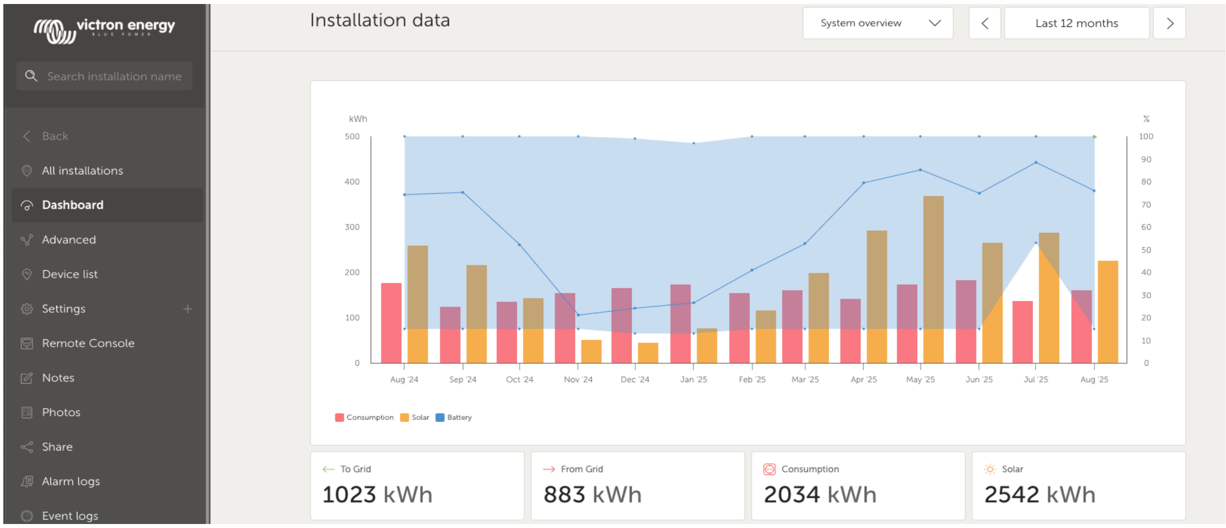


Figure 7 - Victron's energy profile dashboard.

Although Victron and SMA provide valuable insights and backup data capabilities, they are independent providers. For this reason, the InfluxDB database has been developed to centralise data management from different vendors, while also supporting the integration of renewable systems from other manufacturers using open-source protocols.

4.1.3.3 Live weather data

Informatics Research Unit for Sustainable Engineering (IRUSE) at the University of Galway maintains a record of weather conditions in Galway, Ireland. The data can be used to approximate the conditions in the Aran Islands, with the support of the satellite measurements from the SMA systems. The automatic weather station was installed in June 2010 on the roof of the Concourse building at the University of Galway campus. The coordinates for the weather station are:

- Latitude: N 53° 16' 47"
- Longitude: W 9° 03' 37"
- Altitude of 21 m above the sea level

The weather station monitors the following weather data:

- Dry-bulb temperature [°C]
- Relative humidity [%]
- Barometric pressure [mBar]
- Wind speed [m/s]
- Wind speed - 3s gust [m/s]
- Wind direction [deg]
- Total and diffuse solar irradiance [W/m²]
- Rainfall [mm]

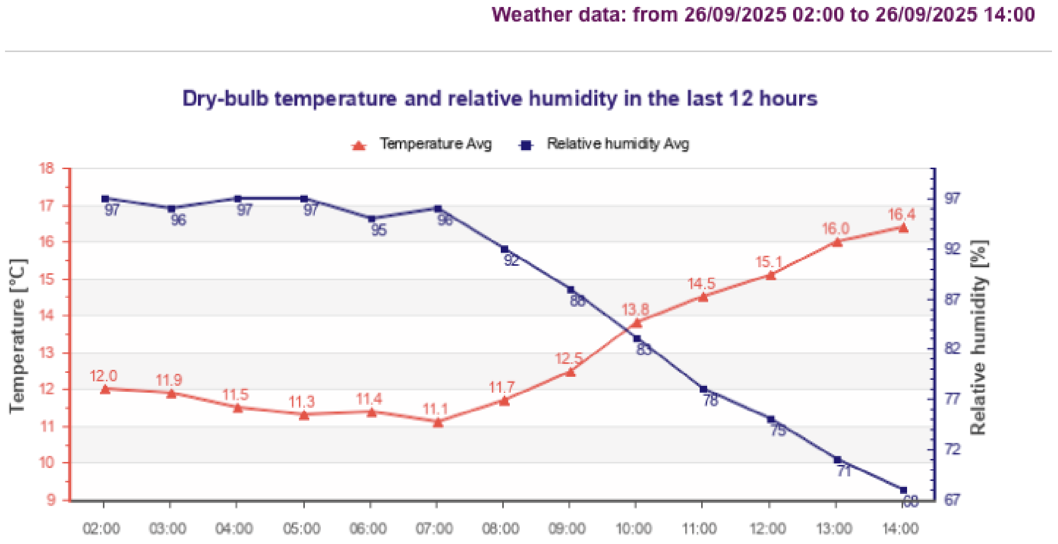


Figure 8 - Weather data chart example 1.

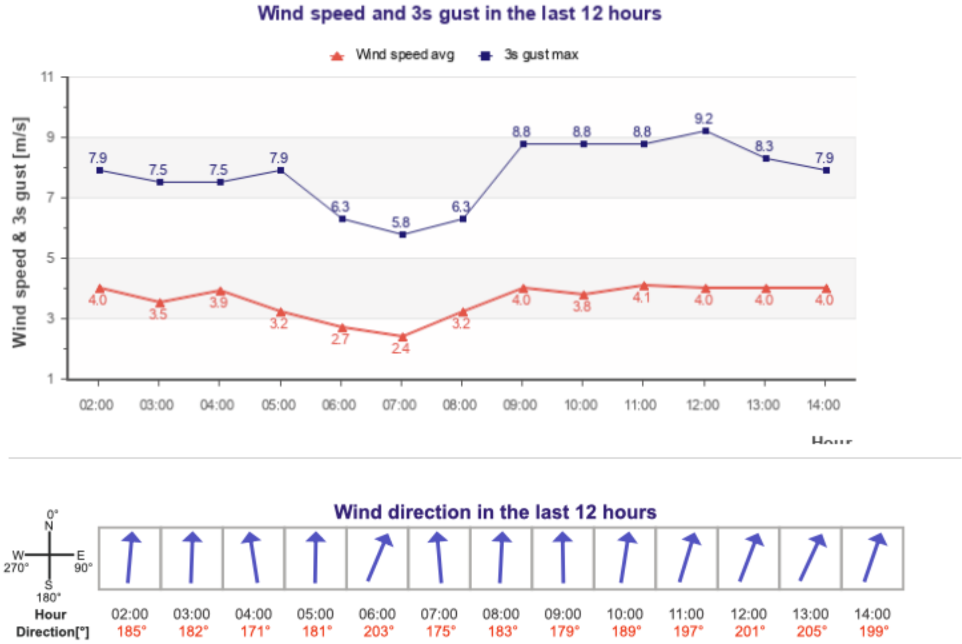


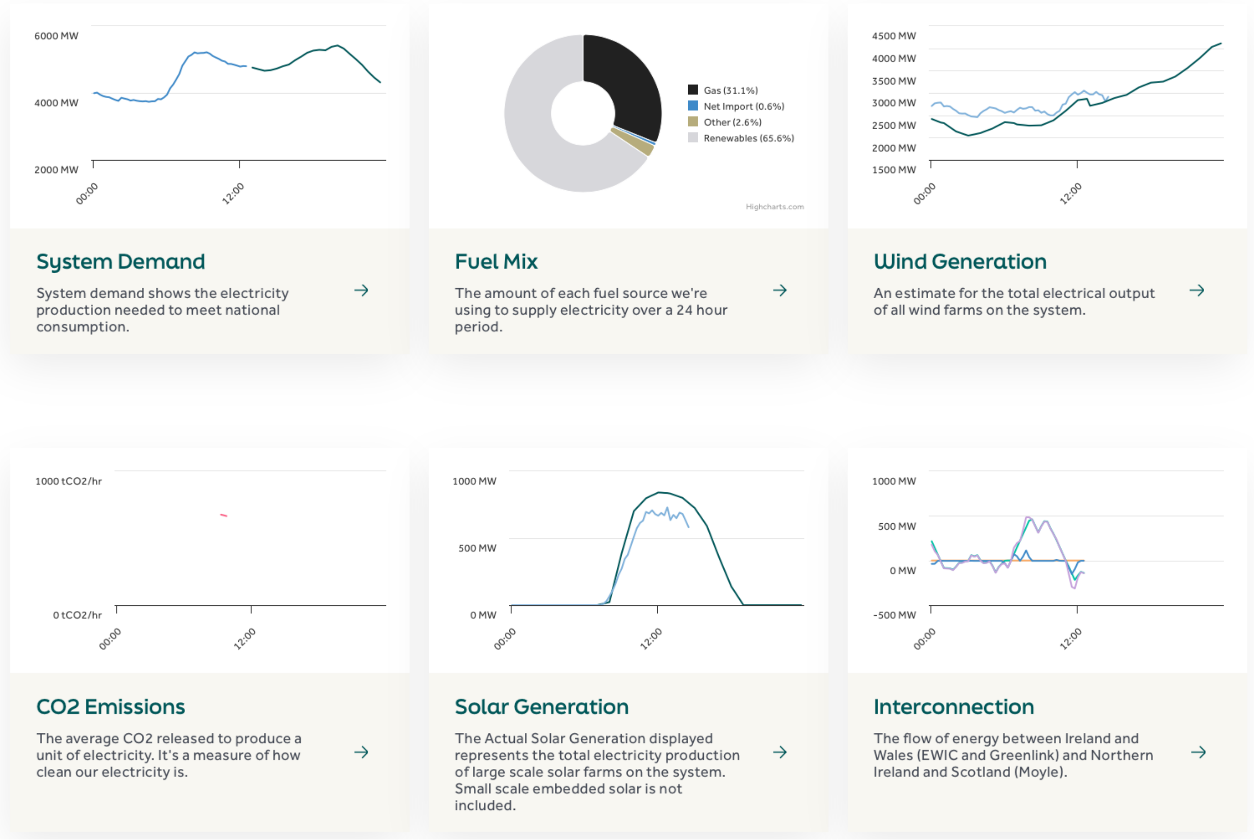
Figure 9 - Weather data chart example 2.

Data is available through a public PHP-based application that provides a User Interface and raw javascript API calls for retrieving storical data.

4.1.3.4 TSO data and dashboards

EirGrid is Ireland's TSO, (Transmission System Operator). They plan, manage and develop Ireland's high-voltage electricity grid for a sustainable future. This grid is connected to the lower voltage distribution system managed by ESB Networks, Ireland's Distribution System Operator (DSO), which supplies power directly to homes and business around the country. EirGrid provides a real-time system information in their website, in which details can be seen about Ireland’s power system in easy to view charts. From system demand to fuel mix, this gives you real time updates about the Irish electricity grid and can provide a high-level perspective to support the RESTOR’s developments in the Aran Islands.

EirGrid smart grid dashboard (available at https://www.smartgriddashboard.com) shows information such as demand, generation summary, wind and solar generation details, interconnection, frequency, imbalance price/volume, CO_2 intensity overtime, and others.



System Demand

System demand shows the electricity production needed to meet national consumption. →

Fuel Mix

The amount of each fuel source we're using to supply electricity over a 24 hour period. →

Wind Generation

An estimate for the total electrical output of all wind farms on the system. →

CO2 Emissions

The average CO2 released to produce a unit of electricity. It's a measure of how clean our electricity is. →

Solar Generation

The Actual Solar Generation displayed represents the total electricity production of large scale solar farms on the system. Small scale embedded solar is not included. →

Interconnection

The flow of energy between Ireland and Wales (EWIC and Greenlink) and Northern Ireland and Scotland (Moyle). →

Figure 10 - EirGrid dashboards.

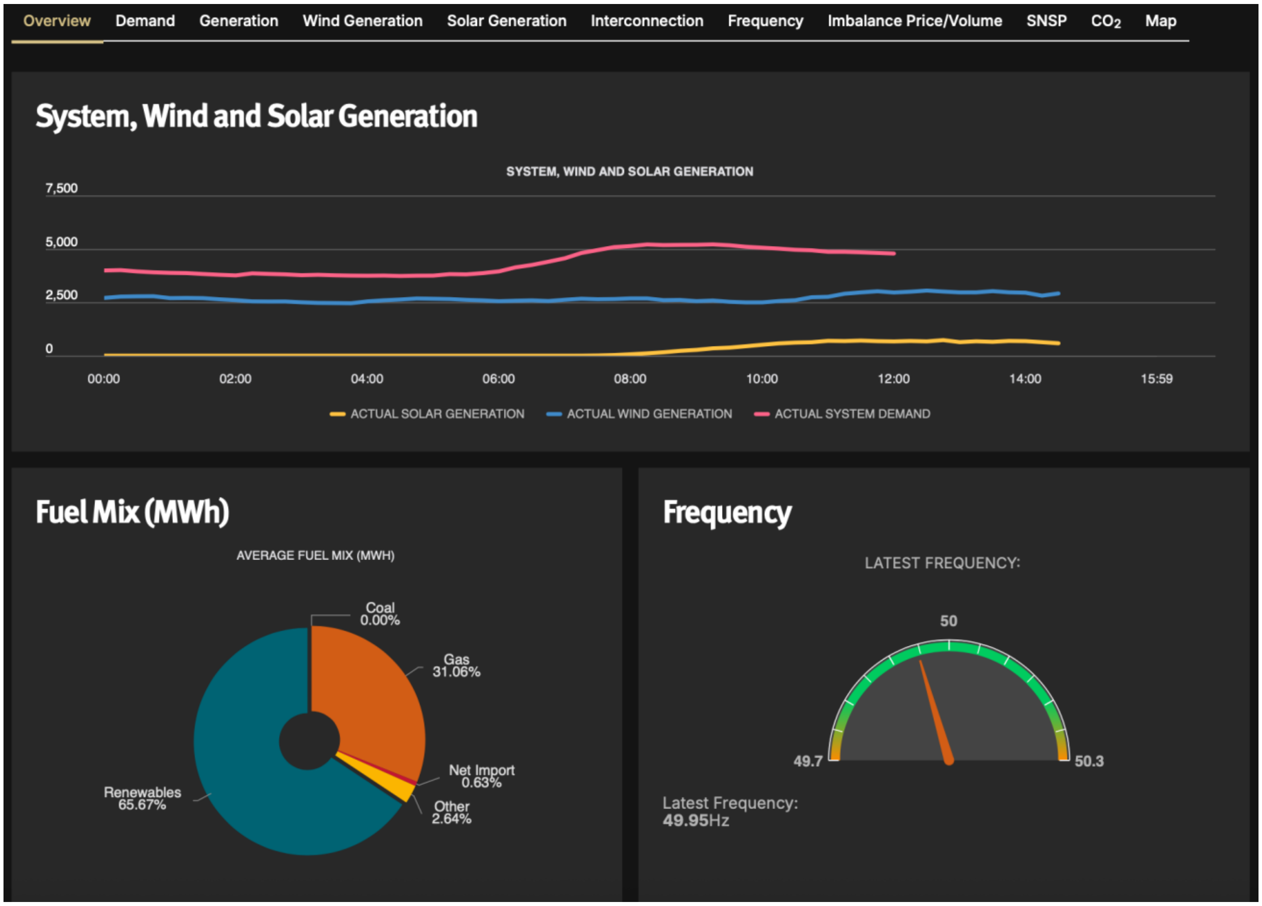


Figure 11 - EirGrid smart grid dashboard.

4.1.4 Data quality

In the Irish pilot site, equipment for data gathering was deployed as part of a previous Horizon 2020 project called REACT. As described previously, there are two main manufacturers of the PV systems: SMA, which was installed in public and commercial buildings, and Victron Energy, used in residential buildings. Both manufacturers provide their own data quality checks through their respective online portals. However, the data available from these portals is limited in resolution, with 5 minutes in the best-case scenario. To improve data granularity (to 1-minute resolution) and enable centralised system control, an additional gateway device was installed. The trade-off is that this device retrieves raw data and stores it in a separate InfluxDB database, which requires cleaning and processing to ensure compatibility with the project's services.

In the InfluxDB database, there are gaps in the data, which may be due to issues such as equipment faults, internet connectivity problems, power outages, server downtime, or suggesting intermittency or instability in the system.For both data sources (VICTRON and SMA) historical data with lower resolution can be downloaded as CSV files from the manufacturers' portals or retrieved using data scraping techniques. The resolution is limited to 5 minutes. For high-resolution or real-time data, the InfluxDB database will be used.

4.1.4.1 Mitigation measures

The following measures will be implemented to mitigate and improve the data quality:

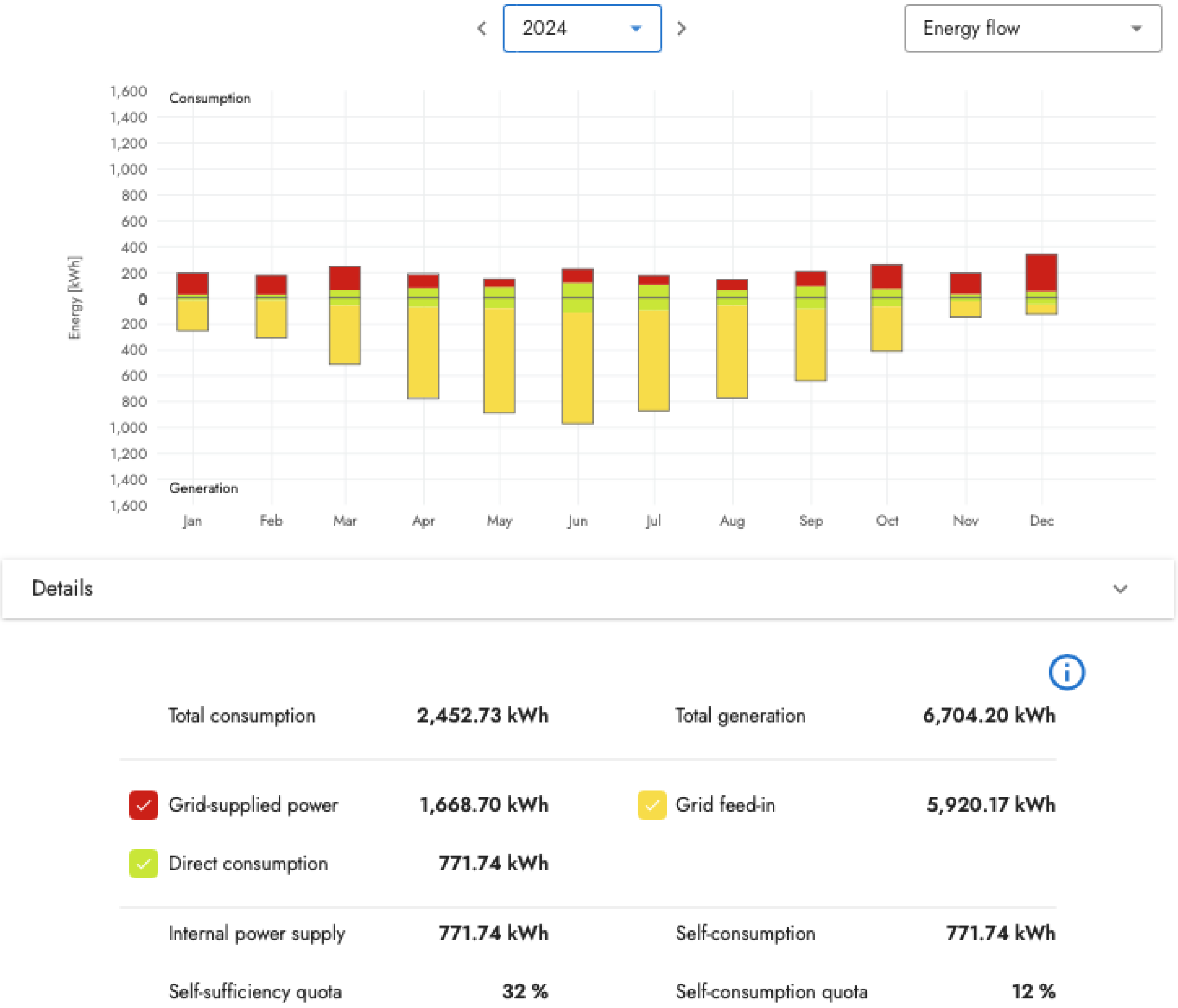
- **Database reconstruction using manufacturers' cloud data:** Historical data from SMA and Victron systems will be downloaded and inserted into the InfluxDB database to fill existing gaps as much as possible. However, it will not be possible to achieve a 1-minute resolution for this reconstructed data. Additionally, Victron systems only retain six months of historical data, which limits the ability to reconstruct complete time series for the residential buildings.
- **Database reconstruction using utility smart meter data:** Currently, residential end users can manually download up to two years of data from their smart meters via the utility's website. UG and CFA will request this data to support the reconstruction of time series for the residential buildings. The limitations include a lower resolution of 30 minutes and the availability of only two variables: energy consumption and energy production.
- **Filtering values directly through SQL queries (or Python scripts): As mentioned previously,** some sensors use the same time series of actual measurements to include alarm signals that can be filtered and analysed later. When retrieving raw data from InfluxDB, this information must be pre-processed to exclude values that are not related to actual measurements.

4.1.5 Insights about energy flexibility

This section presents an analysis of the three public buildings that are part of RESTOR's project. Additional analysis will be carried out during WP4 activities, to support the use cases selected.

4.1.5.1 Community Hall

The chart in Figure 12 presents the monthly energy profile of the community hall for the year 2024, illustrating both energy consumption and generation dynamics. Across most months, on-site PV generation significantly exceeds the building's immediate energy needs, resulting in a large proportion of electricity being fed into the grid. Over the course of the year, the building consumed a total of 2,452.73 kWh while generating 6,704.20 kWh through its PV system. However, only 771.74 kWh of this generation was used directly on-site, with the remaining 5,920.17 kWh exported to the grid. Simultaneously, the building still relied on the grid for 1,668.70 kWh of its electricity needs. Currently, the storage system is not working properly, and it will be re-assessed during the project. These figures reflect a self-sufficiency quota of 32%, and a self-consumption quota of only 12%, indicating that most of the locally generated energy is not being utilised within the facility. This mismatch between production and consumption highlights a significant opportunity for storage systems. For most months, the energy produced is higher than the energy imported from the grid, except in November and December (and possibly January and February), when energy production decreases considerably during the winter period while consumption increases due to the heating system. In summary, while the community hall demonstrates strong energy generation performance, its current operational pattern shows substantial underutilisation of local resources. By addressing this imbalance through targeted flexibility strategies, the building could play a more active role in supporting the community needs.



Total consumption	2,452.73 kWh	Total generation	6,704.20 kWh
☑ Grid-supplied power	1,668.70 kWh	☑ Grid feed-in	5,920.17 kWh
☑ Direct consumption	771.74 kWh		
Internal power supply	771.74 kWh	Self-consumption	771.74 kWh
Self-sufficiency quota	32 %	Self-consumption quota	12 %

Figure 12 – Community Hall analysis.

4.1.5.2 Community Office

The chart below (Figure 13) presents the monthly energy profile of the Community Office for the year 2024. Over the year, the building consumed a total of 15.149 MWh, while generating 11.810 MWh from its PV system. A significant portion of the generated energy was used effectively on-site, with self-consumption of 6.435 MWh. In contrast to the Community Hall, which had a self-consumption quota of only 12%, the Community Office achieved 54% self-consumption, showing a much higher capacity to use its own energy locally. Nevertheless, it still relied on 9.793 MWh from the grid to meet its energy needs, and exported 5.533 MWh of surplus energy, primarily during the sunnier months. With a self-sufficiency quota of 36%, the building shows moderate energy independence. Compared to the Community Hall, the Community Office benefits from more balanced energy use and improved flexibility, partly due to its battery system. However, seasonal mismatches remain evident, particularly in winter months when consumption increases and production drops.

Total consumption	15.149 MWh	Total generation	11.810 MWh
☑ Grid-supplied power	9.793 MWh	☑ Charge battery	3.317 MWh
☑ Discharge battery	2.396 MWh	☑ Grid feed-in	5.533 MWh
☑ Direct consumption	3.141 MWh		
Internal power supply	5.516 MWh	Self-consumption	6.435 MWh
Self-sufficiency quota	36 %	Self-consumption quota	54 %

Figure 13 - Community Office analysis.

4.1.5.3 Childcare Facility

Regarding the Childcare (Figure 14), the building consumed a total of 12.683 MWh, with a PV system generating 8.918 MWh. Of this generated energy, 2.960 MWh was consumed directly on-site, and 1.862 MWh was supplied via battery discharge. The building achieved a self-sufficiency quota of 38% and a self-consumption quota of 62%, showing a better internal usage rate of generated electricity than the Community Hall (12% self-consumption) and a slightly lower but comparable performance to the Community Office (54% self-consumption). The Childcare building exported 3.382 MWh of surplus energy and still relied on the grid for 7.894 MWh, particularly during the winter months when heating demand increased and solar generation dropped. Its battery system helped improve flexibility, storing 2.610 MWh during low-demand or high-generation periods. Compared to the Community Hall, which had strong generation but low on-site usage, the Childcare facility demonstrates significantly improved utilisation of local renewable energy. While its performance is slightly below the Community Office in terms of overall self-sufficiency, the higher self-consumption percentage suggests that it makes more efficient use of the generation it does retain. Further improvements could still be made by optimising battery use and implementing demand-side strategies to reduce grid dependence, particularly in peak winter months.

Total consumption	12.683 MWh	Total generation	8.918 MWh
✓ Grid-supplied power	7.894 MWh	✓ Charge battery	2.610 MWh
✓ Discharge battery	1.862 MWh	✓ Grid feed-in	3.382 MWh
✓ Direct consumption	2.960 MWh		
Internal power supply	4.821 MWh	Self-consumption	5.531 MWh
Self-sufficiency quota	38 %	Self-consumption quota	62 %

Figure 14 - Childcare analysis. Gotland (Sweden)

4.2 GOTLAND (Sweden)

4.2.1 Pilot overview

Gotland is the largest of Swedish Islands, located 90 kms off the south-eastern coast of mainland Sweden in the middle of the Baltic Sea. It is mostly rural with a small urban population in the Hanseatic city of Visby, which also serves as the capital of the island. Very sparsely populated for its size, Gotland has a population of 60,970 permanent residents over an area of 3,100 sq kms. During summer months, Gotland experiences a significant population increase due to tourism. According to the OECD Territorial Review (2022), the island's population more than doubles from approximately 61,000 permanent residents to around 130,000 in July. Annual transport statistics indicate that approximately 2 million passenger journeys are made to and from the island by ferry and air combined, with registered accommodation recording around 870,000 guest nights per year. The tourism sector is highly seasonal, concentrated between mid-June and mid-August, which creates challenges for infrastructure, water management, and energy demand during peak periods.

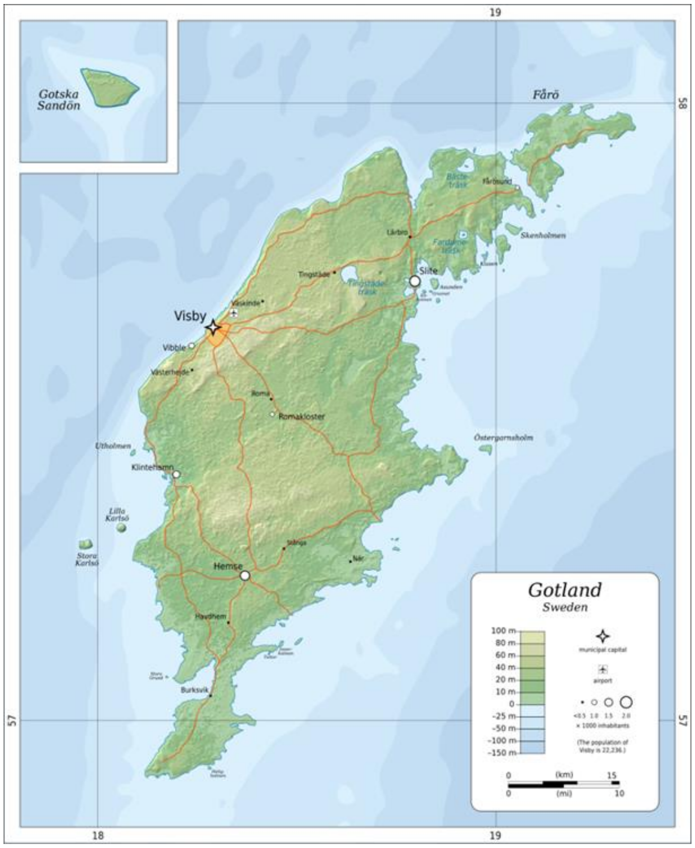


Figure 15 - Map of Gotland.

The economy in Gotland is mostly driven by the above-mentioned tourist season during the summer months. Apart from that, Gotland also has a variety of agricultural and meat industries, especially lamb, with a prominent food processing industry as well. It also has a lime and cement mining industry situated on its eastern coast, which requires a considerable amount of energy to operate.

4.2.2 Pilot's energy asset facility summary

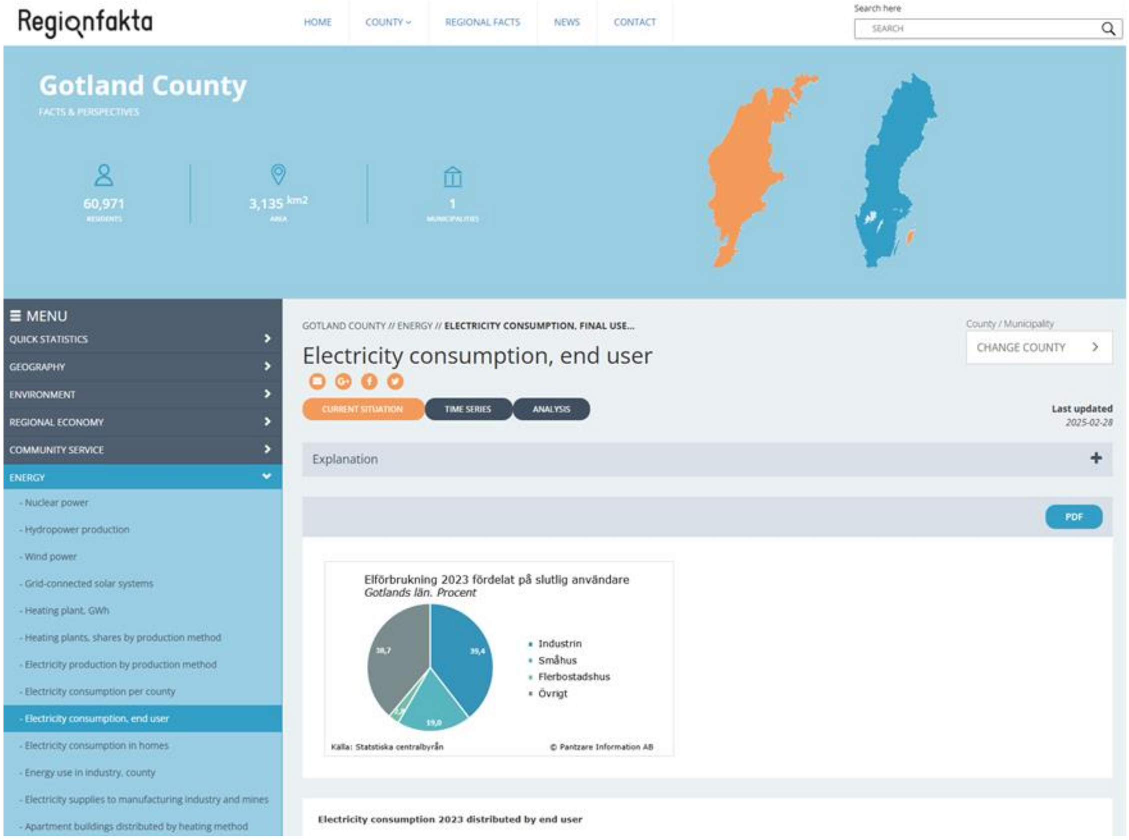
Gotland has an annual electricity consumption of approximately 850 GWh, with a peak demand of around 187 MW during winter, mainly due to heating. Energy intensive such as cement manufacturing contributes siginificantly to the overall demand.

Figure 16 - Gotlands smart grid design by Vattenfall.

The island has a total installed renewable electricity generation capacity of approximately 218 MW, comprised of 180 MW of wind power and 38 MW of solar photovoltaic. For heating, a 127.5 MWth biomass combined heat and power plant provides district heating, primarily serving Visby. Gotland is interconnected to the Swedish mainland via two HVDC submarine cables, each with a transmission capacity of 130 MW. Currently, there are no large-scale electricity storage systems on the island.

4.2.3 Architecture for data collection

Gotland belongs to the SE3 electricity trading zone in Sweden. The overall data on electricity imports and exports can be accessed by various open-source platforms such as Nordpool, ENTSO-E, and others, but supply and demand data for Gotland on a micro scale is not available and is almost impossible to collect manually due to the island's size and population.



Gotland County

FACTS & PERSPECTIVES

60,971 RESIDENTS

3,135 km2 AREA

1 MUNICIPALITIES

GOTLAND COUNTY // ENERGY // **ELECTRICITY CONSUMPTION, FINAL USE...**

Electricity consumption, end user

Last updated
2025-02-28

Elförbrukning 2023 fördelat på slutlig användare
Gotlands län. Procent

Källa: Statstiska centralbyrån

© Pantzare Information AB

Electricity consumption 2023 distributed by end user

Figure 17 - Open-source macro platforms for Gotland.

The best route to conduct optimum research is through obtaining data from GEAB, the local DSO which operates the local grid on the island. It is co-owned by the national DSO Vattenfall and the local government Region Gotland, of which the latter is a part of RESTOR project. Negotiations are underway to acquire data on a macro scale for the island, with the assurance that the data will not be published but used only for research purposes due to security concerns.

For other general data like temperature and wind speed, there are several meteorological stations across Gotland, including larger ones at Visby Airport and Östergarnsholm, as well as smaller stations throughout the island. This data is therefore more readily accessible through various platforms

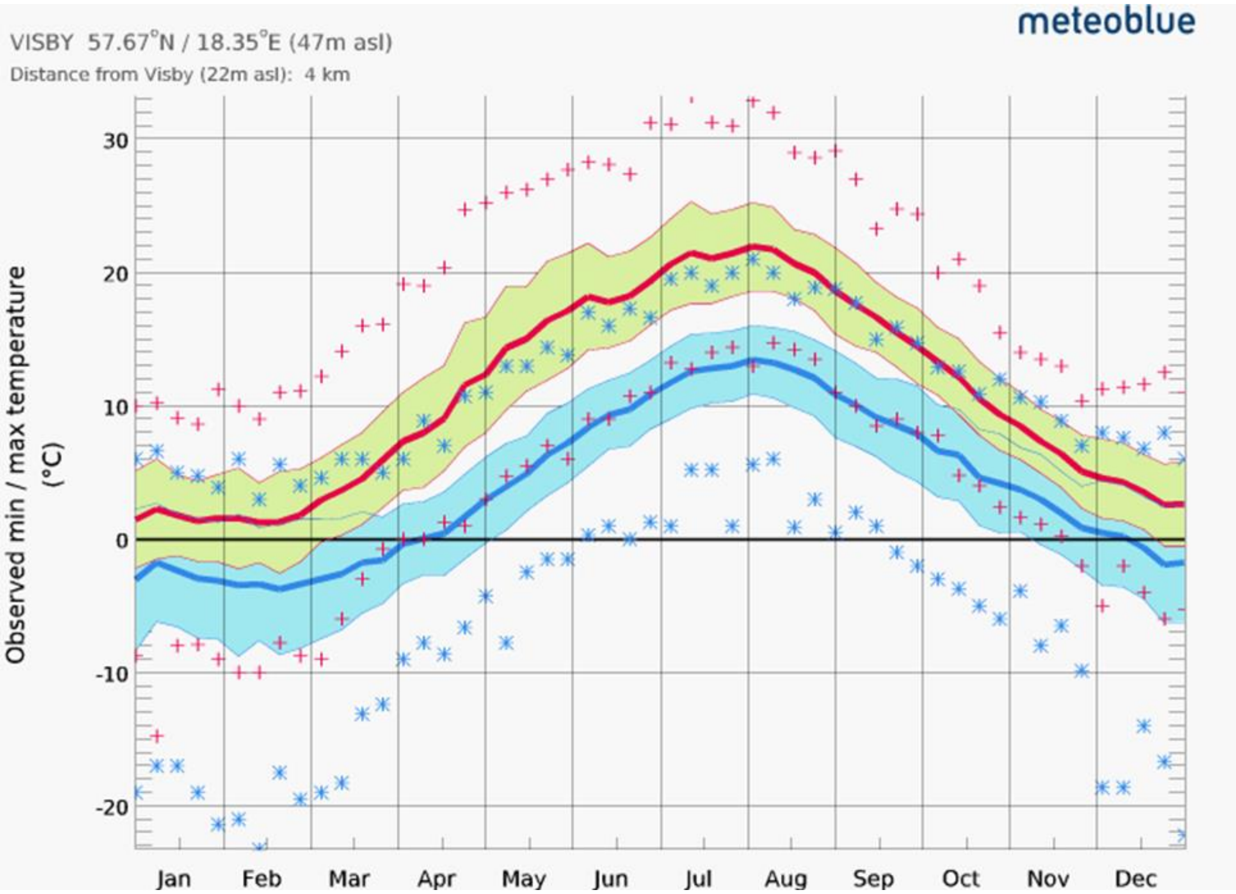


Figure 18 - Climate Data for Visby.

4.2.4 Data quality

The energy data for Gotland is expected to be of high quality and suitable for RESTOR objectives. Since the local TSO (GEAB) operates the island's grid and maintains comprehensive monitoring systems, the datasets available through this source can be regarded as highly reliable from a research point of view. Furthermore, general meteorological data from stations in Visby and Östergarnsholm are accessible through established platforms and meet standard quality requirements. The primary limitation relates to data accessibility rather than data quality. The research team cannot collect granular data directly and must rely on the TSO and open-source platforms. Additionally, high resolution data at micro scale level for individual consumers or distributed assets is not publicly available due to security and privacy considerations.

4.2.4.1 Mitigation measures

Negotiations are underway with GEAB to acquire aggregated macro scale data for the island. Access would be granted under the condition that the data is used exclusively for research purposes and not published, addressing the TSO's security concerns. Region Gotland, as a co owner of GEAB and a RESTOR partner, facilitates these discussions. Once access is secured, the data will support the project's digital twin development and energy storage planning activities.

4.2.5 Insights about energy flexibility

Gotland has an installed wind capacity of about 180 MW and solar capacity of around 38 MW. But due to the intermittency in production and a lack of storage capacity on the island, the renewables production cannot be utilized to its maximum potential. Because of this, about 50% of the electricity on Gotland is imported. This means a high dependence on the mainland and the interconnection cables from it to support the island's electrical demand.

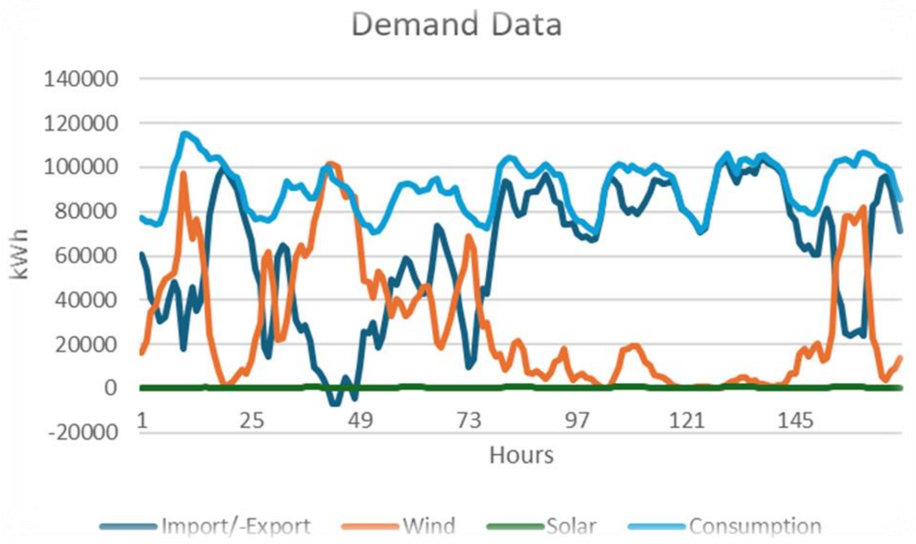


Figure 19 - Demand, Production and Imports for a week.

To address these limitations, long term seasonal storage such as Hydrogen, pumped hydro and Compressed Air Energy Storages could provide the baseload during winters, as these are the times with highest demand and lowest renewable production, especially from solar power. Wind and solar could serve as the main power generation, with mid-term storage such as batteries that could be used in shaving short term peak loads both in the summer and winter times. Flywheel storage could also be considered to act as a frequency regulator for sudden increases and decreases in loads during peak times.

Even though the suggested storage techniques and increase in production capacity would potentially be enough to run the electrical grid year around, the grid can likely never be free from a dependance on the mainland due to a lack of baseload production, at least for the first few years or the lifetime of the installed cable to experiment whether the installed capacity is enough to run the grid year around. Installation of a bidirectional cable to the mainland would allow energy produced by the renewable resources installed on the island to be used to their maximum capacity and possibly supply the local grid all year around without imports from the mainland while also potentially allowing some number of exports.

4.3 La Réunion (France)

4.3.1 Pilot overview

La Réunion Island is a French overseas department located in the Indian Ocean, to the east of Madagascar, its coordinates are 20°18′ S, 55°31′ E and its climate is tropical maritime. According to 2020 census, Reunion is inhabited by 863,000 permanent residents.

This pilot constitutes a non-interconnected island energy system operated by EDF SEI (Systèmes Énergétiques Insulaires), one of the 15 French regions classified as non-interconnected zones. The island's geography includes both large rural and mountainous areas and dense urban centres like Saint-Denis, Saint-André, Saint-Pierre, and Saint-Paul. Its growth plan focusses on sustainability and energy independence.

The island’s energy system combines conventional and renewable sources, with an installed electrical capacity of approximately 984.8 MW as of 2023. Electricity generation relies on a diversified mix that includes hydropower, biomass, solar photovoltaic, wind, and biogas, complemented by limited fossil-fuel backup plants currently being retrofitted to operate on biomass. This balanced approach reflects the island’s ongoing energy transition and supports its goal of achieving 100 % renewable electricity by 2028, as outlined in the *Programmation Pluriannuelle de l’Énergie (PPE)* (Ministère de la Transition Écologique, 2022).

Figure 20 provides an illustrative example of the island renewable infrastructure: the 1 MWp rooftop photovoltaic plant at the E. Leclerc shopping centre in Saint-Leu, on the west coast of the island, which generated about 1.1 GWh in 2021. This type of medium-scale rooftop installation is representative of many systems contributing to La Réunion’s growing solar portfolio.

Figure 20 - Example of rooftop photovoltaic plant in Saint-Leu (1 MWp, Albioma, 2021). Source: Albioma, 2021

4.3.2 Pilot’s energy asset facility summary

La Réunion’s power system is characterised by a diverse and spatially distributed mix of generation assets, reflecting both its insular geography and energy transition strategy. As illustrated in Figure 21, the island’s total installed electrical capacity reached 984.8 MW by the end of 2023 (Observatoire Énergie Réunion, 2024). Generation is concentrated along the coastal areas, where infrastructure accessibility and grid connectivity are optimal.

Local renewable sources account for around 42% of the total mix, led by hydropower (≈132 MW) from major plants such as Rivière de l’Est, Takamaka I & II, Bras de la Plaine, and Langevin, which provide both baseload and peak-shaving capacity. Solar photovoltaic installations contribute roughly 266 MWp, spread across rooftop systems, medium-scale ground plants, and hybrid facilities. The largest single-site PV installation, Sainte-Rose (15 MWp), was commissioned in 2010, complementing a vast network of distributed systems managed by EDF SEI and private operators such as Albioma.

Biomass and bagasse[1]-based thermal plants play a strategic role in ensuring dispatchable renewable generation. The Gol (108 MW) and Bois-Rouge (94 MW) power stations have been fully converted to operate on 100 % biomass fuels, marking a decisive step toward fossil-free baseload generation. Smaller biogas plants (e.g., Grand Prado, Sainte-Suzanne, Pierrefonds) collectively add around 4 MW of capacity, contributing to waste valorisation and decentralised production.

Wind energy remains modest, with about 15 MW of installed capacity, mainly located at Sainte-Suzanne where local topography allows consistent trade winds. The Sainte-Rose wind plant is undergoing a repowering process. Complementing these variable sources, the island has deployed grid-scale energy storage systems, including the 5 MW Li-ion battery in Saint-Leu and Saint-Benoît, designed to provide short-term balancing and frequency regulation services.

Fossil-fuel units—such as those in Port-Est (211 MW) and Bay’s combustion plant (80 MW)— have been converted to renewable fuel (biodiesel) and still provide backup generation. The island’s energy strategy, aligned with the *Programmation Pluriannuelle de l’Énergie* (PPE), aims to phase out fossil generation entirely by 2028–2030, positioning La Réunion among the first French overseas territories to achieve full renewable electricity autonomy.

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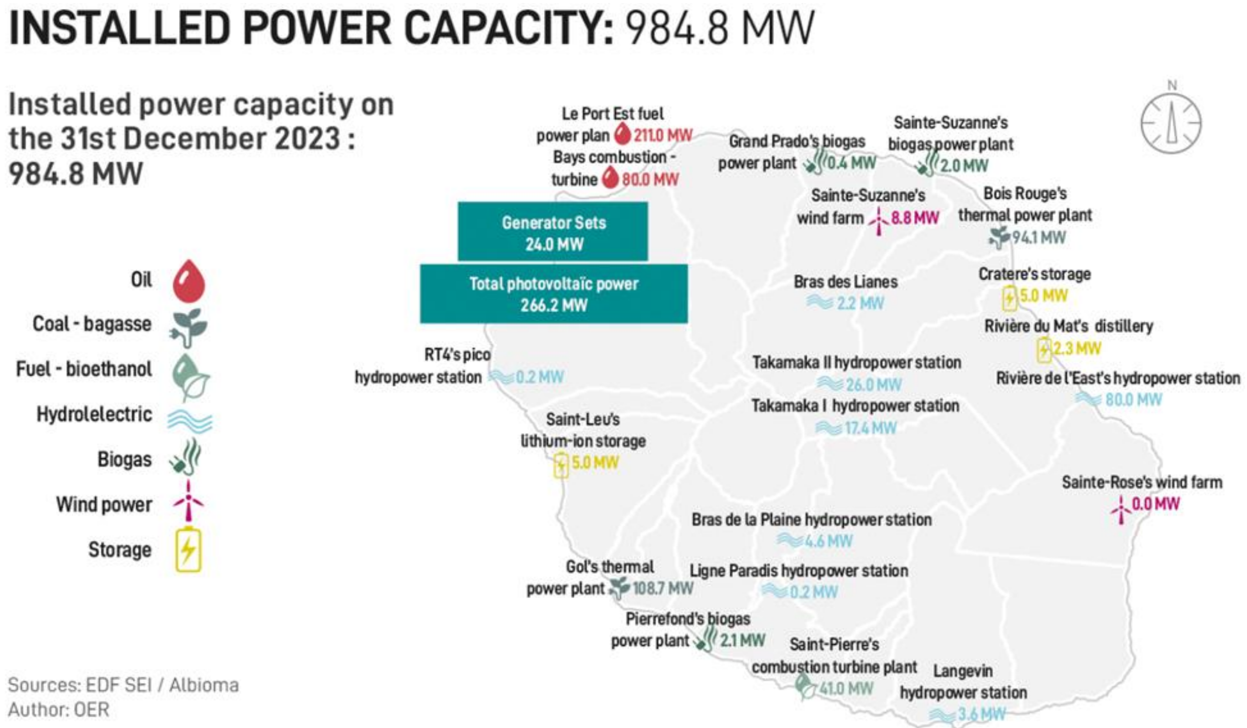
[1] Bagasse: fibrous, pulpy residue left after crushing sugarcane or sorghum stalks to extract their juice.



Sources: EDF SEI / Albioma
Author: OER

Figure 21 - Spatial distribution of installed power capacity on La Réunion (total 984.8 MW, as of December 2023). Source: EDF / Albioma / OER.

4.3.3 Architecture for data collection

The data collection architecture for the La Réunion pilot is based on the island's isolated electricity grid, which is managed by EDF SEI in its capacity as a vertically integrated utility for non-interconnected zones (Notton, et al., 2019). EDF SEI's newly adopted data strategy formalises the use of device and vendor data (solar inverters, battery management systems) and middleware for large PV plants to support advanced analytics and grid stability assessments (Wavestone, 2023). While specific IoT sensor networks (e.g., residential building sensors, EV charging points) have been referenced in research (Vashishth, Chhabra, Khanna, Sharma, & Singh, 2018) (Luo & Nagarajan, 2018), their integration into the main data platform remains under development.

The energy data available for the La Réunion pilot are primarily obtained from EDF's Open Data platform (https://opendata-reunion.edf.fr), which provides official datasets covering the island's electricity generation, demand, renewable integration, and CO_2 emissions. These datasets are sourced directly from EDF SEI's operational monitoring systems for the island's non-interconnected grid (ZNI), ensuring traceability and technical reliability. The Open Data portal includes metadata describing variable definitions, units, and time resolution, typically ranging from 15-minute to hourly intervals, depending on the data type.

In parallel, additional data are available through the PyPSA-Réunion project (https://github.com/Projet-HyLES/pypsa-reunion), which offers simulated and validated datasets for the island's energy system, based on the same official statistics and supplemented by modelled renewable resource and load data. This tool provides a complementary view useful for filling potential temporal or spatial gaps in real-world measurements.

4.3.4 Data quality

EDF’s Open Data portal applies standard internal validation from the utility’s SCADA and energy management systems before publication. Variables are checked for consistency in terms of timestamps, units and physical ranges, while datasets with missing periods are flagged in the metadata. Despite these quality controls, the island's isolated nature and exposure to cyclonic events can cause short interruptions in monitoring or transmission, resulting in occasional data gaps.

The datasets available through both platforms (EDF Open Data and PyPSA-Réunion) therefore provide a robust basis for analytical and simulation tasks within the pilot, combining validated operational records with high-quality modelled data to ensure continuity, cross-validation, and enhanced data integrity for subsequent project analyses.

4.3.4.1 Mitigation measures

No specific mitigation measures are anticipated for the La Réunion pilot. The occasional data gaps resulting from cyclonic events or transmission interruptions are expected to be addressed through the complementary use of the PyPSA Réunion modelled datasets, which can reconstruct missing periods and fill spatial gaps where operational records are incomplete. This approach ensures data continuity without requiring additional interventions.

4.3.5 Insights about energy flexibility

The graph in Figure 22 illustrates La Réunion’s monthly electricity production and maximum power demand for the year 2022. The island’s electricity generation (shown in green bars) remains relatively stable throughout the year, with total production reaching around 2.9 TWh, while demand (yellow line) fluctuates between 430 and 490 MW. The slight decrease in production between April and August reflects seasonal patterns in solar and hydropower generation, coinciding with lower rainfall and reduced solar irradiation during the austral winter.

Despite the overall balance between production and demand, La Réunion’s energy system faces challenges related to temporal mismatches between renewable generation and consumption peaks. Daytime solar generation often exceeds demand, leading to grid feed-in and occasional curtailment, while evening and night consumption relies more heavily on dispatchable sources, mainly thermal backup plants. These patterns underscore the importance of energy storage systems to smooth short-term fluctuations and enhance renewable utilization.

The island currently operates several flexibility assets, including the 5 MW Li-ion batteries systems in Saint-Leu and Saint-Benoît, which provide fast-response balancing and frequency regulation. Simulation data from the PyPSA-Réunion project confirm that expanding battery storage capacity could significantly reduce solar curtailment, improving local self-consumption of renewable energy.

Seasonal dynamics also highlight opportunities for demand-side flexibility, particularly in managing water heating, refrigeration, and air-conditioning loads in public buildings and households. Overall, while La Réunion already demonstrates a robust integration of renewable energy, greater deployment of storage and demand-response strategies remains essential to achieving full decarbonization and self-sufficiency.

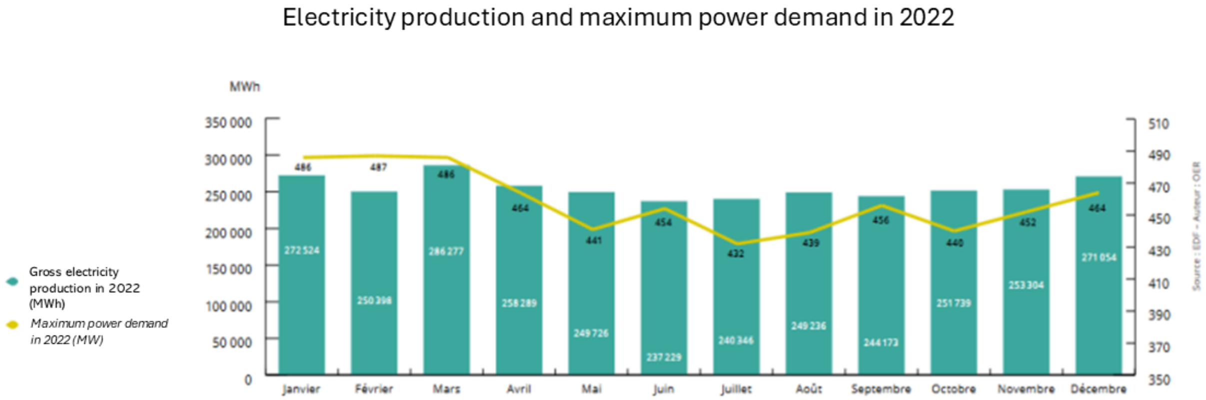


Figure 22 - Monthly electricity production (teal) and maximum demand (yellow) in La Réunion, 2022. Source: OER, 2023.

4.4 Remanso (Brazil)

4.4.1 Pilot overview

This pilot consists in a microgrid project serving the isolated community of Xique-Xique, in the municipality of Remanso, Estate of Bahia (Brazil). Located in the vulnerable Caatinga biome, a semi-arid region characterized by high temperatures and susceptibility to desertification. The community is home to the traditional Fundo e Feixo de Pasto people (Figure 23 and Figure 24). A 2019 baseline assessment of 107 households (264 residents) revealed that 97% were engaged in agrarian activities, with over 60% relying on obsolete, low-power individual photovoltaic (PV) systems (typically 150 W/12V) that failed to meet their basic energy demands. Consequently, the project was strategically launched via national R&D funding, specifically avoiding the conventional grid extension—located less than 20 km away—to mitigate potential environmental and social impacts on the sensitive ecosystem and surrounding ecological reserves. This technical development was continuously coordinated with specialized social and environmental teams, a crucial alignment for the efficient implementation of the project.

The final system, designed to provide 80 kWh per month per unit, serves 113 consumer units, including 110 residences, a school, a community centre, and an artesian well. The core of the microgrid is a PV plant coupled with a Lithium-Ion Battery Energy Storage System (BESS). This BESS integration is the project's primary technological innovation in the national context, designed for grid formation and control while guaranteeing the previously mandated minimum 48-hour autonomy for isolated systems (Figure 25).

Despite facing initial challenges, such as low system loading due to residents' social vulnerability and lack of appliances, monitoring showed a subsequent, gradual shift in user habits and an increase in consumption. Crucially, most consumer loads remain below the projected consumption limit, with only occasional instances where demand has exceeded the original design limits. This performance confirms the system's capacity to handle evolving community energy needs.

Figure 23 - Housing units in Xique-Xique – Remanso (Source: Lactec).

Figure 24 - Views of the Xique-Xique (Remanso) community: Residential areas and rural environment (Source:Lactec).

Figure 25 - Aerial photo of the microgrid pilot plant (Source: Neoenergia Coelba).

4.4.2 Pilot’s energy asset facility summary

The Remanso Microgrid is composed of a comprehensive energy generation and storage facility, including a photovoltaic power plant, a Battery Energy Storage System (BESS), a simplified substation, and a distribution network. The diagram in Figure 26 shows the plant systems.

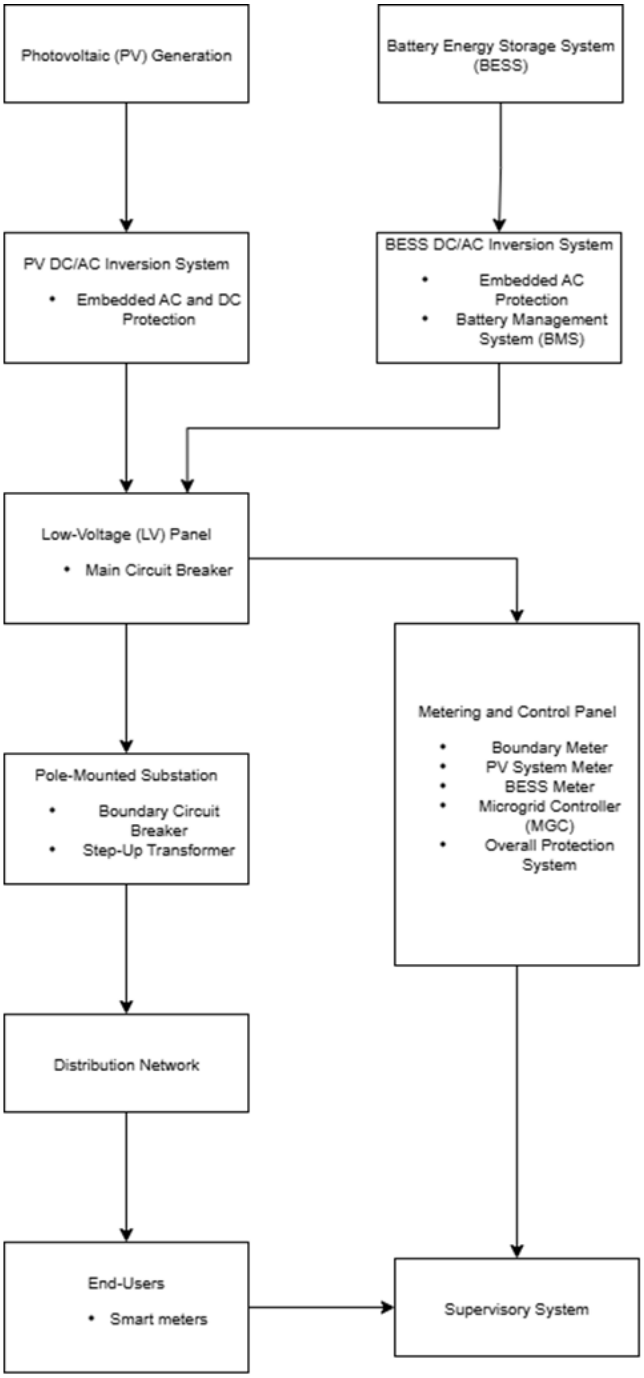


Figure 26 - Diagram of the pilot plant systems (Source: Lactec).

All circuits of the plant are connected to the main busbar, which operates at a nominal three-phase voltage of 480 V. The plant comprises the photovoltaic (PV) generation units, the lithium-ion BESS, control and monitoring panels, and a step-up substation. The PV generation system consists of 616 monocrystalline modules (144 cells, 395 Wp each). The system is arranged into two strings: each string has 11 parallel branches with 28 modules in series, resulting in a power of 121.66 kWp per string and a total installed capacity of 243.32 kWp. Each string is connected to a 111.40 kW inverter with a 480 V nominal AC voltage. Figure 27 shows the photovoltaic modules and inverters of the PV generation system

Figure 27 - Power plant PV system and inverters (Source: Lactec).

The energy storage system is composed of 4 lithium-ion battery modules, each with a capacity of 232 kWh and a charge/discharge power of 58 kW. This totals a capacity of 928 kWh for the entire system. The BESS is connected to the main busbar via four dedicated inverters (one per battery pack), each with a power rating of 70 kW, totaling 280 kW for the entire storage system. The target roundtrip efficiency of the BESS was 89.5%; however, due to the high-temperature climatic conditions of the region, the local operational efficiency is estimated at 84.5%. Integrated with the BESS is the plant control system, which acts as the grid former and is responsible for power flow control and defining the plant’s operational mode. Figure 28 shows the BESS system integrated of the power plant.

Figure 28 - Power plant BESS (Source: Lactec).

The plant includes a Low-Voltage (LV) operation panel equipped with control devices and switchgear for system protection. This panel unifies the terminals of the various systems into the main busbar, which is connected to the substation transformer via a main circuit breaker. Additionally, a dedicated control and monitoring panel houses measuring and protection relays configured with trigger-based protection functions. A supervisory system is linked to these relays, receiving information via a satellite communication system backed by dedicated UPS units to ensure continuous connection with the utility's control center. The distribution network is served by the plant through a 112.5 kVA transformer with a nominal voltage ratio of 480/13.8 kV. The transformer connection is protected by a boundary circuit breaker associated with the utility's official revenue meter.

The distribution network was constructed in full compliance with national standard regulations for rural distribution grids. The system comprises a total of 31.6 km of Medium Voltage (MV) line (operating at 13.8 kV), 33 step-down transformers, and 12.4 km of Low Voltage (LV) line (220V) dedicated to serving the end-users. Figure 29 presents images of the constructed distribution network equipment, and Figure 30 shows the network architecture.

Figure 29 - Distribution network of Xique-Xique (Remanso) (Source: Lactec).

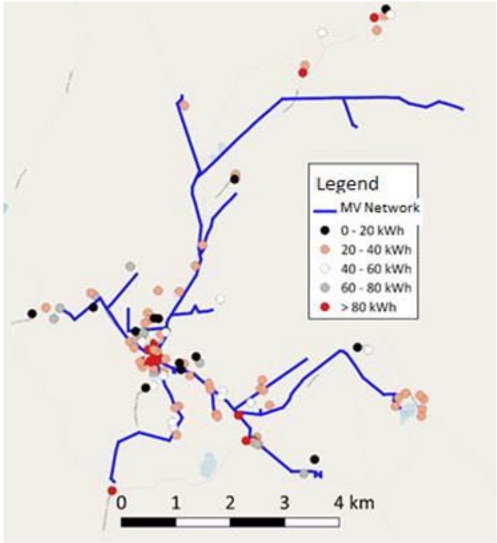


Figure 30 - Network Architecture and Average Monthly Energy Consumption in Xique-Xique (Remanso) (Source: Lactec).

All end-users in the community are equipped with smart meters capable of remote operation. The communication infrastructure leverages a mesh network connecting the smart meters to repeater radios. These radios concentrate the metering data into a central hub at the power plant, which then transmits this information to the Supervisory System (SCADA) for centralized monitoring, data acquisition, and billing.

4.4.3 Architecture for data collection

Figure 31 illustrates the interconnection of the facility's main equipment. At the core of the system is a primary switch, which connects the Siemens SICAM P850 meters for the storage system, photovoltaic system, and feeder head. Additionally, the setup includes a Neoenergia revenue meter housed in the simplified substation panel, a Landis+Gyr data collector that gathers measurement data from customer smart meters for the Command Center, and a computer running the facility's local SCADA system. All devices are connected via Ethernet cables, and the main switch interfaces with Neoenergia's router, which transmits relevant data through Coelba's operational technology (OT) network to the SAGE SCADA platform.

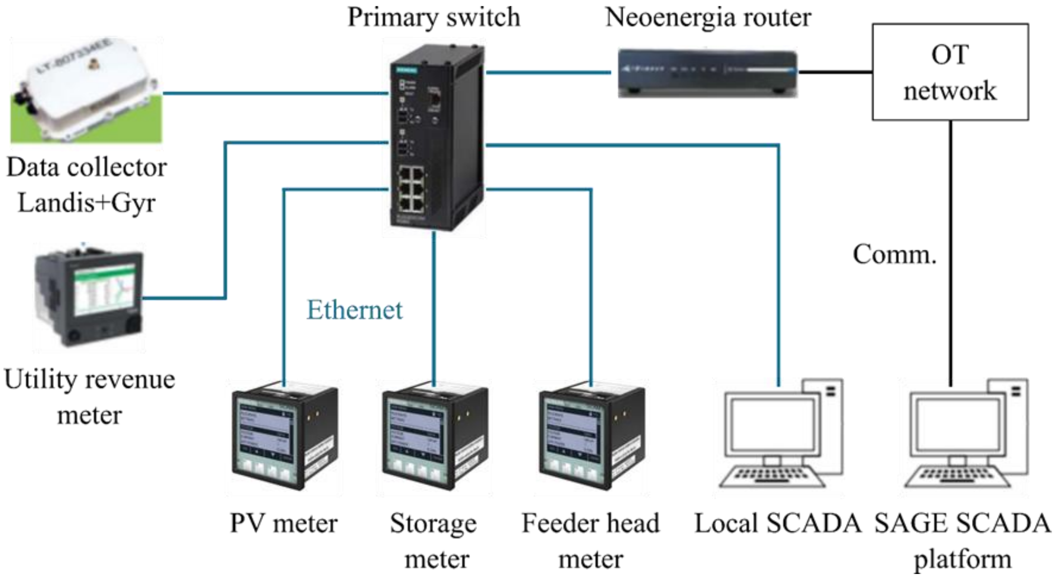


Figure 31 - Overview of the Plant's Communication Architecture and Equipment Interfaces.

Thus, based on this architecture, three types of data are available:

- **SAGE SCADA data:** recorded at five-minute intervals, including measurements from the two photovoltaic system inverters, the storage system, and the feeder head. These data are provided in CSV format.
- **Utility Revenue meter data:** also recorded at five-minute intervals, containing phase-by-phase current and voltage readings, as well as active and reactive energy measurements from the feeder head. These data are available in CSV format.
- **Customer smart meter data:** recorded at 24-hours intervals, with measurements from Landis+Gyr E430 meters for single-phase customers and E450 meters for three-phase customers. These meters and their data are managed by the Command Center application developed by Landis+Gyr (https://www.landisgyr.com.br/product/command-center/). The data are also provided in CSV format.

All data described are proprietary and managed by Neoenergia Coelba. Lactec has access to a subset of this data, including:

- SAGE SCADA records from May 1, 2022, to July 31, 2023.
- Utility revenue meter data from June 1, 2022, to October 3, 2023.
- Sample customer smart meter data from June 23, 2022, to September 26, 2022.

Regarding data updates, although formal requests can be submitted to Neoenergia Coelba, further data sharing is expected to be limited due to the current availability of the utility's technical staff for this project

4.4.4 Data quality

In this section we describe the taks performed to check, purge & transform and ensure data quality of the Remanso pilot meets RESTOR project requirements.

In the Remanso site, the facility data is gathered and transmitted to the SAGE SCADA system of utility's Integrated Operations Centre (IOC). An analysis was performed on the SAGE SCADA data provided by Neoenergia Coelba recorded from May the 1st of 2022 to July the 31st of 2023, aggregated at five-minute intervals. Figure 32 illustrates a sample of the received raw data and the stored variables. Each measurement point includes minimum, average, and maximum values, but only the average was used for standardized analysis.

A Matlab algorithm was developed to process the received file and organize the data depicted on the summarized flowchart of Figure 33 with the main data processing steps. The initial step involved identifying measurement centres using the variable "DS_CENTRO," which revealed three registered centres: "COD_FSA," "COS_SSA," and "COFSSA." These centres often record identical measurements at the same timestamp. Therefore, the filtering routine merges the data from these three centres into a unified dataset. The second filtering step was based on the operation code, identifying four entries: "XQX_10X1," representing the measurements at feeder head; "XQX_BAT," corresponding to the energy storage system; and "XQX_FTV01" and "XQX_FTV02," which refer to measurements from each photovoltaic inverter. For each operation code, a dedicated table was created to consolidate the respective measured data.

```
DTHR_COLETA,DS_CENTRO,ID_EQUIPAMENTO,COD_ID_OPERACAO,DS_DETALHE,SG_ELEMENTO,DS_ELEMENTO,VL_MEDIDO_MIN,VL_MEDIDO_MED,VL_MEDIDO_MAX
01/05/2022 00:50:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,88,93,88,93,88
01/05/2022 00:30:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,94,93,94,93,94
01/05/2022 00:15:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,98,93,98,93,98
01/05/2022 00:10:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,99,93,99,93,99
01/05/2022 00:35:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,92,93,92,93,92
01/05/2022 00:20:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,96,93,96,93,96
01/05/2022 00:05:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,94,94,94
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01/05/2022 00:45:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,9,93,9,93,9
01/05/2022 00:25:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,95,93,95,93,95
01/05/2022 01:00:00,COD_FSA,XQX_480AL_______1_FP___E,XQX_10X1,Fator de Potencia                XQX_10X1,FP,Fator de Potencia                ,0,0,0
01/05/2022 01:00:00,COD_FSA,XQX_480AL_______1_Vbc__E,XQX_10X1,Tensao Composta Fases B e C      XQX_10X1,VBC,Tensao Composta Fases B e C      ,0,0,0
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______1_FP___E,XQX_FTV01,Fator de Potencia                 XQX_FTV01,FP,Fator de Potencia                 ,-0,28,-0,28,-0,28
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______1_IT___E,XQX_FTV01,Corrente Total                    XQX_FTV01,IT,Corrente Total                    ,6,3,6,3,6,3
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______1_P____E,XQX_FTV01,Potencia Ativa                    XQX_FTV01,P,Potencia Ativa                    ,0,01,0,01,0,01
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______1_Q____E,XQX_FTV01,Potencia Reativa                  XQX_FTV01,Q,Potencia Reativa                  ,12,12,12
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______1_S____E,XQX_FTV01,Potencia Aparente                 XQX_FTV01,S,Potencia Aparente                 ,12,12,12
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______2_FP___E,XQX_FTV02,Fator de Potencia                 XQX_FTV02,FP,Fator de Potencia                 ,0,0,0
01/05/2022 01:00:00,COD_FSA,XQX_480GF_______2_S____E,XQX_FTV02,Potencia Aparente                 XQX_FTV02,S,Potencia Aparente                 ,0,0,0
01/05/2022 01:00:00,COD_FSA,XQX_480SA_______0_FREQ_E,XQX_BAT,Frequencia                      XQX_BAT,FREQ,Frequencia                      ,59,99,59,99,59,99
01/05/2022 01:00:00,COD_FSA,XQX_480SA_______0_IT___E,XQX_BAT,Corrente Total                  XQX_BAT,IT,Corrente Total                  ,0,0,0
01/05/2022 01:00:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,84,93,85,93,86
01/05/2022 01:00:00,COD_FSA,XQX_480SA_______0_S____E,XQX_BAT,Potencia Aparente               XQX_BAT,S,Potencia Aparente               ,0,0,0
01/05/2022 00:55:00,COD_FSA,XQX_480SA_______0_PCBa_E,XQX_BAT,Percentual Cap Bateria          XQX_BAT,PCBA,Percentual Cap Bateria          ,93,87,93,87,93,87
```

Figure 32 - Sample of the raw data available.

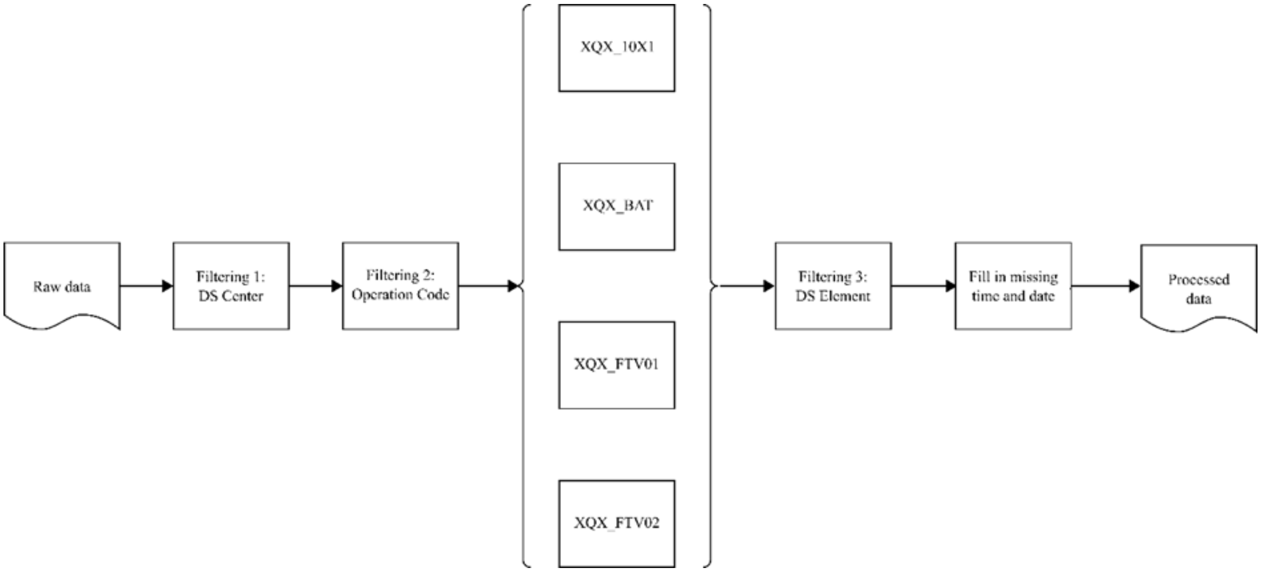


Figure 33 - Summarised flowchart of raw data processing steps.

The third filtering step aimed to identify the available measurement variables for each operation code, using the column "DS_Elemento." The following variables were identified:

- **XQX_10X1:** Phase A Current (A), Phase B Current (A), Phase C Current (A), Power Factor, Apparent Power (kVA), Active Power (kW), Reactive Power (kVAr), Line Voltage VBC (V).
- **XQX_BAT:** Total Current (A), Power Factor, Frequency (Hz), State of Charge (%), Apparent Power (kVA), Active Power (kW), Reactive Power (kVAr), Line Voltage VBC (V).
- **XQX_FTV01 and XQX_FTV02:** Total Current (A), Power Factor, Apparent Power (kVA), Active Power (kW), Reactive Power (kVAr).

Finally, the last step in data processing involved filling in timestamps with missing measurements. Although the data is aggregated at five-minute intervals, several timestamps lack records for the identified variables. This step was essential for enabling graphical visualization of discontinuities caused by missing data.

Table 1 shows the percentage of valid measurements for each variable available in the assets. In general, most variables have more than 85% valid measurements throughout the period. These include current, active power, reactive power, and apparent power at the boundary and in the storage system, as well as the state of charge of the storage system. Valid measurements from the photovoltaic system are 40% approximately. The large occurrence of non-valid measurements during nighttime is an obvious result of photovoltaic system not generating active power in the absence of solar radiation. On the other hand, some variables show a very low number of valid measurements. These include power factor and voltage measurements at the boundary and in the storage system, frequency measurements in the storage system, and reactive power measurements in the photovoltaic system. In general, the percentage of valid measurements for these variables is below 15%.

Table 1 - Percentage of valid data during the period.

Asset	Variable							
Feeder head	Current A	Current B	Current C	Power factor	Apparent power	Active power	Reactive power	Line voltage
	88.20	86.83	88.72	9.97	89.04	89.27	89.48	4.59
Storage	Total current	Power factor	Frequency	State of charge	Apparent power	Active power	Reactive power	Line voltage
	86.09	13.04	10.04	89.10	89.88	89.52	91.31	4.54
PV-1	Total current	Power factor	Apparent power	Active power	Reactive power			
	38.29	50.12	40.43	39.74	10.97			
PV-2	Total current	Power factor	Apparent power	Active power	Reactive power			
	20.19	30.07	22.62	22.55	6.71			

Figure 34 illustrates a weekly dataset from September 15 to 21, 2022, including storage active power, state of charge, and the active power of each photovoltaic inverter. Notably, the data contains non-concurrent gaps. While gaps in the state of charge typically occur around midnight, those in storage active power appear at varying times. Gaps in photovoltaic active power are mostly observed during nighttime hours, although some also occur during the day.

In addition to the SAGE SCADA data from the Remanso facility, there are smart meter readings available for each microgrid customer, as well as data from a utility revenue meter installed at the feeder head. This utility revenue meter records phase voltage and current, along with total active and reactive energy, at five-minute intervals from June 1, 2022, to October 3, 2023. Figure 35 shows the phase currents recorded during this period. It is important to note that zero values indicate gaps in the metering data. Customer smart meter data is managed by the Command Center system developed by Landis+Gyr. The data is recorded at 24-hours intervals from June 23, 2022, to September 26, 2022, and includes received and delivered active energy, four-quadrant reactive energy, RMS voltage of phase A (mean, maximum, and minimum), RMS current of phase A, and power factor. Lactec did not process this dataset, and no information is available regarding its quality. Figure 36 presents a sample of this data.

4.4.4.1 Mitigation measures

Regarding data availability, no additional mitigation measures involving the acquisition of new datasets are envisioned, as further data sharing from Neoenergia Coelba (DSO) is expected to be limited due to the utility's technical constraints. Consequently, the project will rely on the currently available legacy data, for which the following mitigation strategy has been established:

- Data Cleaning and Validation: Standard preprocessing is already embedded in the energy meters, which includes backup memory features to prevent data loss during major disruptions.
- Extrapolation Criteria: For assets presenting missing data, a threshold of 50% availability has been defined.
  - >= 50%: Datasets with 50% or more of the expected records will undergo reconstruction through extrapolation techniques.
  - < 50%: Datasets falling below this threshold will be considered insufficient for reliable reconstruction and will not be extrapolated.

As shown in the Table 1, the current data quality varies across assets, with Feeder Head and Storage showing the highest availability (approximately 88-91%), while PV-2 presents a more critical scenario for some variables (e.g., Reactive Power at 6.71%), which may limit the analysis for those specific parameters.

For datasets where availability is below the 50% threshold and direct extrapolation is not feasible, one potential approach would be to incorporate representative curves from the literature. These theoretical profiles could then be normalized using the existing real-world data points to better reflect the local context. This strategy remains under evaluation as a means to maintain scientific consistency for assets with limited data, such as PV-2, ensuring that the project's modeling objectives are still achievable.

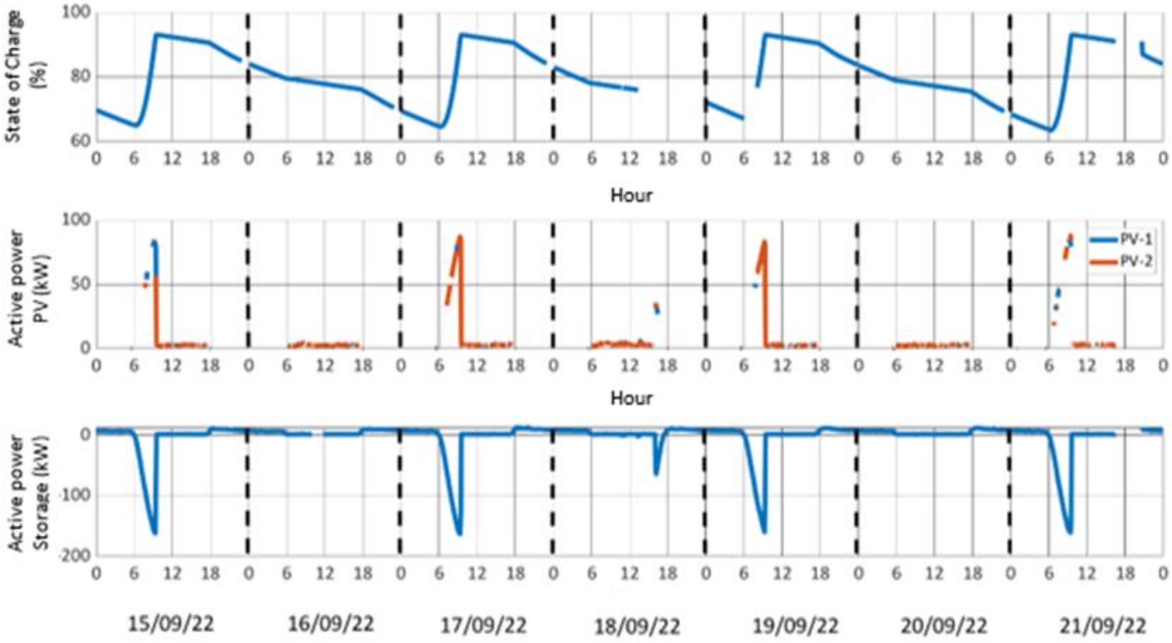


Figure 34 - Sample of processed data between September 15 to 21, 2022.

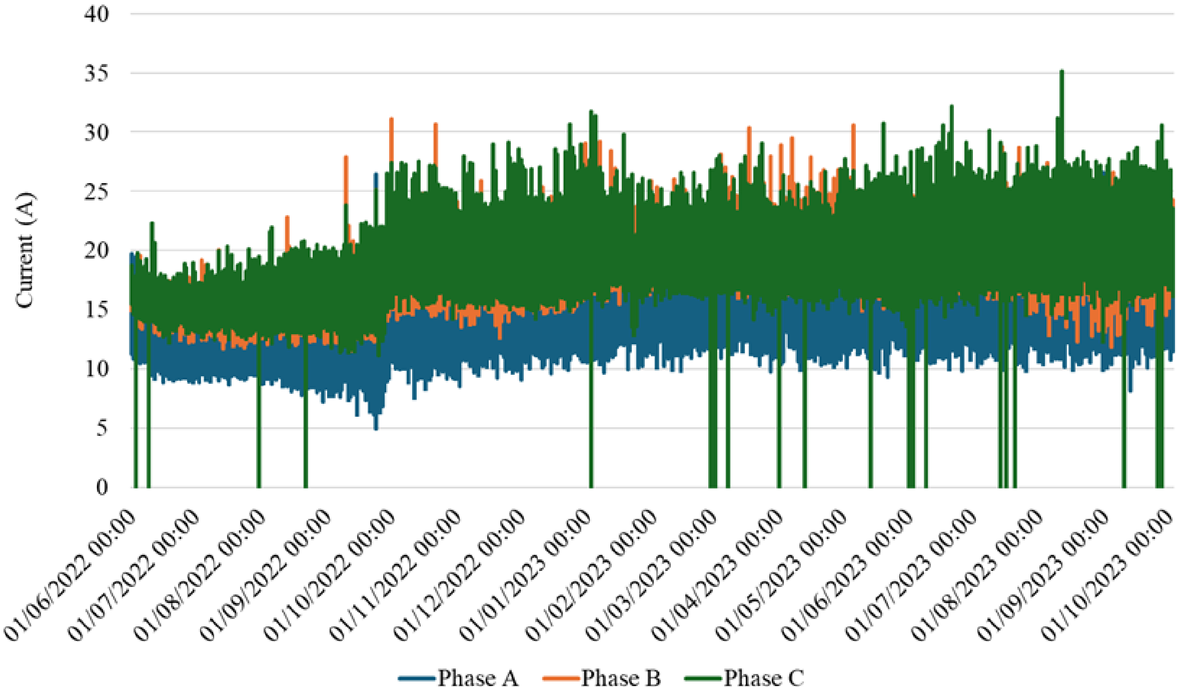
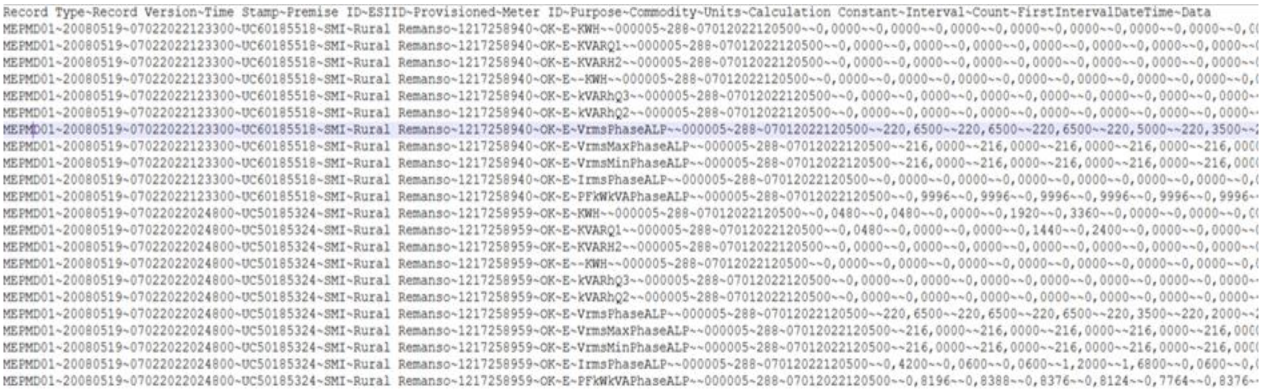


Figure 35 - Current data per phase recorded at the utility revenue meter.



```
Record Type~Record Version~Time Stamp~Premise ID~ESIID~Provisioned~Meter ID~Purpose~Commodity~Units~Calculation Constant~Interval~Count~FirstIntervalDateTime~Data
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~KWH~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~KVARQ1~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~KVARH2~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~-KWH~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~kVARhQ3~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~kVARhQ2~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~VrmsPhaseALP~~000005~288~07012022120500~~220,6500~~220,6500~~220,6500~~220,5000~~220,3500~~
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~VrmsMaxPhaseALP~~000005~288~07012022120500~~216,0000~~216,0000~~216,0000~~216,0000~~216,000
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~VrmsMinPhaseALP~~000005~288~07012022120500~~216,0000~~216,0000~~216,0000~~216,0000~~216,000
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~IrmsPhaseALP~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,
MEPMD01~20080519~07022022123300~UC60185518~SMI~Rural Remanso~1217258940~OK~E~PFkWkVAPhaseALP~~000005~288~07012022120500~~0,9996~~0,9996~~0,9996~~0,9996~~0,9996~~0,9996~
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~KWH~~000005~288~07012022120500~~0,0480~~0,0480~~0,0000~~0,1920~~0,3360~~0,0000~~0,0000~~0,
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~KVARQ1~~000005~288~07012022120500~~0,0480~~0,0000~~0,0000~~0,1440~~0,2400~~0,0000~~0,0000~~
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~KVARH2~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~-KWH~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,
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MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~kVARhQ2~~000005~288~07012022120500~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~~0,0000~
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~VrmsPhaseALP~~000005~288~07012022120500~~220,6500~~220,6500~~220,6500~~220,3500~~220,2000~~
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~VrmsMaxPhaseALP~~000005~288~07012022120500~~216,0000~~216,0000~~216,0000~~216,0000~~216,000
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~VrmsMinPhaseALP~~000005~288~07012022120500~~216,0000~~216,0000~~216,0000~~216,0000~~216,000
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~IrmsPhaseALP~~000005~288~07012022120500~~0,4200~~0,0600~~0,0600~~1,2000~~1,6800~~0,0600~~0,
MEPMD01~20080519~07022022024800~UC50185324~SMI~Rural Remanso~1217258959~OK~E~PFkWkVAPhaseALP~~000005~288~07012022120500~~0,8196~~0,8388~~0,8376~~0,8124~~0,7764~~0,8376~
```

Figure 36 - Customers' smart meter sample data.

4.4.5 Insights about energy flexibility

The system was designed to provide a maximum of 80 kWh of energy per month for each household, ensuring the required minimum 48-hour autonomy without the photovoltaic generation. However, of the 332.8 kWh/day projected for the microgrid, the initial daily consumption in June 2022 was approximately 100 kWh/day, representing about 30.05% of the design value. A consumption increase of around 20 kWh/day was observed between July and August 2022, with some peaks reaching 150 kWh/day during that period.

In September 2022, two key events occurred in the microgrid that slightly altered the equivalent load. The first was the installation of public lighting during the first half of September, which led to an average increase of 25 kWh/day in the microgrid. The second event, at the end of

September 2022, was the result of a refrigerator donation campaign carried out by Neoenergia Coelba. This led to an average daily consumption of approximately 200 kWh/day in October 2022, equivalent to about 60.10% of the projected value.

Figure 37 graphically presents the recorded variations in daily energy consumption. Overall, there is a stable trend in the community's consumption pattern, at least during the first half of 2023. The red line represents the projected energy value defined in the executive design, which is 332.8 kWh/day. The consumption occurrences below 50 kWh/day indicate outages in the microgrid.

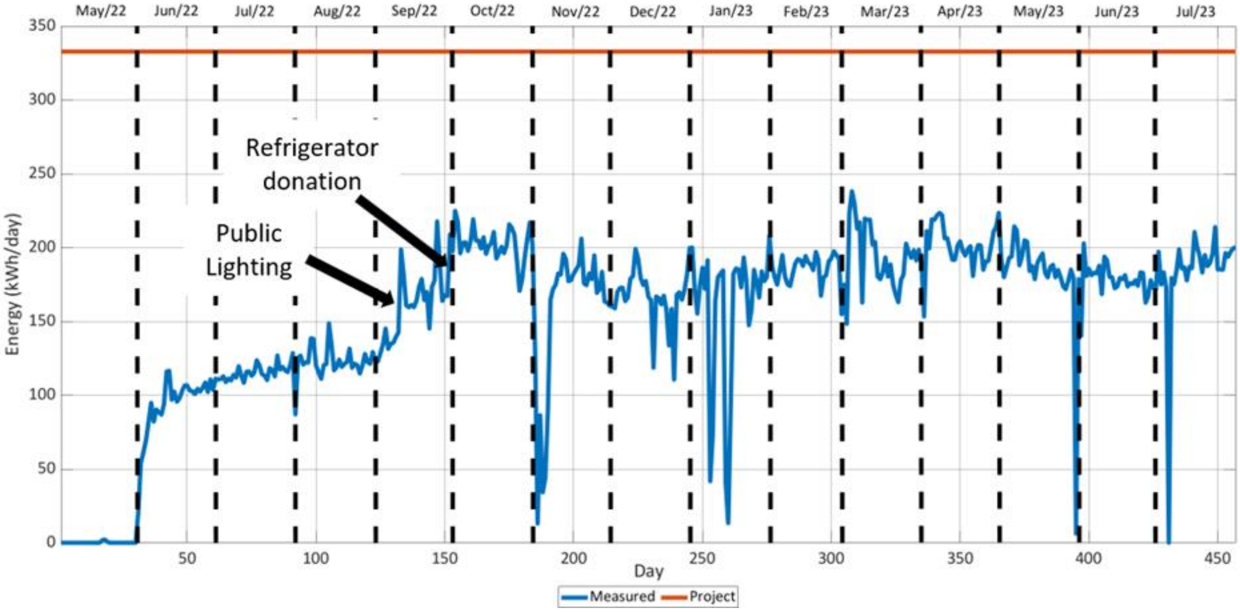

Figure 37 - Comparison between daily microgrid consumption and design consumption profile.

Considering the projected daily energy consumption for the microgrid and the 48-hour autonomy requirement, it was expected that the photovoltaic system would generate approximately 33 percent of its nominal capacity each operational month to ensure a minimally acceptable utilization of the resource. However, monthly production did not exceed 20 percent, as the microgrid load remained below the levels anticipated in the design.

Figure 38 presents a comparison of energy production. The blue bar represents the nominal monthly energy that the photovoltaic system can deliver to the grid. The grey bar indicates the expected generation, excluding the surplus required to meet the microgrid's nominal load. Finally, the orange bar shows the actual monthly energy generated during the analyzed period.

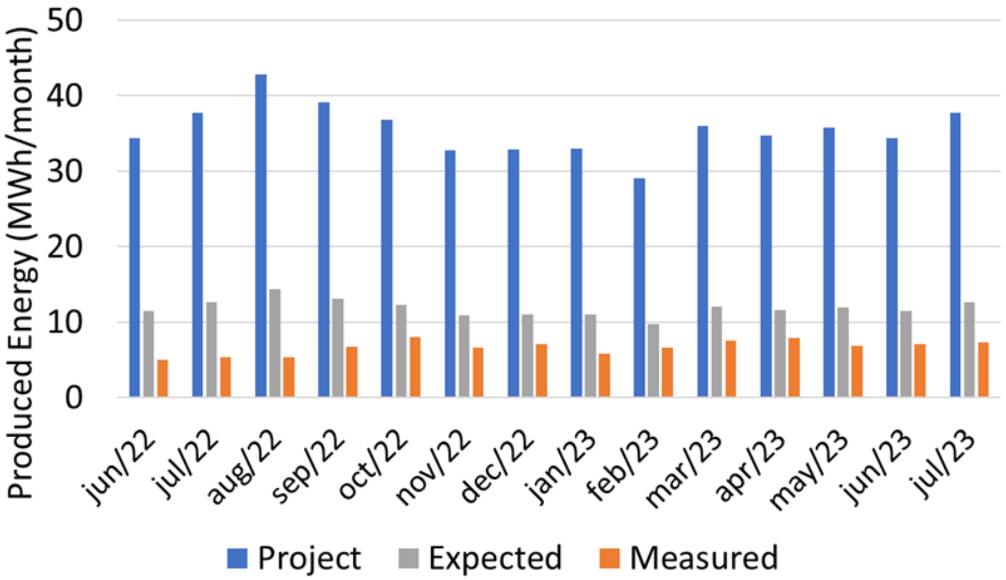

Figure 38 - Comparison of Photovoltaic Generation Performance Between Projected and Measured Values.

As a result, the storage system undergoes charging every two days to increase operational cycling. The operational state-of-charge range between 60% and 75% typically occurs during the second night following the previous charge. Generally, the storage system begins the second operational night with a state of charge around 75% and starts the following day with values between 60% and 65%, depending on the nighttime load. However, it was expected that this operational cycling would take place daily, rather than every two days as observed over the 15-month analysis period. This indicates an oversizing of the resource, given that the expected load in the microgrid has not yet been reached.

The required system autonomy directly impacts the overall cost of the plant. Following project execution, new legislation was introduced that reduced the minimum required autonomy to 36 hours (down from 48 hours). The flexibilization of these operational limits is crucial, as it can significantly reduce construction costs and thereby improve the economic viability of future similar projects.

Therefore, regulatory discussions are warranted to ensure that operational parameters are streamlined, allowing this type of sustainable electrification solution to become financially scalable. There are opportunities to enhance the utilization of the Remanso microgrid assets, such as integrating additional community loads or establishing a connection with the utility distribution grid.

5 Data usability

This section explores how the collected data will be used to support the technical development and implementation of the RESTOR project. Beyond gathering data, ensuring its usability is key to enabling accurate modelling, forecasting, simulation, and validation across pilot sites. The content below highlights how the structured datasets contribute to other work packages, particularly in the creation of digital twins, the training of forecasting models, and the development of the MCDA.

5.1 Developing digital twins of the pilot sites

AIT will develop **DIgSILENT** PowerFactory–based distribution-grid digital twins for the Aran Islands (Inis Mór) and Gotland pilots, parameterised from the structured WP3 dataset (Sections 3–4) and federated with available telemetry (InfluxDB streams, SMA Sunny Portal, Victron portals), weather (IRUSE/UG station proxies for Aran; Visby/Östergarnsholm for Gotland). The Digital Twin (DT) will represent MV/LV topology, transformers, cable impedances, protection settings, and controllable DER portfolios (PV, BESS, heat pumps, EV/V2G), with demand synthesized from facility-level profiles and tariff regimes where metering granularity is constrained. After topology and load-model calibration (time-series power flow against measured feeder import/export) and basic validation, the models will support grid-centric storage sizing and siting: determining optimal BESS power/energy, C-rates, placement (feeder head vs. downstream nodes), and control modes (Volt/VAR, droop, peak-shaving, curtailment relief) to mitigate thermal and voltage violations, reduce RES curtailment, defer reinforcement, and increase self-sufficiency across seasonal scenarios (winter peaks, summer tourism) and contingencies (N-1 cable/transformer outages). Model governance (versioning, scenario catalogs, FAIR-aligned metadata) ensures reproducibility and iterative refinement as additional measurements are ingested.

In cases where detailed distribution grid data or network schematics are unavailable, AIT will employ the **NetGen** tool to generate synthetic but realistic electrical networks for the Aran Islands and Gotland pilots. NetGen, developed in previous European projects, synthesizes plausible low and medium voltage grid topologies using publicly available open data sources such as OpenStreetMap (OSM), demographic datasets, and regional infrastructure information. By applying bio-inspired heuristic algorithms, including the Louvain partitioning and community expansion methods, NetGen reconstructs spatially and electrically feasible networks that capture realistic load distributions, transformer siting, and line connectivity. It further integrates building-level demand profiles coupled with PV, EV, and heat pump data, enabling high-resolution simulation of distributed energy resource (DER) behaviour. The synthetic networks generated by NetGen will be validated and adapted within DIgSILENT PowerFactory, forming the basis for storage sizing and grid flexibility analyses. This approach ensures continuity of digital twin development even in data-sparse contexts, providing robust, traceable, and reproducible grid representations aligned with the overall RESTOR methodology for model-based energy system planning.

With regards to the control of storage systems, a reinforcement learning based approach is developed in the RESTOR project. This approach focuses on providing close to optimal control in real-time, without the need of extensive forecasts. To train the algorithm, the approach requires large amounts of historical data on consumption and generation at the site of installed storage systems. The time resolution of the historical data directly influences the time resolution of the control output. However, the algorithm also allows for increasing the frequency in control output in deployment. The historical data needs to include all relevant seasons and time features for the respective site.

Additionally, historical data on electric energy prices is used. Historical data from the European wholesale energy market have been used for the development of the methodology and this data can be used for the training of site-specific algorithms and their deployment, if there is no detailed data available from the sites.

5.2 Data requirements for forecasting model training

As part of the initial analysis to inform the development of forecasting models, AIT carried out a preliminary assessment to identify the main variables needed for their models. This assessment aimed to identify the key parameters, data sources, and temporal resolutions necessary to support the implementation PV forecasting algorithms. For the initial development of training models for the pilot sites, static historical data is sufficient. AIT outlined a set of initial requirements that address critical inputs such as local weather conditions, historical weather forecasts and energy generation patterns. These requirements are essential to ensure that the forecasting models can be effectively trained and validated for each specific context.

Depending on the data availability of the island region, the PV forecast will be based on meteorological data mainly in case only cumulative generation values are available (Gotland) or if individual generation at dispersed sites is accessible in close to real-time (Aran Islands) then a distributed forecasting algorithm may be employed that features increased forecasting accuracy. This algorithm uses information from neighbouring sites to update the forecast for a close-by located target site. The performance of this neighbour-approach in an island setting will be investigated. Furthermore, if detailed weather forecasts are available a set or ensemble of situation-specific forecasting algorithms will be employed to further improve the forecast performance.

5.3 Multi Criteria Decision Analysis (MCDA) inputs

While portions of the data gathered in this deliverable can potentially be used directly in the project's MCDA assements, such as existing storage technologies, most of the information in the datasets will be used for other key inputs in the MCDA, modelling and the generation of relevant use cases for the islands. The results from this modelling and the use cases for each pilot will then be assessed on the necessary and yet to be finalized criteria relevant to the pilot's interests. The performance scores of these criteria will then be used to evaluate each use case for every island against each other. The final overall performance of each use case will be determined using the stakeholders' preferences for each criterion for island and obtained through focus groups and workshops. These initial data gathering steps are also useful in identifying some of the potential stakeholders to be included in later steps of the MCDA model implementation as well as for inclusion in workshops, focus groups and on the islands' advisory boards.

6 Conclusion

This deliverable has established a consistent and robust data foundation for the RESTOR project by systematically collecting, structuring, and assessing end-user energy data across all pilot sites. The assessment of ICT architectures, data quality, and usability provides transparency on current limitations and defined mitigation strategies, thereby reducing technical risk in subsequent project phases.

The outcomes of this work directly support WP4 (Case Studies) by enabling the creation of realistic and data-driven energy storage scenarios for each pilot, along with T3.1. Furthermore, D3.2 provides essential inputs to WP5 (RESTOR Model Integration). The collected and datasets form the backbone for the MCDA analyses, sensitivity assessments, and cross-pilot comparisons. By documenting data gaps, assumptions, and preprocessing steps, this deliverable enhances the robustness, transparency, and reproducibility of the RESTOR model results, supporting the synthesis of lessons learned and policy-relevant recommendations in later stages.

Finally, the work presented in this deliverable is fundamental to WP6 (Validation, Scalability, and Replication). The structured approach to data collection and pilot characterisation enables the application of the RESTOR model to new validation cases, such as Lesvos, Fiji, and Fernando de Noronha, even in data-sparse contexts. By identifying technical, organisational, and data-related constraints early, D3.2 contributes directly to the assessment of scalability and replicability of the RESTOR framework across different island typologies and geographic regions.

In summary, Deliverable D3.2 acts as a foundation the RESTOR project activities, ensuring coherence between work packages and providing the necessary data for scenario development, model integration, validation, and long-term impact through replication beyond the original pilot sites.

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