D6.1 Initial TRL assessment and development of Terceira technologies roadmaps

Authors: Eduardo Rodrigues (EDP)

H2020-LC-SC3-2018-2019-2020 / H2020-LC-SC3-2020-EC-ES-SCC
EUROPEAN COMMISSION
Innovation and Networks Executive Agency
Grant agreement no. 957810

PROJECT CONTRACTUAL DETAILS

Project title	IntegrAted SolutioNs for the DecarbOnization and Smartification of Islands
Project acronym	IANOS
Grant agreement no.	957810
Project start date	01-10-2020
Project end date	30-09-2024
Duration	48 months
Project Coordinator	João Gonçalo Maciel (EDP) - JoaoGoncalo.Maciel@edp.com

DOCUMENT DETAILS

Deliverable No	D6.1
Dissemination level	Public
Work Package	WP6 – Deployment, Use Cases Realization and Monitoring at LH#2 (Terceira)
Task	T6.1 – Technologies Engineering and System Dimensioning (advancement of TRLs)
Due date	30/06/2021
Actual submission date	30/06/2021
Lead beneficiary	EDP

Version	**Date**	**Beneficiary**	**Changes**
0.1	30/04/2021	EDP	First draft
0.2	09/06/2021	CERTH	Official Review
0.3	30/06/2021	EDP	Final version

Executive Summary

The deliverable D6.1 – Initial TRL assessment and development of Terceira technologies roadmaps – details a first Technology Readiness Level (TRL) assessment of the solutions that will be installed at the Terceira Lighthouse Island (LHI) demonstrator and defines a roadmap for each technology to reach the desired TRL needed for the Terceira demonstrator. The list of technologies includes:

- the PV panels and microinverter by BEON;
- the Heat Battery by Sunamp;
- the electric water heaters by Uninova;
- the HEMS by VPS;
- the Smart Energy Router by Uninova;
- the Flywheel by Teraloop;
- the V2G EV charger by EFAEM;
- the Hybrid Transformer by EFACEC;
- the Fog Enabled Intelligent Devices – FEID-Plus by CERTH;
- and the intelligent Virtual Power Plant (iVPP) also by CERTH.

An overview of the different technologies is given where its main features are detailed, with a focus on its innovative characteristics. For each technology, the proposed roadmap highlights the necessary development and testing plans to increase the TRL of all the individual components integrating the overall system to be installed and commissioned in the pilot. Moreover, a first analysis of the dimensioning and specifications of each technology is provided as well as its testing and installation requirements.

This work will allow the close follow-up of the development of these different technologies and identify any possible deviations with the timeline in timely manner so that any necessary mitigations measures are taken.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

Table of Contents

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

List of Tables

Abbreviations and acronyms

ANN	Artificial Neural Networks
CD	Centralised Dispatcher
CFRP	Carbon Fibre Reinforced Polymer
CHP	Combined Heat and Power
DER	Distributed Energy Resources
DLT	Distributed-Ledger based energy Transactions
ESS	Energy Storage Systems
EV	Electric Vehicle
FEID-Plus	Fog-Enabled Intelligent Devices
UC	Use Cases
HEMS	Home Energy Management System
iVPP	Intelligent Virtual Power Plant
LHI	Lighthouse Island
NWP	Numerical Weather Prediction
PCM	Phase Change Material
PEBB	Power Electronics Building Blocks
RES	Renewable Energy Sources
TRL	Technology Readiness Level
V2G	Vehicle-to-Grid

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

1 Introduction

1.1 Objectives and Scope

Within the scope of Task 6.1(T6.1) of Work Package 6 (WP6) the Deliverable 6.1 (D6.1) intends to provide an overview of all the technologies that are going to be installed in the Terceira LHI demonstrator, specifying their mains characteristics and current TRL as well as the development and testing processes required to increase the individual components' TRLs, rendering them suitable for a successful pilot integration and reach the targeted TRL specified in the IANOS project. Throughout this deliverable where a topic description refers to a TRL, the following definitions apply, unless otherwise specified:

- TRL 1 – basic principles observed.
- TRL 2 – technology concept formulated.
- TRL 3 – experimental proof of concept.
- TRL 4 – technology validated in lab.
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- TRL 7 – system prototype demonstration in operational environment.
- TRL 8 – system complete and qualified.
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space).

The overall goal is to: i) first, identify the different solutions characteristics, on-site requirements and constraints and with that information allowing to assess the pilot's existing infrastructures and the local installation feasibility, considering the installation requirements and the functional specifications of each individual component; ii) second, identify the development plans to reach the targeted TRLs and identify possible risks and mitigations measures.

1.2 Relation to other activities

This is the first of three deliverables of T6.1 and paves the way for the next two: D6.2 where the engineering and laboratorial validation activities related to the Terceira LHI Use Cases (UCs) will be defined; and D6.3 that compiles the results from the preliminary intelligent Virtual Power Plant (iVPP) integration tests.
Regarding other tasks, T6.1 will serve as a basis for the deployment plan that is going to be developed in T6.2 taking into account the development plans and specifications detailed in this derivable and also will be a valuable input for the entire system integration implementation and commissioning foreseen in T6.3.

1.3 Structure of the deliverable

The second chapter of this deliverable identifies the solutions to be installed in Terceira and provides a brief description of its main characteristics. The third one, details the development plan for each of the solutions to reach the commissioning phase in the Terceira demonstrator. The fourth chapter provides an overview of the dimensions and specifications

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

of each solution and its testing and installation requirements. Finally, Chapter 5 compiles the Gantt chart of the developments foreseen for all the solutions to be installed in Terceira and compiles their initial and final TRL.

2 Status of the technologies

2.1 Solutions identification

In this section, the solutions to be further developed and explored within IANOS project, and later integrated at the Terceira LHI demonstrator, will be identified and briefly introduced. The pilot context in which the different solutions will be integrated, commissioned and operated will also be summarised.

2.1.1 PV panels and microinverter (BeOn) [current TRL: 6]

Aligned with the objectives set within the scope of UC#1, focused on community demand-side driven self-consumption optimisation, BeOn will upgrade its microinverters and pioneering plug & play solar kits. Each kit includes a PV panel, support structure, wiring, microinverter and communication configurations, allowing the system to respond in real-time to grid operator commands.

In the residential district of Terra Chã, within the metropolitan area of Angra do Heroísmo, 40 houses will be equipped with BeOn’s individual solar kits. The integrated microinverters will be used to maximise the power output of rooftop PV systems, and allow for individual power generating PV systems to directly connect to any electric socket, just like a common electric appliance, in a safe, reliable and simple way. This bypasses the need to connect them to a switchboard or to an exclusive power line, cutting down on infrastructure needs, reducing systems’ dimension and installation costs without adding complexity.

2.1.2 Heat battery (Sunamp) [current TRL: 5]

The heat batteries provided by Sunamp will be another asset to consider within the scope of UC#1. Twenty-four heat batteries will be installed in the residential district of Terra Chã and integrated into the iVPP, that will consider them for flexibility services. The technology envisioned will enable the production of domestic hot water heating by using grid electricity and surplus PV energy. The heat batteries can be integrated with various energy sources, e.g. solar PV and thermal panels, micro combined heat and power units, and heat pumps, and are extremely efficient systems for recovering waste heat and generating renewable heat.

2.1.3 Electric water heaters (UniNova) [current TRL: 4]

UniNova proposes a non-intrusive use of energy flexibility in water heating systems provided by electric water heaters. Capable of interacting and working according to the remote control of the iVPP, the water heaters can cope with building level energy costs reduction, increased renewable energy penetration and self-consumption and load flexibility maximisation.

UniNova’s electric water heaters will be deployed at the end-user’s premises in Terra Chã and integrated with their solar kits and other electrical smart assets providing a set-up environment for the UC#1 validation.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nº 957810

2.1.4 HEMS (VPS) [current TRL: 6]

The Home Energy Management System (HEMS) developed by VPS will allow to remotely monitor, manage and control the technological solutions that will be installed within the customers' premises. The system can integrate different hardware, such as smart meters, sensors and actuators, data management modules for communication and data processing, and different user interfaces.

Framed within the scope of end-use premises digitalisation and smartening, thus also linked to IANOS UC#1 objectives, the VPS HEMS will be deployed in the selected houses from the residential district of Terra Chã, which will also be equipped with individual solar kits, electrochemical or heat storage systems, and electric water heaters (see above).

2.1.5 Smart energy router (UniNova) [current TRL: 5]

The smart energy router will be developed by UniNova and installed at building level, as a behind the meter solution. The solution is based in a power electronic device that manages the energy transfer from/to different sources, e.g., distribution grid, Renewable Energy Sources-(RES) based distributed generators, loads and electricity storage systems, and is capable of collecting data from these various energy assets, communicate and receive high-level control configurations from the iVPP to establish individual set- points for home environment electrical assets accordingly, acting as an intermediary between the iVPP control layer and the field level equipment.

2.1.6 Flywheel (Teraloop) [current TRL: 6]

To cope with IANOS UC#3 objectives – provision of fast response ancillary services by distributed storage technologies – Teraloop's flywheel would be adapted to deliver fast frequency regulation support. The proposed system is a Gen 1, 3 kWh/ 100 kWe flywheel, to be deployed in Terceira's LHI demonstrator.

The envisioned solution will be fitted for fast inertial response to grid balancing services and will become a distributed asset connected to the island's isolated grid. It will be manageable through the iVPP dispatch algorithms and capable of delivering power quality and demand-side services to the grid, demonstrating how flywheels can support system stability in harsh island conditions.

The PRONICOL dairy factory in Angra do Heroísmo, the largest milk processing plant in Terceira, will be the installation site of the flywheel. With sensitive industrial processes in its daily operational cycle, e.g., for milk pasteurisation, the factory is severely affected by frequency instability that can lead to short-term power outages.

2.1.7 V2G EV charger (EFACEC) [current TRL: 5]

Framed within the technical scope of UC#5, aiming to explore the decarbonisation of transport and the role of electric mobility in stabilising the energy system, EFACEC will develop and deploy two Vehicle-to-Grid (V2G) capable Electric Vehicle (EV) charging units, along with the needed software layers that will support the V2X functionalities. The charging stations will use an appropriate interface to deliver EVs charging and grid balancing services.

Through V2G smart charging schemes the stations will allow the iVPP to fine tune the EV charging pattern and adjust the voltage profile in grid nodes with heavy RES penetration, thus helping to avoid congestions and therefore minimising curtailments. The two V2G charging units of 12 kWe each will be installed in specific nodes of the Terceira's distribution grid, within the metropolitan area of Angra do Heroísmo, where technically both use applications make sense.

2.1.8 Hybrid transformer (EFACEC) [current TRL: 5]

Linked to the main goals envisioned for the implementation of UC#4, focused on the demand side management and smart grid methods to support power quality and congestion management services, EFACEC's fully operable hybrid transformer will be capable to regulate active and reactive power at the Medium Voltage/Low Voltage (MV/LV) substation, minimising power losses and allowing an optimised control of the user's local production and storage and their impact in the island's isolated grid.

The hybrid transformer incorporates two technologies, electrical and electronic, operating simultaneously. These combined technologies will allow a stepless, phase by phase, voltage regulations at the LV side with power factor control and monitoring. These features will benefit the operations within a local network presenting high penetration of distributed generation, also playing a key role in offering ancillary services and balancing three-phase systems.

EFACEC will develop the power electronic block for voltage regulation, introduce new windings to the transformer and associated magnetic circuit, and upgrade the mechanical layout, and install the hybrid transformer at EDA's distribution grid in Terceira.

2.1.9 Fog-Enabled Intelligent Devices – FEID-Plus (CERTH) [current TRL: 6]

The FEID-Plus introduced by CERTH is a fog-enabled computing device equipped with special functions to control I/O, pulse width modulation, and analog signals. It employs enough processing capacity for applying distributed computing, i.e., information capturing and storing, algorithms execution and control over the installation, having the capacity to interface with several field elements through appropriate protocols, e.g., controllable building loads, storage and EV charging stations. FEID-PLUS would be used to consolidate control set-points stemming from the iVPP CD for flexibility services.

2.1.10 Intelligent Virtual Power Plant – iVPP (CERTH) [current TRL: by module]

The iVPP platform integrates different software modules and services co-developed by the IANOS project consortium and will establish an overall management strategy for the Terceira LHI demonstrator. The iVPP design aims in optimal modularity and scalability, offering secured monitoring, aggregation and predictive energy management features, complemented by a set of cloud and fog-enabled software and hardware modules, oriented to serve the needs of island energy market stakeholders.

The iVPP will assume a core role in the implementation of the different UCs foreseen, namely UC#2, targeting the community supply-side optimal dispatch and intra-day services provision. The platform will consider all island energy streams and act within multiple timeframes, computing and setting high-level control guidelines that will foster ancillary services provision, congestion management, generation curtailment avoidance, grid reinforcement deferral, smart technologies – HEMS platforms and smart energy routers – and flexible assets integration – flywheel, EV chargers and the hybrid transformer.

The iVPP framework delivered by IANOS would be the key enabler of RES integration while maintaining stable system operation. Its core functionalities include:

- Exploiting temporary power surpluses from RES through storage, power-to-X and vehicle-to-grid applications at short-to-long term, through multi-temporal dispatch, considering several uncertainties and technical constraints such as ramp-up and down times, compensating imbalances within various timeframes.

- Intelligent flexibility extraction for demand side management-based services.
- Efficient variable RES uncertainties' forecasting and demand profiling through novel meta-learning, artificial intelligence-based predictors and incorporating physical and statistical models based on the specified response-to-accuracy ratio.
- Local-to-global energy assets' management, using edge to cloud infrastructure to deliver intelligence at LV prosumers and empower the levelized electricity costs towards self-consumption and tackling local-to-regional area supply and demand balancing.
- Incorporation of transactive mechanisms based on distributed ledger technologies and smart contracts to support energy credits' exchange between prosumers, aiming on enhancing transparency, immutability and localised energy balance incentivisation, also enabling prosumers' active participation in flexibility services.

2.2 Solutions description

In this section, for the previously identified solutions, the status of the technology is characterised. The core technologies involved, and the disruptive/incremental innovations added by each solution, will be highlighted. For all the solutions involved in the Terceira LHI ecosystem, the departing TRLs are assessed.

2.2.1 PV panels and microinverter (BeOn) [current TRL: 6]

BeOn microinverters allow each solar panel to produce at its maximum power point, delivering up to 25% more power than conventional string inverters. The microinverters are modular and therefore allow an easy upgrade of the PV installation without changing the initial setup, also allowing the installation of PV panels in different areas taking full advantage of unused spaces.

BeOn will perform the integration of internal communication systems with the ability to communicate at an increased range, device-to-device. Also, algorithms, protocol compatibility and communications hardware and firmware will be integrated in the inverters to allow advanced control. With proper interfaces for the microinverters the PV panels will be capable of adopting control setpoints defined at the iVPP control level that will take into account the system needs at each moment.

In the context of IANOS the innovation carried is linked to the creation of proper interfaces – APIs – for the solar kits' PV microinverters, that will allow for the PV panels to function in a more grid-oriented interactive way, according to instructions sent by the iVPP. The solar kits' will be upgraded with state-of-the-art communication capabilities, that will allow every panel to be connected to a communications and control network, providing real time data on energy production and having the possibility to be controlled in real time according to the necessary energy by the grid at any given time.

The TRL of the individual solar kits, including the microinverter, is currently at level 6 – technology demonstrated in relevant environment, industrially relevant environment in the case of key enabling technologies. In Section 3, the development plan envisioned to further improve the solution's TRL, will be highlighted.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

2.2.2 Heat battery (Sunamp) [current TRL: 7]

An innovative thermal storage solution that immerses a powerful heat exchanger into the Phase Change Material (PCM) capsules and therefore maximises its thermal power will be implemented, along with state of charge monitoring controllers for optimal storage use.
The heat battery is a highly efficient heat energy storage and processing technology. It is a packaged store of heat energy which internally uses a PCM to store four to sixteen times more heat than an equal sized hot water tank. During a ‘phase change’, such as a transition from liquid to solid, a lot of heat is stored or released. The mechanical design that makes a heat battery long-lived and easy to integrate is upgraded and turned it into a stackable solution, being easier to connect into heating systems. Sunamp will adapt its controlling interfaces to achieve a full integration with the iVPP.

2.2.3 Electric water heaters (UniNova) [current TRL: 4]

Due to the thermal storage properties of electric water heaters, it is possible to decouple the power consumption of these devices from the hot water consumption. As a result, energy flexibility can be provided by electric water heaters if the maximum and minimum hot water temperature limits are always respected. This innovative element allows the non-intrusive characterisation and use of energy flexibility provided by electric water heaters, which can be considered to achieve objectives at both individual and aggregated levels. The innovative aspect of the equipment’s upgrade concerns to the connection to the iVPP, and to the operation of the devices for the first time at an aggregate level, rather than on individual water heaters. This translates to multi-objective optimisation, i.e. working with several water heaters on a building and community level on a specific collective goal, set by the iVPP). The specific water heater state configuration that would accomplish the iVPP's goal will be done at the UniNova’s servers.
Through coupled sensors performance information can be collected from the water heater, and then passed through a microcontroller and communicated wirelessly to UniNova’s servers and through them to the iVPP. The iVPP will provide high level instructions on the grid's flexibility requirements, e.g., maximise or minimise energy consumption during a specific period, and these instructions will be translated to specific actions on the cloud and communicated wirelessly to the on-site microcontroller which will in turn control individual water heaters. In more detail, the system is composed of:

- A set of sensors to acquire temperature and power data, which are installed on existing electric water heaters with minimum impact on consumers’ equipment and comfort.
- A microcontroller with Wi-Fi communication capabilities to collect and send data, while also receiving the control signals that define the state of the heating element – on/off.
- An actuator that enables the supply of power to the heating element.
- A remote-control system where the energy flexibility characterisation and control strategy are computed, which is also ensures communication with the iVPP.

The non-intrusive nature of the system represents an improvement when comparing to other commercial solutions, which normally require the replacement of the entire electric water heating system to use energy flexibility. The departing TRL of the water heating equipment proposed is 4 – technology validated in lab.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nº 957810

2.2.4 HEMS (VPS) [current TRL: 6]

The VPS HEMS tiered and service-oriented architecture, with well-defined and easy to use interfaces, allows for easy expansion and integration, adding new modules or services and interoperability, upgrading or module replacement. The API module of VPS's HEMS offers a standard and open way to access data and metadata stored on the platform. This specific API is based on RESTful Web Services, also known as REST APIs, and provides a powerful yet simple tool to integrate different systems and develop applications. This approach allows quick prototyping and interoperability capabilities between web applications and other systems in the physical world. The hardware – smart meters, sensors and actuators – that integrates the HEMS can communicate with the central local unit – Gateway.

The VPS HEMS platform is currently in a TRL of 9 – actual system proven in operational environment, competitive manufacturing in the case of key enabling technologies. Nonetheless, the integration effort to include new hardware components in the HEMS platform interaction range will start in a TRL of 6.

2.2.5 Smart energy router (UniNova) [current TRL: 5]

The smart energy router is established accordingly to the Power Electronics Building Blocks (PEBB) IEEE concept, where basic building blocks are consistent with one another, having a defined functionality, standardised hardware and control interfaces, using IEC 61850 protocol, making it easier to be adapted and scalable to different scenarios. The proposed concept includes:

- Supervision and communication controller.
- Boost + buck-boost DC-DC converter + four wire DC-AC inverter.
- Signal acquisition, measuring and control.
- Inductive filters.
- Connecting transformer, making it easily adapted and scalable to different scenarios.

During IANOS, advancements from the current energy router design will take place to adapt it for the requirements of geographical islands. Intelligent algorithms will be developed and implemented to support intelligent energy communities' cooperation mechanisms, assuring the fulfilment of operational rules related with the injection of active and/or reactive power.

Connecting every energy related device input/output, the smart energy router will be responsible for grid-to-grid communication, load management and integration of multiple generation units, electricity storage, heterogeneous appliances and existing distribution grids. The ability to provide distributed ancillary services to the grid will be coordinated through upper layer supervision with voltage management control devices at the secondary substation level.

Thus, there are two main levels of control:

- The power electronics control – inverter, storage state.
- A higher level of control which sets the strategy, e.g., optimal charge, charging period for battery, to maximise self-consumption.

For the needs of IANOS the energy router will receive higher level instructions from the iVPP and control individual assets accordingly. It thus acts as an intermediary between the iVPP and individual assets at building level. The innovative aspect will be the connection of the energy router to the iVPP, which has not been attempted before.

The energy router has been advanced in previous projects and is now at TRL 5 – technology validated in relevant environment, industrially relevant environment in the case of key

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

enabling technologies. During IANOS the solution will further developed, to enhance the digital services and controls which are necessary to manage the available energy flexibility and to provide distributed ancillary services to the grid and will reach TRL of 7 – system prototype demonstration in operational environment. Digital services and controls enhancement will be achieved by technical improvements covering communications between the energy router controller and the upper-level supervision management control, namely the iVPP. By using the data model defined by the IEC 61850 standard, the router connected to the network is virtualised and is recognised through its IP. Advanced functionalities included in the IEC 61850-90-7 standard will be developed, such as INV1 – connect/disconnect from grid – or INV2 function – adjust maximum generation level up/down.

Due to its technical capabilities, which allow a holistic integration of local renewable energy production along with integration of local energy storage, with proven effectiveness in managing the building's energy flux and improving the self-consumption ratios. Taking advantage of cooperative flexibility algorithms, managing the renewable production and storage in an aggregated manner, multiple individual smart energy routers can act as a virtual single smart energy router integrated in the iVPP. The use of standard hardware, considering the IEEE PEBB paradigm, and standard communications – IEC 61850 will facilitate interoperability – will allow for seamless integration of further smart routers within the same community, assuring scalability and replicability.

The smart energy routers proposed will clearly differentiate from other commercial products either by their increased interoperability or by innovative services they can offer, such as the phase load balancing feature. Increased interoperability will allow for seamless integration on islands energy systems, sharing resources and features. The Energy Router will be enhanced with flexibility algorithms that will consider flexibility on the user side, either on equipment either on storage capabilities, to provide ancillary services to the island grid. These algorithms will be implemented on the energy router controller and will command/control the energy flux to, and from, the grid and to, and from, the storage devices.

2.2.6 Flywheel (Teraloop) [current TRL: 6]

The flywheel solutions introduced by Teraloop differs from conventional flywheel solutions since it uses a patented and prototyped hubless outer-rotor design. The typical limiting factor for conventional flywheels is radial stress. When radial stress is very low, this allows a full use of the material tensile stress properties, and all carbon fibres can be wound in the circumferential direction. A relatively high energy density is permitted, achieving 100 Wh/kg, which is comparable to stationary Li-ion modules, and 5 to 7 times more than existing flywheel solutions. Teraloop's rotor is made from filament wound Carbon Fibre Reinforced Polymer (CFRP) as it has very high tensile strength in longitudinal direction – the long axis of the fibres, σt – and very low density. Unlike conventional flywheels, the manufacturing process is continuous and scalable up to several meters of rotor diameter, allowing a significant reduction in the cost per unit energy stored.

Within IANOS the flywheel would be operated as a black box solution, so its internal control systems require adaptations to become compatible with the iVPP environment.

Due to its innovative characteristics and specific integration conditions, the flywheel will be firstly tested in EDP's Smart Lab facilities, to demonstrate full operation in a controlled environment. The communication link between the flywheel's local control and the iVPP layer will be also tested, to ensure its robustness and reliability. All on-site requirements and

constraints will be identified in T6.3 – system's integration and commissioning – where the existing infrastructures and all required installation compliances will be assessed.
Concerning technological positioning, and as a preliminary assessment over the proposed TRL advancement, within the project's scope the flywheel technology is expected to depart from a TRL of 6.
The targeted development plan to foster the required TRL advancement will be introduced next, and includes the indicative timeline, possible risks and associated mitigation measures applicable to the development of the flywheel.

2.2.7 V2G EV charger (EFACEC) [current TRL: 5]

EFACEC's solutions go well beyond the ON/OFF control and already includes smart charging functionalities. Within IANOS the following functionalities for ancillary services and grid support will be improved:

- Load balancing between charging stations.
- Dynamic charging profile scheduling for grid constraints avoidance – over and undervoltage and overloads.
- Dynamic control of geographically and electrically/topologically related charging stations to defer investment on grid or transformer capacity.
- Grid frequency regulation – coordination with AGC and with fast response controls.
- Voltage support and regulation.

The VPP operator can use the smart charging and V2G to optimise the energy consumption and storage in the VPP framework. The EV charger proposed for this project targets a bidirectional power flow capability, which is significantly different and more complex, when compared to a standard unidirectional charging solution. The changes are in the power electronics conversion topology that should cover a more extensive operating area, in the two quadrants of the power curve, and mainly on the dynamic response of the converter. Consequently, the associated digital control algorithms are more complex since the control must be more adaptative and dependent on multiple factors, such as the voltage and frequency variations. The same is applicable to the modulation techniques used for the control of multiple semiconductors. Additionally, the new functionalities related with voltage regulation and specially for primary frequency regulation require advanced control strategies for optimal and stable operation.
The EV Charger is constituted by several high efficiency power electronic conversion stages, using the latest technology in terms of semiconductors and conversion topologies for the inclusion of the bidirectional power capability. The charger will incorporate a dedicated interface and control module with the digital algorithms for the implementation of the charge/discharge profile received from the iVPP. Moreover, there are other embedded control layers to implement innovative grid support functionalities, such as voltage regulation and primary or secondary frequency regulation. These functionalities are especially important for islands and isolated grids and require a superior dynamic response, to respond positively to frequency and voltage variations.
Presently, some of the functionalities already developed are being tested in a laboratory environment, and the departing TRL of the solution is 5.

2.2.8 Hybrid transformer (EFACEC) [current TRL: 5]

The introduction of the identified innovative transformer, which integrates a new concept of on-load voltage regulation based on power electronics, allows voltage regulation without limiting or negatively impacting the generation, or the load profile, providing flexibility of operation to the iVPP environment.

The proposed distribution transformer assumes a hybrid concept that combines the advantages of the power electronics with the characteristics of a conventional transformer, allowing a wide and almost continuous regulation range, with high dynamic response, and without limit of manoeuvres, capable of individual voltage regulation in each phase and reactive power compensation.

The novelty of the advanced concept relies on the application of independent control of each phase and features such as reactive power or unbalance compensation, which cannot be provided by conventional transformers. The commercial solutions available on the market for the on-load voltage regulation are mainly based in motorised mechanical actuation of taps on the primary side of the transformer. There are some drawbacks on this kind of solution, such as the limited number of steps, limit on the number of operations due to the inherent mechanical principle, and the absence of the control of each phase, independently. The integration of a novel transformer concept at the substation level, with the capability to regulate voltage during operation, will improve the quality of service. The hybrid transformer will add new features and is oriented for the application at a distribution level. The objective is to achieve a regulation range of +-12 % of the nominal voltage, in a stepless or a small step approach, with the minimum impact in the conventional transformer layout, to allow a possible upgrade of existing installations. Therefore, the hybrid transformer planned would be able to implement a dynamic voltage regulation actuation, in each phase, with unlimited number of operations and with the addition of other features such as the contribution to reactive power compensation, unbalance correction and improvement in the voltage profile quality.

The hybrid transformer is equipped with a control unit that implements the voltage regulation algorithms according to the configuration and voltage profile sent by the VPP optimisation and control layers. Additionally, this unit collects the information of the operational condition of the transformer that is important for any high-level optimisation. The communication between the hybrid transformer control block and the VPP will be based in substation automation protocols, such as IEC 61850 or IEC 60870.

Key features:

- Voltage regulation block – the use of a power electronics, instead of traditional mechanical systems that switching the transformer's internal taps mechanically, allow a better dynamic voltage regulation at the LV with a small increment/decrement, without limitation of the number of operations, improving the controllability of the transformer output, since any operating point can be selected and changed at any time, which is impossible with mechanical switching. Additionally, this type of control can be applied individually to each phase and may be used to compensate voltage unbalance. The power electronic stage can be used to compensate partially the reactive power, if necessary.

  The topology of the power electronic conversion platform is based on two AC/DC converters. The first one is connected as a shunt converter that is used to generate a controllable DC voltage bus. The second converter is connected to this DC voltage bus and will synthetize an AC voltage waveform that will supply a special transformer inserted in series with the line. The waveform synthetized will sum or subtract a voltage to the line, to obtain the desired value on the output.
- Operational monitoring – besides the innovative actuation capability in terms of voltage regulation, the transformer control unit will integrate advanced sensoring and

diagnostic function blocks for the processing of the status and the condition of the transformer and the grid that is fed by this asset.

The hybrid transformer solution will depart from a TRL 5.

2.2.9 Fog-Enabled Intelligent Devices – FEID-Plus (CERTH) [current TRL: 6]

The FEID is equipped with embedded communication interfaces, either directly on the main unit or in the form of add-ons. It can communicate unobtrusively with most commonly used wired or wireless communication protocols – Ethernet, RS-232/UART, RS-485/Modbus RTU, SPI/ I2C and USB in terms of wired connections, or Wi-Fi, Bluetooth, EnOcean, LoRa, NB-IoT in terms of wireless supported. The device is equipped with a TPM 2.0 chip for hardware-enabled cryptography. These results, for smart meters that support it, into encrypted data exchange and enhanced data integrity. FEID is also compliant with the openADR protocol to support interoperability in demand response schemes. FEID comes with software to deliver monitoring, forecasting and analytics functionalities on-the-edge, having the ability to optimally allocate signals received from upper layers, i.e. operators, to its field level interfaces.

To enable access to and from the FEID-PLUS a Web-App is installed to allow a range of web services. The Web-APP server is developed based on Python's Flask framework. Another innovation aspect of the FEID-PLUS lies in the development and training of the forecasting tools, that are executed daily, such as load forecasting and PV forecasting. The forecasting models are trained by using lightweight machine learning models based on the gradient boosting framework – XGBoost. Also, a time series database is included within the FEID – InfluxDB – where all the measurements, the calculated data and the exchanged messages are stored.

Moreover, the level of innovation added within the scope of IANOS and considering that the departing TRL for the FEID is 6, is linked to the use of the FEID to consolidate control set-points stemming from the iVPP CD for flexibility services. For this purpose, the device will be advanced towards increasing the intelligence offered on the edge, focusing on communication – appropriate API and standards' adoption – and on the computing capabilities integration, before final demonstration in the Terceira pilot. The developed optimisation algorithms in IANOS will follow the combination of cloud modules and dedicated fog-enabled devices, for data pre-processing to harmonise the operation of the grid distribution in a faster and less computationally expensive manner. Following the fog/edge computing principles, within IANOS the focus will be on optimising functional VPP operation through the support of intelligent algorithmic and mathematical processes at both cloud/fog-edge layers.

2.2.10 iVPP (CERTH) [current TRL: by module]

The intelligent VPP framework introduced in IANOS allows to increase the hosting capacity of distribution networks, e.g., the aggregator and/or the DSO can select in advance the grid configuration, which avoids or minimises RES curtailment, facilitating also the management of the distribution network, making easier to schedule in advance the generation required to compensate RES fluctuations and coordination of grid assets.

The IANOS iVPP framework encapsulates the basic notion of setting up a virtual network of decentralised variable renewable generation units, based on wind and sun, dispatchable ones, such as geothermal and Combined Heat and Power (CHP) plants, as well as Energy Storage Systems (ESS), integrated as a single unit, providing flexibility services and fostering island RESs' self-consumption.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

The iVPP is expected to spur the deployment of localised RES and storage systems, promoting the concept of self-consumption solutions in households, buildings and/or districts. The solution will be cross-functional, allowing high replicability and scalability – even on an island scale –, and should be capable of taking advantage of the already available RES while fitting in a comprehensive way to the island specificities. The optimal, autonomous, real-time VPP operation will be driven by multi-level decision making intelligence, complemented by predictive algorithms for smart integration of grid assets into active network management based on relevant energy profiles. Technologies backing up the iVPP would be built upon relevant expertise brought by CERTH, TNO, VPS, NEROA, UBITECH, ENG, ETRA.

The operative orchestration toolkit proposed for the IANOS iVPP comprises the following elements:

- **Aggregation and Classification [current TRL: 6]**
  The units' information extracted through the monitoring mechanisms will be analysed in terms of key static or dynamic factors, e.g., static information would include the type of load/storage, installed plant capacity, geo-location, whereas dynamic would entail the generation profile, reliability – declared vs committed flexibility. The classification mechanism would examine different guidelines/strategies to segment the portfolio into aggregates.
  This tool will combine novel data mining and pre-processing techniques, such as standardisation, dimensional reduction and outlier detection algorithms to create groups of segments – energy pools – based on their load profiles. In addition, it will be used to collect and pre-process raw data from multiple heterogeneous sources to reduce the volume of the data, while extracting significant insights for the instant operations and decision making of the centralised dispatcher. More specifically novel clustering techniques, like fuzzy learning, hierarchical and neural network clustering algorithms will be used, based on specific strategies and attributes for the classification of the energy-portfolio detecting and providing the optimal groups to participate in optimisation process.
- **Forecasting Engine [current TRL: 6]**
  A fully customisable tool providing demand/generation forecast slots for multiple time horizons ahead to the iVPP platform, considering different time scales. More specifically, the output of the forecasting engine will be used as input to the CD to extract the optimal setpoints. The forecasting model will exploit past demand/generation and weather measurements as input features. Furthermore, to improve the accuracy and to capture the time periodicity detected in the demand/generation time series, the forecasting models will include temporal features such as time, day of year, month and year. The development and the training of the models will use innovative machine and deep learning techniques, such as AI and ensemble methods resulting in accurate forecasts.
  Different forecasting methods, from statistical to machine learning have been applied for forecasting. IANOS would develop the needed production/consumption forecasting mechanisms considering multiple time scales, for the short and shortest-term forecasts for day-ahead and intra-day markets. The use of high-grade Numerical Weather Prediction (NWP) models for the former and innovative statistical methods, such as Artificial Neural Networks (ANN) will be considered for the latter. Via accurate vRES forecasts, the possibility for such sources to participate on the balancing power markets will be examined.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

- **Centralised Dispatcher (CD) [current TRL: 6]**
  It is the iVPP main decision maker and adopts two core elements: i) utility-scale & ii) behind-the-meter assets schedulers, to denote the multi-level optimised dispatch of both large- and small-scale assets in the physical world, having the main objectives of: self-consumption; establishing intra-portfolio operating reserve; provision of balancing/ grid quality restoration power and dispatch, when needed. Such elements enable for automated, simultaneous appropriate decision making, in terms of power units' operation and management of short time imbalances and provision of ancillary services, in multiple scheduling intervals – seconds-to-day planning. Realising the most cost-effective operation for the overall power network would require: a) continuous monitoring of each of the power production/ consumption/ storage assets, and b) the support of an iterative decision-making process that considers KPIs of the various impacts on the different timescales and level of variability in which they occur on the electric grid, achieving system reliability and security of supply.
- **Distributed-Ledger based energy Transactions (DLT) [current TRL: 5]**
  The deployment of an integrated DLT multi-layered hybrid IoT-on chain data governance layer would be used to support multi-stakeholder energy debits sharing, while fully preserving data sovereignty. In IANOS, the ledger architecture will be carefully designed, considering the off-loading of computational resources – for services such as monitoring and control – on the sidechain, while broadcasting only the very necessary information on-chain.
- **Virtual Energy Console [current TRL: 6]**
  This module will offer unique linked data exploration, perception and knowledge extraction for effective energy flows' assessment. The virtual energy console will include necessary innovations on visual and data analytics, enabling the dynamic connection of different datasets with several types of visualisation, so that user selection in one visualisation feature can have a direct impact on the others. Indicative information of-value, to be visualised through this component will entail: i) composition summary mix of VPP's portfolio of units, ii) monitoring of dispatchable vs vRES installed capacity, iii) actuation of energy assets and iv) a diagnostics history.
  The novel virtual energy console will be designed to embrace relevant advances in relation with the various services to be offered – multiple data fusion, monitoring and profiling, aggregation and classification.
  In terms of communication, the platform will exchange information and signals with the IoT devices and energy assets, mainly using secure and standard TCP/IP and MQTT protocols. Other protocols and API support will be added to the platform to assure interoperability among all market vendors. These protocols are to be defined during the integration project phase.
  These are some of the main functions in terms of monitoring and visualisation that are supported or partially supported by the current available version of the Virtual Energy Console:
    - Collect telemetry/status data from devices and other data.
    - Graph view of real time and forecast data: There are various modules where monitoring, baseline, weather, flexibility, demand, and market data can be analysed.
    - Flexibility calculation: baseline calculation, load forecast and PV forecast.

  - Planning: make plan based on available flexibility and program settings, rebalancing upon flexibility changes.
  - Device control by immediate or scheduled actions including on/off or setpoint definition.
- **Enterprise Service Bus [current TRL: 6]**
  In the downstream direction, IANOS iVPP platform would communicate with numerous geographically scattered units, such as storage vectors, dispatchable generators and flexible prosumers' assets. For this purpose, the capability to securely monitor energy-related and exchange contextual data from dispersed field-level AMI/ EMS/ BEMS infrastructure will be established. The iVPP would include for this purpose a set of virtual agents, retrieving upstream data from field components and delivering the setpoints computed by the CD. An on-line connection with external end-points-databases and operators' platforms – through created APIs – would be also developed to retrieve information such as weather and price data. At field-level, a runtime environment would be used to connect with deployed devices. Using the open standard platform – DefPi –, it would be possible to decide where the intelligence/algorithms must be executed, locally or in the cloud.

3 Development plan

In this section, the final technological maturity of the different solutions, envisioned for the end of the project, is evaluated. IANOS's technological roadmap is now proposed, framing the development plans to reach the targeted TRLs and including the indicative timelines, possible risks associated and mitigation measures to consider.

3.1 PV panels and microinverter (BeOn) [target TRL: 8]

Development timeline

- BeOn's development in the context of IANOS will be mainly focused on the development of the communication and control capabilities of its solutions. Therefore, based on the already commercial solution of the PV panels with integrated microinverters, it will develop the necessary APIs to communicate with the iVPP and also increase the actual communication system range, ensuring that no communication difficulties arise when the modules are installed further away from the HEMS. All of this will undergo testing and qualification procedures within the development phase ensuring that the system reaches the expected TRL of 8.

Associated risks

- Risks at this point are neglectable, particularly on the microinverter side. BeOn has its own production line, and the required technology development for IANOS implementation is already satisfactory. Covid-19 impacts on BeOn operation are not expected. The only potential issue might be on the installation of the PV systems at the end-user's premises, if the project's acceptance at the community level is not satisfactory, or if, for example, privacy issues are raised.

Mitigation measures

- With regards to the main risk identified, and if there is an effective rejection from the end-users regarding the solutions' installation, a close collaboration with local

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

stakeholders that can facilitate the required interaction with the community and the access to the targeted installation sites will be privileged. The project consortium will articulate and collaborate with local actors, namely at the municipality, parish and community levels, to ensure the implementation of a proper plan to reach out and effectively engage the community members, providing them with all the information and support required and increasing their trust and acceptance over the foreseen project initiatives. Additionally, and as back-up plan, the number of targeted end-users can be extended, increasing the possibilities of a positive engagement in a timely manner.

3.2 Heat battery (Sunamp) [target TRL: 8]

Development timeline

- Given the fact that Sunamp's Heat Batteries are an established technology already brought to the market, the development effort within the frame of IANOS will focus on the optimization of its hardware for a smoother installation process and better performance and of the software modules for the integration of the iVPP. As of today, the baseline technology is fully developed and only refinements to optimize its operation within the iVPP framework are needed. This will be achieved throughout the next months in close collaboration with the project's partners.

Associated risks

- The development of these new functionalities might put at risk the CE mark that the product and the controller have and require a new certification process.

Mitigation measures

- If a new certification procedure is needed, the partners might need to agree to start the testing procedures in parallel with the certification procedure.

3.3 Electric water heaters (UniNova) [target TRL: 7]

Development timeline

- The innovative elements identified have already been validated in the laboratory, where the benefits associated with the non-intrusive characterisation and use of the energy flexibility provided by electric water heaters have been assessed. UniNova's current efforts are focused on the extension of this energy flexibility characterisation to community-level, so that external entities, e.g., the iVPP, can define the objective for the operation of the aggregated assets' cluster, while ensuring that consumers user experience is still respected. This multi-objective optimisation will be guaranteed by the remote-control system previously mentioned, which will also interact with the identified high-level entities. Following the development plan foreseen, UniNova's electric water heaters' TRL advance should reach a 7.

Associated risks

- The supply of equipment necessary to further develop the solution and address the innovative element highlighted may be delayed due to the current context imposed by the COVID-19 pandemic. More importantly, site visits to prepare its installation may also be affected due to the same reason and impact the installation process. Moreover, local installation conditions may not be optimal for deploying the

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

equipment, e.g., no space for the installation of sensors on existing electric water heaters, lack of Wi-Fi connection. There could also be privacy risks with personal data.

Mitigation measures

- With regards to hardware/supply problems they are not expected to be severe since the number of systems installed on Terceira will be small, and they do not require components that would be hard to find. This also relates to the fact that in this case the control of water heaters is a simple on/off and would not require specialised hardware. With regards to location/installation issues as well as privacy issues timely communication with the Terceira local authorities should be enough to mitigate any risks.
- To reduce impacts associated with the current context imposed by the COVID-19 pandemic, UniNova will anticipate the development phase and stablish close contact with partners to improve cooperation. Early location decision is fundamental to secure the adequate conditions at the installation sites.

3.4 HEMS (VPS) [target TRL: 8]

Development timeline

- As for the VPS's HEMS, the further developments required are related to the integration of the new hardware components from other IANOS partners and other third-party manufacturers.
  VPS has a long track record on the integration of multiple energy assets and equipment's from different manufactures using distinct protocols and manufacturers restricted APIs. Based on VPS experience with other similar equipment's, the development of the interfaces required for smooth integration will advance the platform's TRL to an 8 at the end of the project's pilot phase.

Associated risks

- Being a software-based platform VPS's HEMS will not require field commissioning, since all the configurations required to ensure proposer integration and interoperability can be performed remotely, after the APIs are fully developed and tested, mitigating any pilot's installation relevant risk.

Mitigation measures

3.5 Smart energy router (UniNova) [target TRL: 7]

Development timeline

- Energy routers have been pre-piloted in office buildings and detached houses under previous initiatives, where both single and three-phase energy routers were considered and developed, and within IANOS the focus should be on the enhancement of the digital capabilities of the solutions in terms of services based on control set-points computed by high-level centralised solutions, which will entail a development effort mainly linked to the communication and interrogability needs. By the end of the project, the targeted TRL for the smart energy router solution is 7.

Associated risks

- The supply of equipment necessary to develop the smart energy router may be delayed due to the current context imposed by the COVID-19 pandemic. Site visits to prepare the installation of the routers may also be affected due to this reason. Additionally, regulation restrictions may impact the installation of the energy routers at consumer's location if, e.g., the DSO demands certification of the equipment, since the solution's prototype is not expected to become a certified product during the lifetime of the project. Space conditions at the installation sites must also be verified.

Mitigation measures

- Like what is being proposed for other solutions UniNova will be deploying, to reduce impacts associated with the current context imposed by the COVID-19 pandemic, UniNova will anticipate the energy router development, trying to secure components acquisition as soon as possible. Concerning regulation restrictions, UniNova will closely cooperate with the local DSO to choose an adequate location for the smart energy routers deployment. Automatic circuit breaking can be foreseen to be installed between the routers and the points of common coupling. Early location decision is fundamental to secure adequate conditions at installation sites.

3.6 Flywheel (Teraloop) [target TRL: 8]

Development timeline

- The present flywheel solution has been delivered to Teraloop's high-speed testing facility, where the high-speed testing and operating programme has begun. According to its specifications the operating range of the flywheel is 6000-18000 rotations per minute, and Teraloop has successfully demonstrated that the device can operate within the set boundaries for its use in IANOS.
  The connection to the grid will pass through outsourced power electronics interface, which are readily available off the shelf, and Teraloop's development plan relates to the system behind these power electronics.
  The device was successfully commissioned, operated and tested beyond rotor rotational speed of 4300 rotations per minutes – "low speed" trials –, and will be shortly delivered to the high-speed testing facility, where it will be operated and tested up to the required speed range – the "high speed" trials –, to render it in position to offer the required capacity of around 3kWh.
  The steps required to implement the development plan and advance the solution's TRL as part of the IANOS project are:
    - Step 1: completion of pilot device high-speed test and commissioning.
    - Step 2: receipt of requirements from the iVPP development team and adaptation of the internal control systems of the flywheel system, to be compatible with the iVPP.
    - Step 3: provision of pilot device as a black box solution to EDP's Smart Lab facilities to ensure the demonstration and operation of the full system in a controlled environment.
    - Step 4: installation and commissioning of flywheel system on Terceira island and integration with the iVPP.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

- Step 5: successful operation of the flywheel system on Terceira island, controlled by the iVPP.

The indicative timeline to follow is:

- Step 1: by end of Summer 2021.
- Step 2: by mid-summer 2021.
- Step 3: To be agreed with EDP.
- Step 4: follows original project GANTT chart T6.3.
- Step 5: follows original project GANTT chart T6.4.

Flywheel's technology at the end of the project targets a TRL of 8.

Associated risks

- Risk of lack of funding – medium risk, medium impact – the availability of private funds, especially from venture capital and corporate venture capital sources which are key to our operations has strongly diminished since the beginning of the CoVid-19 pandemic.
  This lack of private funds could lead to delays in project implementation, in the worst-case bring insolvency risks due to the nature of business at the start-up stage.
- Risk of failure to deliver the flywheel technological solution – low risk, high impact – testing and operational difficulties during the high-speed trials, notably due to the CoVid-19 situation limiting the possibility to assemble the full team required for the trials, could delay the project implementation.
  There is also a risk, related to the control systems of the flywheel and their possible failure during the high-speed testing phase which could lead in the worst case to a catastrophic failure of the system.
- Travel restrictions risk – high risk, medium impact – inability to travel to the target pilot site may limit our capability to acquire the required data to optimise the system design and subsequently system integration. It may also impact the capability to build key relationships with project partners and stakeholders.

Mitigation measures

- Mitigation of risk 1, risk of lack of funding:
  Teraloop have broadened our scope of target funding sources, not limiting themselves to corporate venture funds. Teraloop have further negotiated with their internal stakeholders for possible additional support if required.
- Mitigation of risk 2, risk of failure to deliver the flywheel technological solution:
  Teraloop have implemented strict health safety guidelines for our technical team, as well as optimised internal communication channels through digital platforms to minimise the internal impacts of the CoVid-19 situation. The mitigation of risks related to failure in control systems is performed with test plans elaborated before each flywheel operation event, which includes identification of objectives, data collection plan, test procedure, risk identification and safety measures.
- Mitigation of risk 3, risk of travel restrictions:
  Teraloop can ensure that proper communication channels via digital format with project partners, and stakeholders, will be established. Such communication tools minimise the possible impacts related to the lack of travel possibilities.

3.7 V2G EV charger (EFACEC) [target TRL: 7]

Development timeline

- EFACEC will further develop its smart charger by providing control algorithms for ancillary services and grid support, i.e., dynamic charging profile scheduling to avoid grid constraints, voltage support/regulation, grid frequency regulation in coordination with the system's automatic generation control.
  Within the project's scope an industrial prototype is to be designed, compliant with all the necessary requirements in terms of certification, especially in terms of safety, electromagnetic compatibility, and interoperability, to perform the validation in a real field trial context of operation. During the project it is expected that the solution evolves up to a TRL 7, and the time plan for this development is estimated in 9 months.

Associated risks

- The Covid-19 pandemic – generalised quarantines and/or travel restrictions – can lead to constraints/delays in the R&D process, laboratory activities, site installation and commissioning and the realisation of an extensive testing program for the new grid support functionalities, that can also affect the EVs user experience and limit the battery life.
- There is also the need to conclude any procedure to certify the installation of a bidirectional charger connected to the distribution grid required from the responsible authorities.
- The interface with the iVPP demands the exchange of additional information that is not supported in current communication interface and protocols, such as OCPP, that is more suited for the transmission of data from the EV Charger to the backend.

Mitigation measures

- Continuous monitoring of the pandemic situation and the evaluation of the respective impact on the project.
- Detailed study of the impact of the charger in the demonstrator installation and establishment of contacts, in an early stage, with the Authorities that intervene in the authorisation process.
- Establishment of specific testing and simulation program based on the Terceira island grid information.
- Study and promotion of information actions related with the V2G user experience and analysis of how the grid support features are impacted if there are restrictions, or limitations, on the battery use.
- Analysis and discussion of the applicable protocols within the smart grid framework that may be interesting to support EV Chargers, and, that may be oriented for the V2G chargers, with special focus on the power balancing and transmission of profiles for frequency or voltage reaction curves.

3.8 Hybrid transformer (EFACEC) [target TRL: 7]

Development timeline

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

- The activities planned to achieve the level of innovation proposed in IANOS can be divided into three areas: the transformer, the regulator and the monitoring system. The status of each of these technologies is as follows:
    - Transformer: mix of an already mature technology with the incorporation of new materials, which will allow lower losses, will work at higher operating temperatures and will be more environment friendly and fire resistant.
      The energy efficiency of the distribution transformer will be improved in the transformer design process. Some options to be studied are:
        - The use of ferromagnetic materials with low losses.
        - Adoption of alternative configurations.
        - New materials, such as the ester dielectric fluid.
        - Reduction of the power electronic losses.
    - On-load voltage regulator: EFACEC will build a prototype of the electronic block featuring the stepless or small approach voltage regulator and meeting the required insulation level of the LV Grid.
    - Monitoring system: the addition of embedded sensors and a local controller unit enable the optimisation of the operation, maintenance and further exploitation of the data available on this asset.

  The steps required to implement the foreseen development plan are:
    - Step 1: development of the power transformer.
    - Step 2: development of the monitoring system.
    - Step 3: development of the voltage regulation block.
    - Step 4: factory acceptance tests.

  Indicative timeline:
    - Step 1: between March 2021 and June 2022.
    - Step 2: between September 2021 and June 2022.
    - Step 3: between March 2021 and June 2022.
    - Step 4: between July 2022 and September 2022.

  The targeted TRL for the hybrid transformer at the end of the project is 7.

Associated risks

- Delay or poor definition of the hybrid transformer requirements due to the complexity of the solution.
- Within the scope of the Covid-19 pandemic, travel restrictions can lead to constraints/delays in the installation of the transformer in Terceira.
- Like what will happen with the V2G chargers, there will be also the need for acceptance and/or certification by the corresponding authority, prior to the installation and connection of the hybrid transformer to the distribution grid.
- Introduction of new technologies lacks the proven reliability of conventional transformers.
- Layout review of the existing transformer substation for the integration of the new hybrid transformer.
- Low quality cellular signal for communication between the hybrid transformer and EFACEC's platform.

Mitigation measures

- Fluent and frequent communication between EFACEC, EDA, EDP and the certification authority right from the beginning of the project.
  The following sessions were identified:
  With EDA and EDP:
    - After receiving the first technical specification of the hybrid transformer to confirm all the data and obtain the characteristics of the site where transformer will be installed.
    - Design review of each component – transformer, voltage regulation, monitoring system.
    - Before producing, ask for approval of the final drawings.
    - Definition of the qualification tests.

  With the authority that approves/certifies new devices in the distribution grid, after the design review is approved by EDA and EDP.
- Close surveillance of the hybrid transformer during operation on the grid through the EFACEC platform to detect/anticipate possible fault operations.
- Detailed study of the necessary changes and impact of the intervention in the existing installation.
- Using signal amplification equipment or using LoRa, available on monitoring system, with adequate gateway.

3.9 Fog-Enabled Intelligent Devices – FEID-Plus (CERTH) [target TRL: 8]

Development timeline

- Within IANOS the solutions will proceed to increase the intelligence offered on the edge, focusing on developing advanced forecasting mechanisms for the energy consumption and PV generation based on historical and meteorological data, improving the existing forecasting models by using innovative machine learning techniques. Furthermore, the device will receive and perform all the actions and decisions coming from the iVPP CD to provide the requested flexibility services. Finally, the FEID-PLUS will be able to control on-field V2G and storage assets through the installation of the appropriate communication protocols.
  FEID-PLUS is based on the FEID control solutions developed in previous projects, and the device/software will be adapted as needed to follow the requirements of IANOS project.
  The deployment plan regarding the FEID-PLUS will be further detailed and the local integration at the buildings' level will take place in T6.3, starting in M15. These activities will mainly take place from M6 to M24.
  The targeted TRL for the IANOS FEID-PLUS is 8.

Associated risks

- User acceptance barriers:
  Users/consumers may have a reluctance to install additional equipment on their premises.
- Insufficient data barriers:
  Data needed to perform analysis and estimations, e.g. forecasting, should have enough capacity.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

- Integration barriers:
  Proper integration of FEID into the consumers' premises would demand identification of available communication protocols, relevant energy management systems available, type of legacy equipment to be controlled.
- Privacy barriers:
  FEID would gather and analyse energy data which can be considered as personal user/customer information. Data processes such as energy forecasting would be handled on-device for FEID-enabled consumers.

Mitigation measures

- Positive impacts – environmental and cost benefits/energy reduction – would be emphasised to overcome such issues.
- Pilot data gathering would start at an early stage to overcome such issues.
- Such identification would be available in the deployment plan for Terceira pilot, to be prepared within the scope of T6.2.
- Information that is going to be delivered into the iVPP platform for further processing would be anonymised before such transaction takes place.

3.10 iVPP (CERTH) [target TRL: by module]

Development timeline

- The characterisation of the technological maturity of the supporting solutions/modules brought by the different partners involved in the development and configuration of IANOS iVPP is as follows:

  Solutions
  TNO's ReFlex [target TRL: 8]
  ReFlex will be an essential part of the CD module of the IANOS iVPP. ReFlex is compatible with multiple open smart grid standards – EFI, USEF, OCPI – and allows an interaction with energy markets and congestion/flex markets, allowing different mechanisms' real-life validation within the scope of IANOS.
  The departing TRL is 6 and it is expected to reach a TRL of 8 by the end of the project.
  CERTH's optiMEMS toolset [target TRL: 8]
  The set of energy and flexibility control algorithms for intelligent decision-making systems that use big data analysis and machine learning are developed by CERTH and were already validated using real-life data.
  Within IANOS its capabilities will advance and the types of resources they will be able to coordinate, including V2G and thermal storage components towards fully optimised flexibility extraction, will be extended.
  The departing TRL is 6 and within the scope of IANOS it is expected to evolve to a TRL of 8.
  VPS's KIPLO [target TRL: 8]
  The platform proposed by VPS enables an optimisation of low carbon energy communities, with aggregation of RES and Distributed Energy Resources (DER). KIPLO's core computing platform will be expanded to be able to integrate with external advanced services, such as load and RES forecasting, clustering, and storage optimisation, and manage novel types of equipment.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

The platform has now the capacity to remotely monitor, manage and control many energy assets, namely smart plugs, energy meters, contactors, water heaters, solar PV and battery inverters, hydro and wind power plants, V2X, HVAC, heat pumps, IR controllers, chillers, refrigeration systems, lighting control systems.
The departing TRL is 6 and during IANOS will reach a TRL of 8.

Modules

Aggregation and classification intelligence [target TRL: 8]

CERTH has developed the module to support intelligent clustering of dispersed small-sized prosumers, using flexibility related indicators. During IANOS, the novel algorithms would consider several user and assets' profiles, until validated within several clusters of prosumers in a real environment.

The aggregation and classification tool is under development and will be designed considering all the requirements defined within IANOS project aiming to achieve the TRL 8, while the Task 4.2 is taking place between M18-M32. Through the aggregation module the raw data will be converted to the appropriate format and will be served as inputs to the classification. The classification process will provide clustering mechanisms to create groups of energy pools with common characteristics depending on the relevant clustering strategy.

Forecasting engine [target TRL: 8]

UBETECH and CERTH forecasting tools will be advanced to support: i) training/finetuning of core forecasting algorithms addressing specific challenges, i.e., high RES penetration, sector coupling, weak network/low capacity corridors/inertia and flexibility services, ii) data management and processing as prescribed by IANOS architecture.

The forecasting engine is currently on TRL 6 and is limited only to forecasting demand and solar generation. Within IANOS project additional forecasts for the rest of the generation units will be developed based on their own attributes and characteristics. The TRL should reach level 8 at the end of IANOS.

The forecasting engine is under development and will be designed considering all the requirements defined within IANOS project aiming to achieve the TRL 8, while the Task 4.2 is taking place between M18-M32. The forecasting engine will provide demand/generation forecasts for day-ahead and intra-day levels regarding all energy units included within IANOS project.

DLT-based Transactive Platform [target TRL: 7]

ENGINEERING will build on-top of the DLT blockchain-enabled VPP solution previously developed and empower it to integrate and deploy a multi-layered VPP architecture, seamless incorporating a scalable hybrid IoT/on chain cross-stakeholder data governance layer, fully integrated with a decentralised P2P optimised coordination of flexibility resources.

By the end of the project a TRL of 7 will be reached.

Virtual Energy Console [target TRL: 8]

The virtual energy console is under development and will be specially designed with the requirements of IANOS project. The dashboard will allow the VPP operator to easily access different dataset and important information in line with IANOS KPIs such as generation mix of the VPP portfolio, penetration of RES in the system and historical data.

The platform KIPLO, supporting the iVPP, is composed by a logical architecture with different modules. Some of the modules are required to be updated and expanded to accommodate the new functions developed during the project.
A significant upgrade to the platform compatibility and capacity to integrate new energy assets has been performed and will continue during IANOS.
At the end of the project, the innovative elements included in the expansion of the virtual energy console should result in a TRL of 8.
Enterprise Service Bus [target TRL: 8]
ETRA I&D has already tested and made the technology ready for its use in real conditions. Within IANOS, both SGAM and BRIDGE guidelines will be followed to meet with the high-quality data management standards, that iVPP requires.
The departing TRL is 6 during IANOS will be evolved to a TRL of 8.

Associated risks

Aggregation & Classification:

- As the aggregation & classification tool deals with raw data of many heterogeneous sources, data transmission problems may occur resulting in lack of data.
- Another important issue during the management and the processing of the huge amount of data lies in the fact of data privacy.

Forecasting Engine:

- The proper development of forecasting models is based on the amount and the quality of the data. Within IANOS project where multiple forecasts from heterogeneous sources are required, there is a high probability of data transmission problems resulting in a lack of data.
- Another impending challenge is the fact that the vRES units are characterised by high stochasticity and volatility as they are highly dependent on weather changes and therefore, inaccurate forecasts can be provided to the CD leading in false estimated setpoints.

Virtual Energy Console:

- The tool will be developed in line with the Portuguese and Netherlands regulatory framework, which VPS is familiar with. No major regulatory risks are foreseen.
- The only technical foreseen risk is related to the adequate design and implementation of the human-computer interface, which is time-consuming and presents several challenges. Some of the challenges are related to the available technology: existing limitations of programming languages and design tools, that can limit for instance, the level of detail of graphics and their intuitiveness and user friendliness.
- The platform communicates with the IoT devices and energy assets mainly using secure and standard TCP/IP and MQTT protocols. Other protocols and API support will be added to the platform to assure interoperability among all market vendors, according to the needs of each pilot site. Even so, there are risks and issues associated with the interoperability, especially with the already installed energy assets, that in some cases were not prepared to be remotely managed/controlled or use closed manufacturers protocols. Depending on the type of energy asset, there are now available several hardware tools for interfacing between different protocols, that can be used to overcome interoperability issues that may occur. If not possible, the possibility to develop a new hardware will be thought and even other possibilities

will be considered, namely the interaction with vendors to discuss potential upgrades or the use of other vendor tools – software and hardware.

Mitigation measures

Aggregation & Classification:

- All the cases of false or missing data acquisition can be managed by applying appropriate pre-processing techniques, such as adopting outlier detection and data imputation techniques – interpolation/extrapolation.
- Regarding the data privacy issues, well-proven technologies and standards for the protection of consumer identity will be adopted.

Forecasting Engine:

- To deal with the high volatility of the vRES units, an accurate weather forecast service is required providing the forecasting engine with reliable information.

Virtual Energy Console:

- Digital tools based on advanced AI algorithms and remote automatization are required to help aggregators and/or retailers to optimally manage all energy assets from demand and supply side. The existing KIPLO core platform back office already runs AI and optimisation features, comprising machine learning algorithms and advanced data analysis and forecast for VPP deployment. These algorithms will be further enhanced during the project using also external iVPP components being further developed by third parties. The training of the algorithms will be performed using testing data at first and then real-world data from the use cases, that will provide their assessment and validation. These algorithms are based on models and predictive methods that may not completely be able to forecast the dynamics and complexity of all associated variables and restrictions. To mitigate this risk, a possible solution may be to use the access to the real-time data and control to perform the necessary adjustments to correct potential gaps from the algorithms forecast.
- Efforts will be made, to as much as possible, comply with all the functional and non-functional requirements and have the most intuitive and user-friendly interface design.

4 Dimensioning, specification, testing and installation requirements

In this section, following on the previously described development plans, the solutions' technical specification and the major installation requirements are identified, apart from any relevant testing protocols to consider that may be aligned with the technology providers' expectations on the field testing and commissioning procedures to implement at the LHI environment.

4.1 PV panels and microinverter (BeOn)

Technical specification

- Nominal power, for each installation (W): 1.500,00 W, 5X300W
- Dimensions (square meters): 10, around 2 sqm per panel
- Max voltage (V): 49 V DC, 230 V AC

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

Testing and installation requirements

The space needed is about 10sqm.

4.2 Heat battery (Sunamp)

Technical specification

Table 1 Heat battery's technical specifications

WIDTH X HEIGHT X DEPTH (MM)	575 X 429 X 365
GROSS WEIGHT (KG)	72
NET WEIGHT (KG)	70
HEAT STORAGE CAPACITY (KWH)	3,5
WATER CONTENT (L)	SINGLE PORT
DUAL PORT (COMBINED)	N/A
EQUIVALENT HOT WATER CYLINDER SIZE (L)	71
V40, VOLUME OF HOT WATER AVAILABLE AT 40°C (L)	85
STANDBY HEAT LOSS RATE (KWH / 24H (W))	0.48 / (20)
ENERGY EFFICIENCY RATING CLASS	C
RECOMMENDED MAXIMUM HW FLOW RATE (L/MIN)	6
MINIMUM MAINS SUPPLY PRESSURE AT INLET OF HEAT BATTERY (BAR)	1,5
MAXIMUM WORKING PRESSURE (MPA / (BAR))	1,0 (10)
HOT WATER OUTLET TEMPERATURE AT DESIGN FLOW RATE (°C)	45-55
CONNECTED LOAD AT ~ 230 V, 50HZ (W)	2.800,00
POWER SUPPLY / STANDBY CONSUMPTION (W)	1 PH ~ 230 V / 7
ELECTRICAL EFFICIENCY (HELECWH) (%)	81,4
ANNUAL ELECTRICITY CONSUMPTION (KWH/ANNUM)	542
TAPPING CYCLE:	S

Testing and installation requirements

- The heat battery is suitable for indoor use only.
- Due to the weight of the heat battery, ensure the floor is level, sound and capable of supporting its weight.
- Allow for space of 150mm around the heat battery, i.e. to view LED lights, and space of 450mm above it, i.e. to remove the lid if necessary.

4.3 Electric water heaters (UniNova)

Technical specification

- This innovative element consider within the scope of IANOS is to be applied to 1.5 kW power electric water heaters – 230 V –, with a maximum capacity of 150 litres.
- The solution comprises the installation of the following components:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

- A set of sensors to acquire temperature and power data, which are installed on existing domestic electric water heaters.
    - A microcontroller with Wi-Fi communication capabilities to collect and send data, while also receiving the control signals that define the state of the heating element – on or off.
    - An actuator that enables the supply of power to the heating element.

Testing and installation requirements

- A cubic space with 30X30X30 cm is needed at the water heater electric socket. Additionally, a cubic space with 20X20X20 cm is needed at the water heater's hot water output.
- These cubic spaces should be available to IANOS personnel.
- Moreover, local Wi-Fi connection is required. These cubic spaces should be available to IANOS personnel.

4.4 HEMS (VPS)

Technical specification

Table 2 HEMS' technical specifications

ASSET TYPE	MAXIMUM LIMIT CAPACITY	
	Monitor / Device	Manage / Device
LOADS (SOCKETS) – USING WI-FI PLUG	16A 3kW	16A 3kW
LOADS (GENERIC) – USING DIN-RAIL ZIGBEE DEVICES INSTALLED ON DISTRIBUTION BOARDS	From 16A to 32A	From 16A to 32A
LOADS (GENERIC) – USING DEVICES (METERS AND I/O + CONTACTORS) INSTALLED ON DISTRIBUTION BOARDS	Direct measurement: 100A AC (1 Phase); 65A AC (3 Phase)	Control: 25A (1 Phase); 25A to 63A (3 Phase), others on request
LOADS (SMART APPLIANCES) – USING WI-FI INTEGRATION	Depend on appliance, typical: 2 kW	Depend on appliance, typical: 2 kW
LOADS (HVAC) – USING DEVICES (METERS AND I/O) INSTALLED ON DISTRIBUTION BOARDS	Direct measurement: 100A AC (1 Phase); 65A AC (3 Phase)	Control: using digital output signal.
LOADS (WATER HEATER)	16A 3kW	16A 3kW
GENERATION (SOLAR PV) - USING INTEGRATION WITH INVERTER	Dependent on individual inverter rated capacity: (from 1.5 kW to 50 kW). Capacity can be increased by grouping inverters.	
STORAGE (BATTERIES) - USING INTEGRATION WITH INVERTER	Dependent on individual inverter rated capacity: (from 0.8 kVA to 10 kVA). Capacity can be increased by grouping inverters.	

Testing and installation requirements

- The HEMS platform will be installed on a cloud-based platform. It will communicate with the equipment's through a central local unit – gateway – that can be connected to an ethernet cable, to WiFi or GPRS/3G/LTE.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

- As for the hardware equipment installation requirements, these depend on the type of flexible loads to be monitored and controlled, and on the manufacturers, but here are some examples that may be installed on Terceira pilot:
    - The VPS gateway, which is much smaller than a common household internet router. Must be connected to a common household plug and to the internet through an ethernet cable. Other gateways are available, namely using WiFi or GPRS/3G/LTE, that must be connected in the din rail of the mains switch board. This operation must be performed by a qualified electrician.
    - VPS smart plugs, which have no special requirements in terms of installation procedures are plug and play devices that will automatically pair with the gateway.
    - VPS smart meters, that will need to be installed by a qualified electrician on the switch board and will also automatically pair with the gateway.
- As for the other hardware components, namely the inverters and PV systems the PCM heat batteries, the water heaters and the battery based ESS, the manufacturers installation procedures must be followed.
  In terms of other required installation procedures, namely the need to install other communication transmitter hardware, more details will be acquired during the development phase of the integration of these equipment's in collaboration with the manufacturers.
- Ideally the initial integration activities testing phase needs to be performed in VPS facilities, using physically installed third-party equipment's. If not possible, some procedures could be performed remotely, depending on the equipment characteristics and access permission granted. This initial phase could run for at least one to two months. After this, when the equipment is fully integrated with the VPS HEMS and remote access is granted and reliable, other testing procedures can be performed after equipment's are physically installed on the pilot sites, during the pilot monitoring phase.

4.5 Smart energy router (UniNova)

Technical specification

Table 3 Smart energy router's technical specification

INPUT PV SYSTEM (DC)	
MAX. PV ARRAY POWER	5.000,00 Wp
INPUT VOLTAGE RANGE	300 V to 800 V
MPP VOLTAGE RANGE	350 V to 750 V
RATED INPUT VOLTAGE	550 V
MAX. INPUT CURRENT INPUT A / INPUT B	7.5 A / 7.5 A
MAX. DC SHORT-CIRCUIT CURRENT INPUT A / INPUT B	12.5 A / 12.5 A
NUMBER OF INDEPENDENT MPP INPUTS	2
INPUT/OUTPUT GRID (AC)	
RATED POWER (AT 230 V, 50 HZ)	5.000,00 W

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

MAX. APPARENT AC POWER	5.000,00 VA
POWER FACTOR RANGE	0.7 lag to 0.7 lead
NOMINAL AC VOLTAGE	3-NPE 400 V / 230 V
RATED GRID FREQUENCY / RATED GRID VOLTAGE	50 Hz / 230 V
MAX. INPUT/OUTPUT CURRENT	3 x 7.5 A
MAX. INPUT/OUTPUT OVERCURRENT PROTECTION	12 A
TOTAL HARMONIC DISTORTION	5 %
PHASES	3
GENERAL DATA	
DIMENSIONS (W X H X D)	300 mm x 500 mm x 200 mm
OPERATING TEMPERATURE	0 °C to 60 °C
TOPOLOGY / COOLING METHOD	Transformerless / convection
MAXIMUM SWITCHING FREQUENCY	50 kHz

Testing and installation requirements

- Two smart energy routers will be installed at residential or services buildings with three phase power supply. All equipment will be installed behind the meter. PV generation must be available on-site and Smart Energy Routers will substitute the existing power inverters. An indoor cubic space with 1x1x1 meters is required for the installation. This cubic space should be available to IANOS personnel but not for the buildings' users. Local Wi-Fi connection is required.

4.6 Flywheel (Teraloop)

Technical specification

Table 4 Flywheel's technical specifications

MAXIMUM POWER RATE (KW)	100,00
MAXIMUM ENERGY RATE (KWH)	3,00
MAXIMUM ENERGY STORAGE RATE (KJ)	10.800,00
MAXIMUM EFFICIENCY (%)	95

FLYWHEEL TYPE	Hubless rotor, magnetic bearings, vacuum
OPERATING ROTATIONAL SPEED (RPM)	6000 – 18000
FLYWHEEL RUNTIME (SEC) (LOAD)	3600 (3kW), 512 (25kW), 216 (50kW), 162 (75kW), 108 (100kW)
FLYWHEEL RECHARGE TIME (SEC@100KW)	130
SELF-DISCHARGE (H)	1
DC LINK VOLTAGE (VDC)	400-750

DUTY CYCLING (MIN)	4 (minimum full cycle, discharge and recharge time combined)
OPERATING TEMPERATURE (°C)	-25 to 40
CABINET DIMENSIONS (MM)	2 x 1000 (width), 800 (depth), 2000 (height)
INGRESS PROTECTION (IEC 60509:1989)	IP61 (flywheel with vacuum cover), IP48 (cabinets)
GRID OPERATING VOLTAGE (VLL)	380/400/415 VAC 3-phase, 4-wire plus ground
FREQUENCY (HZ)	50/60
POWER (KW)	100
POWER FACTOR	0.99 at rated load and nominal voltage
PHASES	3
SURGE WITHSTAND	Meets IEEE 587/ANSI C62.41
WEIGHT (KG)	750 (flywheel only), 1200 (20kW AC), 2200 (100kW AC)
AUDIBLE NOISE (DBA)	<75 (at 1 meter)
OPERATING TEMPERATURE (°C)	0 to 40 (cabinet)
STORAGE TEMPERATURE (°C)	-25 to 70 (flywheel)
HUMIDITY (%)	5 to 95 (non-condensing)
EMISSIONS AND IMMUNITY	EN 62040-2
CONNECTIVITY	System to grid or flywheel to DC link

Testing and installation requirements

- Concrete bed/floor with four M33 size thread rods for machine attachment. Rods anchored to the concrete foundation. Foundation must be able to sustain a mass of 1500kg
- Dry environment with good ventilation
- Flywheel space requirement: 2x2x2 m, including vacuum and cooling system
- Power electronics space requirement: 2x1x2 m
- Flywheel and power electronics to be installed in the same facility
- Connection requirement: 400Vac 3x250A main fuse for 100 kW machine
- Additionally, 230Vac 3x16A and 16A sockets required for the auxiliary systems

The connection to the grid will pass through power electronics provided by Siemens Plc, which are readily available off the shelf and include the grid capability to be tested for the iVPP. This connection should already be qualified by Siemens. Testing will be required to verify the operation for IANOS.
The test plan must be in cooperation with IANOS since they control the grid.
The indicative testing timeline will follow the IANOS Gantt Chart:

- Installation & Commissioning - follows original project GANTT chart T6.3.
- Use case testing - follows original project GANTT chart T6.4.
- Optimisation of the algorithms - follows original project GANTT chart T6.4.
- Performance Monitoring - follows original project GANTT chart T6.4.

4.7 V2G EV charger (EFACEC)

Technical specification

- Rated power (kVA): 10,00
- Grid connection: three-phase + neutral, 400 V+-10 % / 50 Hz.

Testing and installation requirements

- The V2G chargers are wall mounted equipment. The dimensions – WxHxD – of the wall box are 650x650x250 mm, excluding the cable connection. A free space around the equipment should be considered for user access and to manipulate the charging cable. Moreover, the equipment is rated as IP44. The place of installation may need additional protection/filtering conditions, if necessary. Additionally, there should not be a direct exposure the sunlight.
- The detailed testing plan is up to be defined yet, but should cover at least power tests, for charging and discharging, frequency regulation support, power quality tests, interface and communication tests, user authentication and user interface, and power quality parameters.

4.8 Hybrid transformer (EFACEC)

Technical specification

- Rated power (kVA): 400,00
- Rated voltage (V): 15.000,00 ± 2 x 2,5% / 420,00/242,00 ± 12%

Testing and installation requirements

- It will be necessary space for the installation of the distribution transformer, approximately 1510 mm x 1380 mm x 900 mm, and for the cabinet that will contain the control and voltage regulation component.
- Cellular signal for communication between the hybrid transformer and EFACEC platform.
- Industrial low voltage supply for auxiliary systems, e.g. 400Vac 3~.

The factory testing phase will follow the development plan and will be conducted as 4th step of the development stage, between July 2022 and September 2022.
The testing protocols applicable to the hybrid transformer are the ones foreseen within the scope of the normal standard inspections and test plans implemented by EFACEC to all the hermetically sealed distribution transformers, but it will be reformulated for the special case of the hybrid transformer.

4.9 Fog-Enabled Intelligent Devices – FEID-Plus (CERTH)

Technical specification

Fog-Enabled Intelligent Devices-Plus

Computing device equipped with a dual step-down current-mode DC-DC converter – PAM2306 – for power management and convention, from 5V input voltage to two outputs of 3.3V and 1.8V.

Processing

The main processing module for the FEID-PLUS is the Raspberry Pi Compute Module 3+ – CM3+. The module is equipped with a BCM2837B0 processor, 1Gbyte LPDDR2 RAM and eMMC Flash and supporting power circuitry.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

Operating characteristics of FEID-PLUS

- FEID-PLUS power consumption measured @ 5V DC
- Boot 0.25A
- Idle 0.45A/network connection
- Full 1.2A
- FEID-PLUS max voltage 5.5V
- FEID-PLUS
- Max current 1.5V

Dimensions

- FEID-PLUS PCB dimensions: 87 x 68 x 35mm
- FEID-PLUS enclosure dimensions: 96 x 72 x 50 (4 DIN positions)
- 1x Pluggable terminal blocks 2P: 5mm
- 1x Pluggable terminal blocks 6P: 5mm
- 1x Pluggable terminal blocks 7P: 3.5mm
- 1x 5V 2.4A power supply (1 DIN position): 90 x 17.5 x 54 mm

PSU

- Max supply voltage of PSU: 264V AC/370V DC
- Max power supply of PSU: 12W

Testing and installation requirements

For the installation of the FEID-PLUS the following are required:

- Indoor installation – does not have the necessary protection from weather, therefore it is not suitable for outdoor areas.
- Power supply 5VDC.
- Ethernet – connection to the local network for the configuration of the device.
- The testing phase will follow the development conclusion and should take place during the last three months of the development plan advanced.
- Several testing protocols must be conducted before the installation and operation in the pilot site. The testing protocols will be applied both on hardware and the software of the FEID-PLUS. Regarding the hardware testing, the first test is to check if every subsystem is being supplied with the required voltage level. After the initial setup and boot of the FEID-PLUS the peripherals of the device must be tested. Afterwards, the Ethernet and the Wi-Fi/BLE are checked and in both cases, an online file will be downloaded to check for internet connectivity. The remaining interfaces – SPI, UART, I2C, RS-232, RS-485 – will be tested by attaching a dummy device with embedded communication LEDs that blink on receiving protocol packet, after running an automated test script. Finally, the two relays will be tested using a test load.
- Regarding the software, a unit testing will be applied to evaluate the FEID-PLUS functionalities. The unit testing will cover the RESTful services, where the communication with external entities and the transfer of correct data will be checked. Furthermore, a functional testing should be applied to the various software components that will be running on the device to check if the requirements specified within IANOS are accomplished, such as the accuracy of the forecasting tools, the

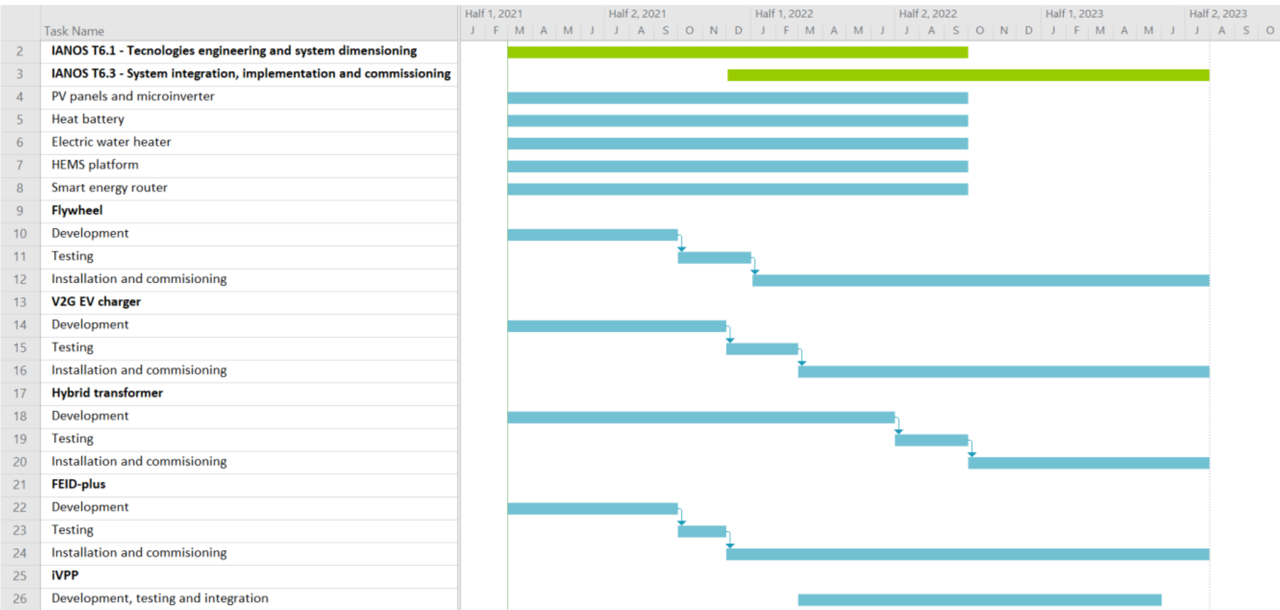
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

proper storage of the data etc. Finally, apart from the unit and functional testing, a benchmarking should be conducted between the FEID-PLUS and a virtual machine, to compare the performance in terms of execution speed of the entire implementation running on FEID.

5 Implementation Plan

Following the solutions' readiness assessment, to comprehensively address the expectations related to the implementation of the Terceira LHI demonstrator and considering the technologies roadmap envisioned, the following development, testing and installation schedule provisional is proposed.

Since all the solutions, both acquired and provided by project's partners, will be later tested in EDP's Smart Lab facilities, to check their integrability and operability in a controlled environment before the actual field commissioning, relevant testing protocols to be considered will be identified, and a preliminary test timeline will be defined in the next



deliverable of this task.

Figure 1 Development, testing and installation schedule

To summarise the TRL advancement prosed within the scope of IANOS, the following table highlights the departing and targeted TRLs for all the solutions considered within the scope of the Terceira LHI demonstrator.

Table 5 Technologies' TRL advancement

	Departing TRL	Targeted TRL
PV PANELS AND MICROINVERTER	6	8
HEAT BATTERY	7	8
ELECTRIC WATER HEATER	4	7
HEMS	9 (platform)	9 (platform)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

	6 (interfaces and integrability)	8 (interfaces and integrability)
SMART ENERGY ROUTER	5	7
FLYWHEEL	6	8
V2G EV CHARGER	5	7
HYBRID TRANSFORMER	5	7
FEID-PLUS	6	8
VPP – SOLUTIONS		
REFLEX	6	8
OPTIMEMS TOOLSET	6	8
KIPLO	6	8
VPP – MODULES		
AGGREGATION AND CLASSIFICATION	6	8
FORECASTING ENGINE	6	8
DLT-BASED TRANSACTIVE PLATFORM	5	7
VIRTUAL ENERGY CONSOLE	6	8
ENTERPRISE SERVICE BUS	6	8

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 957810

IANOS

SUSTAINABLE SOLUTIONS
for islands' decarbonisation

H2020-LC-SC3-2018-2019-2020 / H2020-LC-SC3-2020-EC-ES-SCC
EUROPEAN COMMISSION
Innovation and Networks Executive Agency
Grant agreement no. 957810