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IANOS

SUSTAINABLE SOLUTIONS
for islands' decarbonisation

D3.8

Decision Support Toolset Pre-Validation/Assessment of LH & Fellow Islands Plans_v2

AUTHORS:

Anastasis Tzoumpas, Athanasios Bachoumis, Katerina Drivakou, Ermis Vasileiou, Magda Foti, Kostas Mylonas (UBE)

Enrico Salvatore, Corinna Ponti (RINA-C)

Nuno Santos Lopes (RGA)

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Executive Summary

The assessment of investment activities is a pillar in strategic management at any level. When investment activities involve the deployment of projects, project evaluation aims at determining the effects caused to foster the best allocation of scarce resources. In project evaluation, laws of economics are pivotal to determine the profitability of an initiative. However, projects that also have a social interest must be assessed considering a broader range of impacts. Assessment shall be performed before project deployment to forecast the effects expected (ex-ante), during project deployment to check the performance level and to identify corrective measures (in medias res) and after the time horizon of the project to verify the actual impacts generated (ex-post). Cost-benefit analysis (CBA) is the most acknowledged tool for financial viability assessment. CBA provides a wider project assessment by considering soft effects and intangible and non-monetizable impacts.

Therefore, the decision-makers across the energy value chain need a tool that can provide quantifiable insights supporting their potential investment decisions in clean and smart energy interventions. Toward that direction, the activities of WP3 aim at proposing an IANOS Energy Planning and Transition (IEPT) suite that supports the investments of the different stakeholders, providing a holistic approach that quantifies both the costs and the benefits of the IANOS interventions in the demonstration sites, i.e., Lighthouse and Fellow Islands of IANOS, as well as providing a tool that facilitates the fundraising campaigns.

The main objective of Task 3.4 is to conduct a pre-validation of the IEPT suite, in order to justify its applicability and fitness level to the intervention activities that take place in the IANOS demonstrators. The work of this task is consolidated and presented in this deliverable (D3.8), which is the updated version of deliverable D3.7, taking into account all relevant information regarding the IANOS activities up to M30.

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To fulfil the objectives of Task 3.4, D3.8 briefly presents the components and functionalities of the IEPT suite. Afterwards, a literature review analysis is carried out, to assess the existing regulatory framework in place in the Lighthouse and Fellow Islands of the IANOS project. The long-term planning procedures regarding the innovative smart grid interventions are also presented. In addition, in order to validate and test the functionalities of the IEPT suite, a thorough investigation and description of the electricity and gas networks for each country is provided. Specific information about the transmission and distribution operators in both energy networks is included. This information will be used not only as an input for the IEPT suite and particularly for its CBA component, but also as an additional explanatory element which reflects the current conditions/dimensions used in the investment practices of the Operators.

Following the literature review, this deliverable presents the dimensioning of the used assets and the scenarios that will be tested by each demonstrator. The content and the information reported in this deliverable describes the progress of the project up to M30. In addition, the information describing the status in M30 regarding the power system topology that those assets will be installed on, has been described in the other IANOS WPs and has been taken into in order to perform the pre-validation of the interoperability scenarios. Finally, for each Use Case, the benefits, along with the defined KPIs that are linked to the IEPT suite are presented. A screening process takes place, where from those KPIs that are linked to the IEPT suite, the ones that can be monetized through the KPI component are presented. These KPIs provide fine-grained quantified insights for the decision-makers, enabling them to better assess the smart grid interventions.

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List of abbreviations and acronyms

Abbreviation	Description
CBA	Cost-Benefit Analysis
CEC	Citizens Energy Communities
DER	Distributed Energy Resources
DLT	Distributed Ledger Technology
DSO	Distribution System Operator
FI	Fellow Islands
FiP	Feed-in-Premium
FiT	Feed-In-Tariff
HV	High Voltage
ICT	Information and Communication Technology
IEPT	IANOS Energy Planning and Transition
KPI	Key Performance Indicators
LCA	Life Cycle Analysis
LCC	Life Cycle Cost
LH	Lighthouse Islands
LV	Low Voltage
ML	Machine Learning
MV	Medium Voltage
NDP	Network Development Plan
OHL	Overhead Lines
RES	Renewable Energy Sources
TSO	Transmission System Operator
UC	Use Case
WACC	Weighted Average Cost of Capital
WP	Work Package
GUI	Graphical User Interface

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1. Introduction

1.1 Objectives and Scope

The overall objective of WP3 was to develop a concrete energy planning and decision-making toolkit to assist the energy transition of geographical islands, integrating a dedicated web platform for Life Cycle Analysis (LCA)/Life Cycle Cost (LCC) studies, an equity crowdfunding tool, power system modelling capabilities, simulation tools and a Cost-Benefit Analysis (CBA) tool. The main objective of Task 3.4 was to produce practical feedback to finetune the efficiency of the toolset regarding calculations and functionalities, by examining holistically the smart grid solutions in the Lighthouse (LH) and Fellow Islands (FI), using the developed toolset. Within the scope of Task 3.4, the regulation set in the geographical area, incentivizing and reimbursing innovation, as well as the operators' long-term planning procedures were considered. In addition, an assessment of the IANOS Use Cases (UCs) was performed and a pre-validation of the decision support toolset and the interoperability aspects was conducted.

1.2 Relation to other IANOS activities

As shown in Figure 1, Task 3.4 is closely interrelated with the rest of the tasks of WP3, as well as with WP2, WP7 and WP9 activities. More specifically:

- Input from WP2: This WP integrated the developed market design concepts with the findings of Task 2.3 and the results coming from the demo clusters.
- Output to WP7: This WP will use the initial assessment of LH and FI plans as a starting point for performing the technical, social and impact assessment of the IANOS solutions.
- Output to WP9: Based on the Task 3.4 output, WP9 will assess the scalability and replicability potential of IANOS UCs in the LH and FI.

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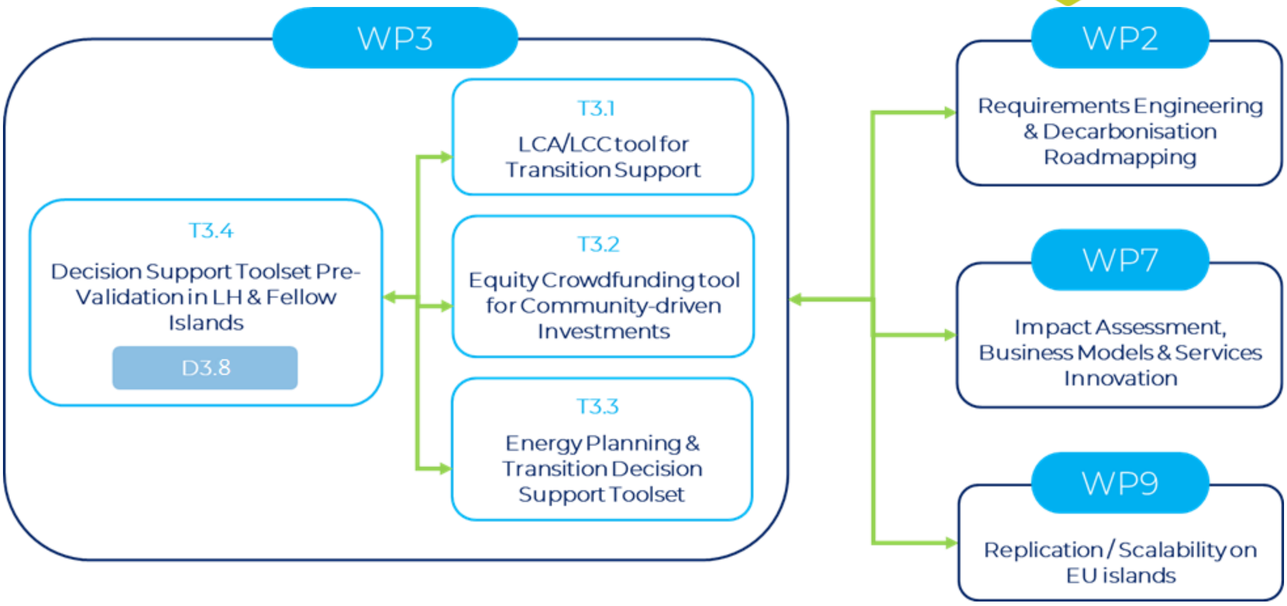

Figure 1: Interactions between Task 3.4 and other WPs in the IANOS project.

1.3 Deliverable outline

This deliverable aimed to present the respective work carried out in Task 3.4, including the pre-validation of the decision support toolkit in the LH and FI. First, Chapter 2 provides an overview of the decision support toolkit and its main functionalities. Chapter 3 presents the existing regulatory barriers to innovation that IANOS islands face and the long-term planning processes of System Operators.

Then, Chapter 4 describes the IANOS UCs in detail and performs an initial assessment, while Chapter 5 presents a relation among the KPIs calculated for each UC, their calculation engines and an initial assessment for their utilization in the IEPT suite. In Chapter 6 the interoperability of the IEPT suite is validated by presenting the tests that were conducted, considering different interoperability aspects and operational scenarios, as well as the IEPT suite GUI functionalities. Finally, in Chapter 7 the work of Task 3.4 is concluded.

1.4 Extension to D3.7

The current deliverable (D3.8) is an updated version of D3.7. New sections were added and some of the content was modified to accurately reflect the status of the project up to M30. Specifically, the changes from the previous version include:

- Chapter 3: New information in section 3.4 regarding financial support mechanisms for RES integration at French Polynesia.
- Chapter 4: Completed dimensioning of assets for both LH islands and added a brief description of each of the UCs' scenarios.
- Chapter 5: Updated KPIs mapping according to deliverable D2.3.
- Chapter 6: New chapter describing the IEPT tools' interoperability validation process and the IEPT suite's GUI functionalities.
- The rest of the content was updated accordingly, based on all available information and progress of the project up to M30.

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2. Overview of Decision Support Toolset

During the WP3 activities, a concrete IANOS Energy Planning and Transition toolkit (IEPT suite) was developed to assist with the decision-making regarding the energy transition of the Lighthouse (LH) and Fellow Islands (FI). IEPT suite constitutes a holistic tool able to evaluate the overall benefits expected from clean energy/smart grid interventions, from various perspectives, based on the viewpoint of each stakeholder (Municipalities, Distribution System Operators (DSOs), community representatives, etc.). This toolkit is pre-validated in this deliverable (D3.8), where the LH and FI UCs are evaluated holistically for their sustainability, scalability and replicability potential according to all relevant information up to M30 of the project.

The different components that have been integrated under a unified concept are the following:

a) VERIFY District Platform (VERIFY-D): A dedicated web platform for Life Cycle Analysis (LCA)/Life Cycle Cost (LCC) studies. Environmental and economic analyses are expected through the computation of emissions extracted (life cycle environmental footprint), which depend on the technology applied in the grid and the type of fuel mixture used to generate energy in the LH Islands. Also, this tool will compute the life cycle cost based on the energy components that appear in the energy grid. Finally, it will make a comparison between baseline and target scenarios in terms of environmental gains and economic profits.

b) An equity crowdfunding tool (CrowdEq): This tool will create a crowd-equity (or crowdfunding) platform, where actors (i.e., project investors, islanders and other key stakeholders) will be able to register their foreseen projects and set a funding goal in return for equity, creating a fundraising campaign. The platform would ultimately enable fractional ownership of RE assets, supporting projects' fundraising and

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transactions either via normal FIAT currency or tokenized energy over Distributed Ledger Technology (DLT).

c) Energy System Simulator (ESSIM): This tool simulates network balancing and the effects, thereof, in an interconnected hybrid energy system over a period of time. It takes as input the energy system defined in ESDL and calculates the optimal schedule of flexible producers and the effect of this schedule in terms of emissions, costs, load on the network, etc.

d) INTegrated Energy Management Simulator (INTEMA.grid): It is an energy system modelling and simulation platform. It is based on open-source non-proprietary tools. It is composed of the following main components: (a) Power System Simulations–Based on the acausal, object-oriented, equation based Modelica language to conveniently model complex physical systems, (b) Power Optimization–Ability to construct optimization problems using Python optimization tool pyomo along with the neos-server that provides the required solvers and (c) Power Forecasting–Utilizing open-source Machine Learning (ML) frameworks in Python, i.e., scikit-learn and Keras.

e) A Cost-Benefit Analysis tool (CBA): The CBA tool was based on the JRC's and ENTSO-E's CBA methodologies. For this reason and depending on the activities and vision of the various stakeholders, the factors of interest will be selected and respective KPIs will be calculated to assist them in setting strategic priorities, aligning horizontally in all cases with the priorities set by the EU Green Deal. The CBA tool offers an analytical approach for the stakeholders/investors and provides a quantifiable insight regarding whether a smart grid intervention exceeds the existing baseline scenario in terms of costs and benefits. This tool is considered as the cornerstone of the IEPT suite and will assist the activities in several tasks across the WPs of IANOS, such as the CBA of WP7 and the scalability and replicability studies activities that will be conducted in WP9.

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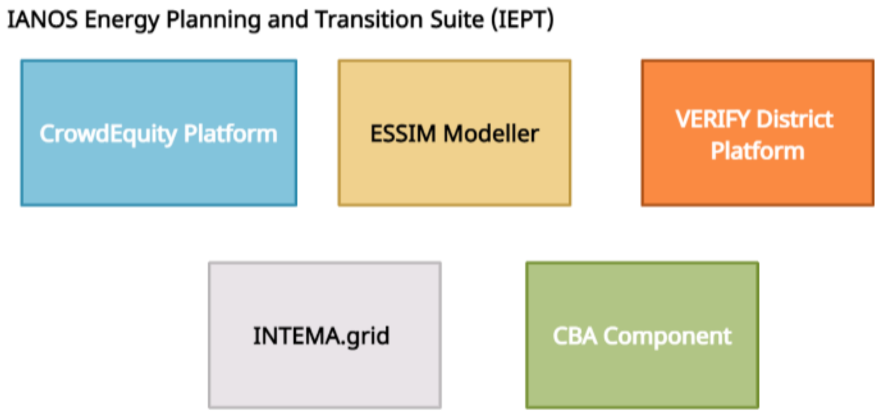

Figure 2: Conceptual Model of the IEPT suite.

3. Regulatory barriers landscape and planning procedures in IANOS islands

A brief overview of the existing regulatory barriers to innovation that IANOS Lighthouse (LH) and Fellow Islands (FI) face and a description of the existing long-term planning processes and the regulatory framework for investment of the system operators.

3.1 Regulatory barriers to innovation

Island territories that are not connected to the mainland grid have some peculiarities deriving from their high level of isolation, like higher cost of energy, grid instability and high energy dependence. For these reasons, they are the subject of specific regulation and policies under the EU, national and local legislation. In this context, for deliverable D2.4 entitled as "Report on regulatory/legal and financial aspects", a questionnaire was circulated aiming at collecting this information directly from the islands' authorities. This contribution can be considered as an integration of the future questionnaire output with other external literature, aiming at collecting relevant information about regulations applied on the different locations on the IANOS Islands on a national and on a local level, underlying potential challenges in the area.

Regarding Portugal, Greece and French territories, a work published in [1] offers a good review of all regulatory challenges for the implementation of renewable energy system on isolated islands, identifying some domains of action.

- Remuneration scheme

Greece: Feed-in-Premium (FiP) scheme in 2014, that adds a premium to price received by renewable generators in the wholesale electricity market. The FiP Contracts of renewable energy projects participate in the wholesale electricity

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market (either directly or through aggregators) and enter with zero price energy offers on an hourly basis. Regarding renewable energy from hybrid stations there was still not a clear remuneration mechanism, as a special tariff only of hybrid stations is currently under consideration. The pricing issue is a main barrier for the project as the framework mainly refers to pumping systems rather than battery-powered hybrid stations.

Azores: The Regional Legislative Decree No. 26/2006/A [2], subsequently updated by the Regional Legislative Decree No. 5/2010/A and the Regional Legislative Decree No. 14/2019/A [3], defines an additional remuneration mechanism known as PROENERGIA or "System of Incentives for the production of energy from renewable sources". The support for electric energy production, electric energy storage and heat energy production covers 25% of eligible expenses, while the support for domestic hot water production covers 35% of eligible expenses. Grant bonuses are foreseen according to specific Azorean Islands: Pico and Faial (+5%); Santa Maria (+10%); Graciosa, São Jorge, Flores and Corvo (+12%) [4].

French territories: In France, renewable energy is also promoted through feed in laws and competitive tenders. More concretely, a combination of Feed-In-Tariffs (FiTs) for installations below 500 kW and FiPs for installations above 500 kW has been in place since 2015. The overseas departments are subject to this special remuneration, which defines a guaranteed purchase price over a period of 15-20 years. In order to deal with the problems of energy security during load peaks in extreme weather events, the maximum share of intermittent generation is legally limited to 30% within the island's electricity grid [5].

- Unified price electricity systems

Insular systems also have higher investment and operating costs, which normally should have been translated into the electricity prices the consumers pay monthly. All the examined cases have unified price systems, which want to play down the differences in the prices between islands and the mainland that can lead to discrimination.

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However, the unified price systems although aim to ensure fair prices and to avoid discrimination between the habitants of mainland and the islands do not allow for a pricing structure that reflects the cost of energy production and thus, promote the renewable energy [6]. This creates various issues, such as the costly and underperforming hybrid station in the island of Tilos in Greece, but also in cases of resistance from the local population, which does not recognize to have any direct economic benefit from the deployment of Renewable Energy Sources (RES). Other issues include the rising costs for the governments that can lead to deficits, and economic disincentives for the electrical utilities which are forced to sell power on these islands at the same price.

- Energy storage systems

This is a crucial point as until the various barriers in storage technology are overcome it will be difficult to achieve 100% self-sufficiency. Greece was the first European country to adopt specific regulation regarding the installation of hybrid systems [7]. According to this framework, there are two different tariffs, one for the electricity that is fed to the grid and one for the electricity that comes from storage units. Additionally, there is a limited amount of energy from the grid that can be used to store and only be used when RES is not available. There is the need for improvements in the legal framework for hybrid systems, in particular in the regulation "dealing with battery technology". Regarding Portugal and French territories there was a lack of coherent regulation regarding energy storage systems, at least up to 2020.

In this regard, very recently in Ireland the "Renewable Energy Regulations 2022" was published, which also cover energy storage systems [8]. In particular, the regulation declares the rights of **active costumers which own an energy storage facility**: they shall be offered the transmission or distribution system within a reasonable time since their application, should not be subject to any double charges, for stored electricity remaining within their premises or when providing flexibility services to system operators, object to disproportionate licensing requirements or fees and they may provide several services simultaneously, if that is technically feasible. Regarding RES **self-consumers** (individually or through

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aggregators), they can generate renewable energy for their own usage and also store and sell their excess production of renewable electricity, through the Power Purchase agreements (PPAs), electricity suppliers/retailers and Peer-to-Peer (P2P) trading arrangements, without being subject to any discriminatory or disproportionate policies and fees. They may install electricity storage systems combined with installations generating renewable electricity for self-consumption, without any double fees. We could expect that this regulation will formulate the regional ones.

Regarding the **Lampedusa** case, according to [9], the main regulation barriers to a massive penetration of RES in Sicily's islands are:

- <u>Economic</u>: Since the early years after the World War II, to lower the electricity bill paid by the inhabitants of Italy's remote island, the Italian government paid a subsidy to the local utilities burning diesel fuel transported at high cost with ships. This could lead to a disincentive for the implementation of RES.
- <u>Environmental and landscape constraints</u>: Old regional regulation which demands every building's owner willing to install solar modules to undergo a tedious authorization route with authorities in the Sicily's mainland.

Fortunately, this is rapidly changing and Sicily "Piano Energetico Ambientale della Regione SICILIA" (PEARS) [10] has been updated and will also shape future regulations. To meet the plan objectives, it is of vital importance the 'Programma Isole Minori (DM 14/02/2017)' [11]. According to this program, the remuneration of the producers (electricity network operators and third parties) will be commensurate with the cost of the fuel saved due to the lower consumption of the efficiently produced electricity, i.e., the cost of fuel avoided (cost avoided efficient) due to the replacement of the production of electricity from fossil sources through Best Available Technology with a similar amount of electricity from RES. Regarding landscape constraints, Presidential Decree no. 31/2017 identified the interventions excluded from the landscape authorization and those subjected to a simplified authorization procedure. Thanks to the multiple incentive possibilities of these plants, it is possible to foresee a consistent

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development of RES plants on the Sicilian Minor islands. Moreover, Lampedusa and Favignana islands have adopted the Action Plans for Sustainable Energy (PAES) [12], thanks to an agreement of Mayors program, coordinated and financed by the Regional Energy Department.

3.2 Long-term planning procedures

Transmission and Distribution on electricity grids, are activities subject to unbundling (Electricity Directive, 2009 hereafter E-Directive) [13]. The concept of unbundling requires 'vertically integrated' companies (a firm which performs activities ranging from production to distribution) to be 'unbundled' into a distribution and production and/or supply company. Today in Europe there is an estimated number of 48 Transmission System Operators (TSOs) and 2400 Distribution System Operators (DSOs), of which only 13% are subject to unbundling. More in-depth considerations on the different realities of European DSOs show a very fragmented landscape. The E-Directive does not require the separation of the assets' ownership; therefore, DSOs are required to be at least legally independent from vertically integrated undertakings (art. 26 E-Directive) to avoid any possible conflict of interest between system operation, and production and supply. In the Netherlands, unbundling goes beyond the minimum requirements of the E-Directive: the E-Act requires DSOs to be ownership unbundled. In other words, DSOs should be fully separated from production and supply companies (art. 10b E-Act).

More recently, in 2019, the European Commission proposed a new directive for the electricity markets, Directive 2019/944, also defining the role of the DSO in the market and setting the requirements for its independence. The required regulatory framework shall be provided by Member States in order to incentivise DSOs to procure flexibility services in the areas under their supervision. All customers should have access to electricity markets, where they can trade their self-generated electricity and potential flexibility [14].

Art. 32 of the Directive states that:

- the development of a distribution system shall be based on a transparent network development plan that the DSO shall publish at least every two years and shall submit to the regulatory authority,
- the network development plan shall provide transparency on the medium and long-term flexibility services needed and shall set out the planned investments for the next five-to-ten years, with particular emphasis on the main distribution infrastructure, which is required in order to connect new generation capacity and new loads, including recharging points for electric vehicles,
- the network development plan (NDP) shall also include the use of demand response, energy efficiency, energy storage facilities or other resources that the DSO will use as an alternative to system expansion.

The following topics from the European Commission's report in 2019 focus on the innovative services and roles that DSOs can play in the future transition towards carbon neutrality:

- collaboration with small legal entities (CECs - Citizen Energy Communities) which can undertake electricity generation or provide any other type of energy-related service,
- appropriately manage flexibility sources in the grid integrating RES, Electric Vehicles, and Distributed Energy Resources (DERs),
- DSOs investment plans should carefully reflect on the grid expansion and/or upgrade, in order to deliver the transition towards carbon neutrality.
- DSOs should ensure neutrality by no owning energy storage facilities and shall cooperate with TSOs sharing balancing services across their grids.

After briefly presenting the European framework, we analysed the national framework of the two LH islands.

Starting with the Netherlands, where the government considers as the overarching objective the low carbon dioxide energy supply system. In their 2015 Energy Report, the Dutch Ministry of Economic Affairs stated that for the energy system to be sustainable over time, it is expected to simultaneously serve public

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values availability, affordability and safety. However, a discrepancy between the Dutch legislator's objectives and the Dutch DSO's daily practice exists.

The DSO's primary task is the safeguarding of public values (such as availability, affordability and other qualities) which are inherent to the power system. Over the past two decades, the energy industry has radically changed through concentration, liberalisation, unbundling, privatisation and internationalisation. Energy transition is now a potentially more fundamental change which is affecting the energy sector. This phenomenon consists of a simultaneous decarbonisation, decentralisation and digitalisation. The change driver is the need to reduce the energy production and consumption impact on the planet. Achieving this transition also affects the DSO, which is steadily changing from a passive network operator to an active manager of a smart distribution system.

The provisions of the current Electricity Act (E-Act) and Gas Act (G-Act) contain a public value balance, determined by the government, which reflects the government's priorities for the energy sector prior to the roll-out of the energy transition. This balance has been translated into a number of DSOs obligations- such as:

- DSOs are legally obliged to invest in network upgrading, despite lower social cost alternatives sometimes being available.
- DSOs are legally obliged to keep creating gas networks and implementing gas connections, despite gas losing its importance as a consequence of electrification and the switching to heat.
- DSOs are legally obliged to charge all small consumers the same fixed connection fee, despite some consumers causing congestion which then triggers network upgrading.

DSOs acting in accordance with these dictated preferences for a long time contributed to the public value balance the government aimed for. Lately, this balance has come under pressure. The current E-Act and G-Act dictate DSOs to take decisions that disregard the technological changes brought about by the energy transition. Consequently, the public value trade-off, imposed by this legislation, is no longer perceived as resulting in a socially acceptable balance between public values.

On the other side, in Portugal, the Directive 2019/944 has been transposed into the National legal framework and according to Art. 40 DL 76/2019, the electricity HV and MV distribution networks operator must prepare, every two years in even years, a five-year development and investment plan (NDP) for its networks, based on the technical characterization of the current and planned network and supply & demand [15]. Similar process is done for the natural gas distribution networks (11 network operators plans) and, during odd years, for the electricity transmission network and the natural gas transmission network, storage facility and LNG terminal planning.

Relevant content of the development and investment plan are for instance objectives and planning strategy, main strategic vectors (security and quality of supply, network efficiency and access to new services), renewal and/or refurbishments of existing network assets, network resilience, e.g., moving existing overhead lines (OHLs) to underground cables, vegetation management, Information Communication Technology (ICT) & Cybersecurity, smart grids, risk analysis and investment costs and network tariffs impact assessment.

Both the HV and MV distribution networks in Portuguese mainland are a national concession operated by one network operator that presents the referred NDP. On the other hand, the LV distribution network is divided into 278 municipal concessions with their specific investments not being considered at the NDP approval process. However, as the supply points of MV distribution network are the interconnection points between MV and LV networks, major aspect of the LV planning is already included during the preparation of the MV network development at the NDP. In addition, as the HV and MV network operator is responsible for data collection and treatment from all the "smart" and "traditional" meters in all the HV, MV and LV networks, this facilitates the inclusion in the NDP of the strategic investment topic of smart grids, optimised distribution grid dispatch and local flexible markets.

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A first challenge for Portugal resulting from the Directive (EU) 2019/944 is to assure a better integration of the HV and MV network, along with the LV network development planning. This will allow to assume that the NDP represents an integrated distribution networks development and investment plan, recasting the national law in line with the recent European legislative developments. Major consequences to the distribution network are expected from the challenges resulting from the impact that technological developments, related to decarbonisation, digitalisation and decentralisation, will impose on available electrical distributed resources, i.e., PV and other RES generation, self-generation, storage, electric vehicles, etc.

3.3 Existing investment regulatory framework for operators and the relevance with Decision Support Toolset

In order to validate and test the functionalities of the IEPT tool, it is essential to investigate the regulatory framework of each country of interest. Hence, a detailed description is provided in the tables below for each country, for both the electricity and gas networks [16]. Specific information about the transmission and distribution operators in both of the energy networks is included. That information will be used not only as an input in the IEPT tool and particularly in the CBA component, but also as an additional explanatory element which reflects the current conditions/dimensions used in the investment practices of the Operators.

The information included in the tables below includes the following:

- General: Incentive regulation is the use of rewards and penalties to induce the utility to achieve desired goals where the utility is afforded some discretion in achieving goals. Most countries use a mixture of a cap regulation (revenue or price) and a guaranteed Rate of Return (RoR). Revenue cap regulation can thereby be seen as an indirect form of price cap regulation, where the revenue is the result of price multiplied by the

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quantity. Nowadays, cost-plus regulation is used in a small amount of counties.

- Rate of Return (RoR): Most regulatory systems allow for an RoR on investments. There are various possible methods to calculate the RoR. Mostly the WACC factor is used. The WACC can be expressed in a simplified manner by the given formula:

$$WACC = \frac{equity}{(equity + debt)} * cost\ of\ equity + \frac{debt}{(equity + debt)} * cost\ of\ debt$$

The National Regulatory Authorities can make a distinction between nominal or real and before and after taxation, as well as "vanilla" WACC, i.e., the weighted average cost of capital using a pre-tax cost of debt and a post-tax cost of equity.

- Regulatory Asset Base (RAB): In general, the RAB serves as an important parameter in utility regulation to determine the allowed profit. The structure of individual components included in the RAB and their valuation differ significantly among countries and even among the regulated sectors. The RAB value is usually also linked with depreciation, depending on an individual NRA's approach. In general, the RAB provides for remuneration of both historic and new investment. The RAB should be formed by the assets necessary for the provision of the regulated service in their residual (depreciated) value. The RAB can be comprised of several components such as fixed assets, working capital or construction in progress. Other elements such as capital contributions of customers, government (e.g., subsidies) and third parties are, on the contrary, usually excluded. The RAB may be valued according to different methods (e.g., historical costs, indexed historical costs or actual re-purchasing costs), which will have an influence on the determination of CAPEX. A RAB based on indexed historical costs would, therefore, require the use of a "real" instead of a "nominal" WACC. As a result, it is important to understand the relation between the RAB definition and the WACC structure.

- Depreciation: Depreciation decreases the asset value through use and the shortening of theoretical asset life and should also allow a firm to

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cover replacement investment costs during the economic lifetime of an asset. Concerning the duration of depreciation, the economic lifetime of the asset should be taken into account in a forward looking, long-run approach. The two most common approaches towards depreciation are straight line and accelerated depreciation. The straight-line depreciation method spreads the cost evenly over the life of an asset. On the other hand, a method of accelerated depreciation such as the double declining balance, allows the company to deduct a much higher share in the first years after purchase.

Table 1: Existing regulatory framework for the investment decisions of the operators in the Netherlands.

Netherlands					
		Gas Network		Electricity Network	
		TSO	DSO	TSO	DSO
General	System regulation	Incentive regulation / revenue cap			
Rate of return	Type of WACC	Real, pre-tax			
	Determination of rate of return on equity	Sum of risk-free rate and equity risk premium * beta. Equity risk premium is based on data in individual Eurozone countries over the period 1900-2015 (Dimson, Marsh and Staunton database). An average of both the geometric and arithmetic average is taken. Multiplied by beta based on comparator group			
	Rate of return on equity before taxes	6.7% in 2021 (based on 5.02% after taxes and 25% tax rate)			
Regulatory asset base	Components of RAB	Fixed assets and certain intangible assets (such as software) are included (no working capital)			
	Regulatory asset value	Indexed historical costs			

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	RAB adjustments	Annual indexation for inflation and adjustment for certain specific (expansionary) investments	Annual indexation for inflation and adjustment for certain specific (replacement) investment	Annual indexation for inflation and adjustment for certain specific (expansionary) investments	Annual indexation for inflation
Depreciations	Method	Straight=line depreciation, corrected for inflation each year			
	Depreciation ratio	Most assets are depreciated over a period of 35-55 years			
	Consideration	Depreciation is part of the total costs, which are subject to an X-factor over the course of the Regulatory period			

Table 2: Existing regulatory framework for the investment decisions of the operators in Portugal.

Portugal					
		Gas Network		Electricity Network	
		TSO	DSO	TSO	DSO
General	System regulation	Price-cap (OPEX) and rate-of-return (CAPEX)	Price-cap (OPEX) and rate-of-return (CAPEX)	Price-cap (OPEX) and standard costs/rate-of-return (CAPEX)	Price-cap and rate-of-return (HV/MV) and TOTEX (LV)
Rate of return	Type of WACC	Nominal, pre-tax The WACC (pre-tax) is indexed to the Portuguese ten-year bond benchmark and depends, in each year, on its evolution, with a cap and a floor. Tax rate= 31.5%			
	Determination of rate of	CAPM: $Market\ risk\ premium = risk\ premium\ for\ mature\ market + country\ risk\ spread,$			

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	return on equity	where: The risk premium for mature market is the spread between S&P 500 and USA ten-year treasury bond yields since 1961 and the country risk spread is the spread between Portuguese ten-year bond yields and ten-year bond yields of Germany, Finland, Austria, the Netherlands and France.			
	Rate of return on equity before taxes	6.7%	7.1%	7.9%	8.5%
Regulatory asset base	Components of RAB	Fixed assets deducted from third parties' contributions			
	Regulatory asset value	RAB is based on historical and re-evaluated costs	RAB is based on historical and re-evaluated costs	RAB is based on historical costs and standard costs	RAB is based on historical costs
	RAB adjustments	Each year the RAB is adjusted to consider new investments, write-offs and depreciation			
Depreciations	Method	Straight line depreciation			
	Depreciation ratio	Five-45 years	Five-40 years	15-30 years	Five-40 years
	Consideration	Part of CAPEX			

Table 3: Existing regulatory framework for the investment decisions of the operators in Greece.

Greece					
		Gas Network		Electricity Network	
		TSO	DSO	TSO	DSO

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General	System regulation	Cost-plus	Revenue cap	Revenue cap	Cost-plus
Rate of return	Type of WACC	Nominal, pre-tax	Nominal, pre-tax	Real, pre-tax	Nominal, pre-tax
	Determination of rate of return on equity	WACC: a) CAPM and additional country risk premium for cost of equity, and b) cost of debt based on operators' proposal and actual figures of base year			
	Rate of return on equity before taxes	8.23%	8.01%	8.20%	8.16% (2020)
Regulatory asset base	Components of RAB	Fixed assets, working capital, assets under construction			
	Regulatory asset value	Historical costs		Historical costs since 2009	
	RAB adjustments	No adjustments, historical values			
Depreciations	Method	Straight line			
	Depreciation ratio	Most assets are depreciated over a period of 25-50 years			
	Consideration	Depreciation ratio depends on asset type and is integrated directly into the revenues			

Table 4: Existing regulatory framework for the investment decisions of the operators in Italy.

Italy					
		Gas Network		Electricity Network	
		TSO	DSO	TSO	DSO
General	System regulation	Cost-plus for CAPEX. Price cap for OPEX	Cost-plus for CAPEX. Price cap for OPEX. Standard	Cost-plus for CAPEX. Price cap for OPEX	Standard cost approach

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		Price cap for OPEX.	cost approach for centralised costs	Cost-plus for CAPEX.	for smaller DSOs
Rate of return	Type of WACC	Pre-tax, real			
	Determination of rate of return on equity	Sum of real risk-free rate (with a floor of 0.5%), a country risk premium, and a beta risk factor multiplied by an equity risk premium (determined as the difference between total market return and the risk-free rate)			
	Rate of return on equity before taxes	5.4%	5.8%	5.3%	5.7%
Regulatory asset base	Components of RAB	Fixed assets, working capital, assets under construction			
	Regulatory asset value	Historical cost re-valued for inflation, net of depreciation and grants	Both historical cost and standard unit cost (sectoral average) depending on type (central vs local assets). Both are revalued for inflation and are net of depreciation and grants	Historical cost re-valued for inflation, net of depreciation and grants. Investments prior to 2004 are considered as lump-sum with standard net value evolution	Historical cost for bigger companies. Standard unit cost (sectoral average) for smaller companies. Both are revalued for inflation and are net of depreciation and grants

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		Gas TSO	Gas DSO	Electricity TSO	Electricity DSO
				and depreciation	
	RAB adjustments	New investments, depreciation, grants	New investments, depreciation, grants. For standard costs, changes in the driver	New investments, depreciation, grants. For investment prior to 2004, standard evolution	New investments, depreciation, grants. For standard costs, changes in the driver
Depreciations	Method	Straight line			
	Depreciation ratio	Buildings 3%, pipelines 2%, stations 5%, metering 5%-7%, other 10%-20%	Buildings 2%-3%, pipelines 2%, city gates 5%, metering 5%-7%, other 14%	Buildings 3%, lines 2%, stations 3%, metering 7%, other 5%-20%	
	Consideration	Deducted from gross RAB to form net RAB			

Table 5: Existing regulatory framework for the investment decisions of the operators in France.

Portugal					
		Gas Network		Electricity Network	
		TSO	DSO	TSO	DSO
General	System regulation	System regulation			
Rate of	Type of WACC	Pre-tax, real		Pre-tax, nominal	N/A

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	Determination of rate of return on equity	Sum of a nominal risk-free rate and a risk premium (market risk premium multiplied by a beta risk factor) multiplied by a corporate tax factor, and expressed in real terms		Sum of a nominal risk-free rate and a risk premium (market risk premium multiplied by a beta risk factor) multiplied by a corporate tax factor	N/A
	Rate of return on equity before taxes	8.6%	8.4%	7.8%	N/A
Regulatory asset base	Components of RAB	Fixed assets			
	Regulatory asset value	Historical revaluated costs (considering inflation and depreciation)			
	RAB adjustments	Subsidies and grants are removed from the value of assets before entering the RAB			
Depreciations	Method	Straight line			
	Depreciation ratio	Depends on asset type. Ratio between 2% and 4% for network assets (lines, pipes, etc.)			
	Consideration	Integrated directly and with 100% (except assets that were funded through subsidies or grants)			

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3.4 Financial support mechanism for RES integration in IANOS demonstration islands

The main financial support mechanisms available in member states throughout the EU include [17]:

1. **Net metering (NM):** NM is suitable for residential and business users. It represents a profitable investment, achieving the offsetting between the energy generated by the photovoltaic panels and the energy that the user consumes. This enables the direct supply of the energy required and thus the electricity bill is reduced to zero.
2. **Feed-in tariffs (FITs):** A contract between RES producers and authorized buyers allows the former to sell the electricity they actually produce at a predetermined price to the latter. This kind of contract usually lasts a number of years coherent with the economic lifespan of the generation assets (15-25 years). In many countries, FITs do not include balancing responsibilities. At the same time, in some other countries (e.g., Finland), FITs are called "feed-in-premium support" and do include balancing responsibilities.
3. **Feed-in premiums (FIPs):** RES producers sell their expected generation in the wholesale market and are subjected to balancing responsibilities. In addition to this source of revenue, they receive an amount of money, usually for each MWh they actually produce, over a period usually coherent with the lifespan of their assets. This money can be predetermined and fixed for the whole contract duration (ex-ante premium) or adjusted periodically (ex post premium). The premium can be either fixed (i.e., independent of market prices) or variable (i.e., depending on the evolution of market prices, like for Contract for Differences) and complemented with caps or floors.
4. **Green Certificates (GCs):** RES producers sell their expected production in the wholesale market and are subjected to balancing responsibilities. In addition to this source of revenue, they receive a certificate for each MWh they produce that they can sell to market participants (often suppliers). The latter have to buy a predetermined number of certificates, typically each year; the total obligation corresponds to the (increasing) RES target set up legally. Scarcity of the

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certificates creates a positive price that remunerates RES producers on top of their revenues from the wholesale electricity market.

5. **Investment subsidies**: In addition to other sources of revenues from the wholesale market and/or from another support scheme, RES producers receive money either upfront (possibly in the form of tax reductions) or yearly for a predetermined duration, typically proportional to the installed capacity.

The amount of money granted through a price-based support scheme can be set administratively, but alternatively, the administration can choose a quantitative target and set up a call for tender to allocate the support. In this case, respondents bid on the level of support (typically the price in a FIT or the premium level in a FIP), and the support is granted on a merit order basis.

An overview of the financial support mechanisms as they take place in the countries, where the IANOS lighthouse and fellow islands are located, is provided below.

1) Netherlands

Overview of Dutch national support schemes in place by RES technologies in 2016 and 2017 [18]:

Type of support	Process determining the level of support or the quota	PV	On-shore wind	Off-shore wind	Bioenergy	Hydropower	Duration of support (years)
Feed-in Premium	Tendering procedures	x	x	x	x	x	8 to 15

The Stimulation of Sustainable Energy Production (SDE+) support scheme is the main policy measure encouraging the deployment of renewables. SDE+ was established in 2011 and supports renewable electricity, gases and heat. In 2020, SDE+ was expanded into the Sustainable Energy Transition Incentive Scheme (SDE++), which supports renewables and a wider range of technologies that reduce CO2 and other GHG emissions, including methane. SDE+ includes sustainability requirements for biomass, which will be maintained in the transition to SDE++. Since in 2019, renewable electricity projects require confirmation from

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the relevant network operator showing that sufficient grid capacity is available to support the project before they can be awarded SDE+ funding; this requirement will be maintained under SDE++.

Funding under SDE+ and SDE++ is awarded via competitive technology neutral auctions, which are open to bids from private companies, institutions and non-profit organisations. Under SDE+, projects including biomass and biogas, geothermal, hydropower, onshore wind and solar PV compete with each other. The final SDE+ auction was held in the first half of 2020. Starting in the second half of 2020, SDE++ auctions will allow bids from renewable technologies along with carbon capture and storage (CCS), waste heat, heat pumps and low-carbon hydrogen. The technologies eligible to participate in SDE++ auctions will be reviewed annually. It is currently planned that SDE++ auctions will be held once a year (SDE+ auctions were held twice a year).

SDE+ and SDE++ auctions are conducted in phases with the lowest level of financial support offered in the first phase. Once the first phase is closed, if there is still money remaining, additional phases are opened with increased levels of support for each successive phase (up to a limited maximum subsidy) until the total budget for the auction is awarded. If the number or quality of project bids is too low for all funding to be awarded, then this budget is rolled over for use in the next auction. This approach gives priority to the most cost-effective project bids. Winning bids that pass a project viability assessment conducted by the RVO are eligible to receive financial support once they start production.

Under SDE+, the level of support was determined via a sliding feed-in premium mechanism designed to cover the difference between the cost of renewable energy production and the relevant corresponding market price for electricity, gas or heat. The level of support under SDE++ covers the difference between the base tariff awarded per tonne of CO2 equivalent avoided and an estimated market remuneration. Conversion factors determine the CO2 reduction level for various technologies, with emissions reductions for renewable electricity based on displacement of the expected marginal generation source in 2030.

A project awarded support under SDE+ or SDE++ is required to start operating within a certain number of years after being selected through the auction process.

The time limit is based on normal project lead times for the eligible technologies. The period over which a project receives support payments is technology dependent and goes from 8 to 15 years from the commissioning of the project [19].

2) Portugal

Overview of Portuguese national support schemes in place by RES technologies in 2016 and 2017 [18]:

Type of support	Process determining the level of support or the quota	PV	On-shore wind	Off-shore wind	Bioenergy	Hydropower	Duration of support (years)
Feed-in Tariff	Administrative procedures	x	x	x	x	x	15 to 25

In Portugal, a FIT scheme drove strong deployment of wind generation from 2004 to 2012. As a result of the financial crisis, Portugal eliminated the FIT for renewable energy projects commissioned after November 2012. Qualifying projects commissioned before this date continue to receive FIT payments of EUR 74 – 270 per megawatt hour (MWh) for 12 - 25 years from the project's commissioning, with payment level and period of eligibility depending on the technology applied. Following the economic recovery, the government reintroduced a limited FIT in 2014, supporting small – scale PV, biogas, biomass and hydro projects. The updated FIT is only available for small production units (UPP), with a maximum capacity of 250 kilowatts (kW). In 2018, the government increased this FIT to EUR 95 per MWh. PV and hydropower generation receive the full FIT rate, while biomass and biogas systems receive 90% of the full rate. The government is also supporting small-scale distributed generation by encouraging the development of energy communities and self-consumption of renewable electricity [20].

3) Greece

Overview of Greek national support schemes in place by RES technologies in 2016 and 2017 [18]:

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Type of support	Process determining the level of support or the quota	PV	On-shore wind	Off-shore wind	Bioenergy	Hydropower	Duration of support (years)
Feed-in Tariff	Tendering procedures	x	x				20 to 25
Feed-in Premium	Tendering procedures	x	x				
Feed-in Tariff	Administrative procedures	x	x	x	x	x	
Feed-in Premium	Administrative procedures	x	x	x	x	x	

RES and HECHP projects up to a certain threshold of installed capacity (i.e., 500kW and 3MW for wind parks) are supported by operating aid on the basis of a feed-in-tariff (FIT). The RES and HECHP units with an installed capacity over the aforementioned thresholds are supported on the basis of a sliding Feed in Premium (FIP). Tendering procedures as basis either for FIP or FIT are organized only for PV and wind stations, with the exception of wind stations of installed capacity less than 3MW. For these stations the level of FIT is being determined administratively. Finally, for the rest RES technologies (other than PV and wind) the level of the applied FIP is being determined administratively.

4) Italy

Overview of Italian national support schemes in place by RES technologies in 2016 and 2017 [18]:

Type of support	Process determining the level of support or the quota	PV	On-shore wind	Off-shore wind	Bioenergy	Hydropower	Duration of support (years)
Feed-in Premium	Tendering procedures		x	x	x	x	15 to 25

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Feed-in Tariff	Administrative procedures	x	x	x	x	x	
Feed-in Premium	Administrative procedures	x	x	x	x	x	

- Feed in premium: It replaced Green Certificates since 2016. It is applied to energy produced by power plants that have been enabled to Green Certificates mechanism and it is no longer in force for new projects. The premium, different for each source, is granted for 12 years for power plants that started operation between April 1999 and December 2007, for 15 years for power plants started operation after January 1st, 2008.
- Feed in premium for PV plants: It is applied to energy produced by PV in operation before August 27th, 2012. Different values, depending on the power plant size, are granted for 20 years.
- Premium tariffs for PV plants: They are applied for PV plants in operation between August 27th, 2012, and July 6th, 2013, as described below, and are granted for 20 years.
    - PV plants with capacities up to 1 MW: FIT for electrical energy injected to the grid, plus a feed in premium for self-consumption [11]. Member Nature of the support PV Onshore wind Offshore wind Bioenergy Hydropower Explanation energy; in case of PV plants with capacity higher than 1 MW: feed in premium, computed on hourly basis as the difference between a total tariff and the zonal energy price, for electric energy injected to the grid, plus a feed in premium for self-consumption energy.
- Premium tariffs for RES – E plants except for PV plants: These were defined by the Ministerial Decree July 6th, 2012 and they are applied as described below. They are also granted for different time periods, depending on the source (from 15 up to 25 years).
    - Plants with capacities up to 1 MW: FIT (different for each source) for injected energy.
    - Plants with capacities over 1 MW: FIP (different for each source) for injected energy. The premium is calculated, on an hourly basis, as the difference between a total tariff, different for each source, and the

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hourly zonal energy price. Furthermore, the premium value is determined through auctions for largest plant (capacity over 5 MW, augmented to 10 MW for hydro plants and to 20 MW for geothermal plants). It is no longer in force for new projects.

- Updated Premium tariffs, defined by the Ministerial Decree June 23rd, 2016, for RES – E plants except for PV plants: They are applied as described below, and are granted for different time periods, depending on the source (from 15 up to 25 years):
    - ➢ Plants with capacity up to 500 kW: FIT (different for each source) for THE injected energy.
    - ➢ Plants with capacity over 500 kW: Feed – in – premium (different for each source) for the injected energy. The premium is calculated, on an hourly basis, as the difference between a total tariff, different for each source, and the hourly zonal energy price. Furthermore, the premium value is determined through auctions for largest plant (capacity over 5 MW).

5) French Polynesia

Overview of French Polynesia's support schemes in place by RES technologies:

Type of support	Process determining the level of support or the quota	PV	On-shore wind	Off-shore wind	Bioenergy	Hydropower	Duration of support (years)
Feed-in Tariff	Administrative procedures	x				x	15 to 25
Subsidies	Administrative procedures	x				x	

- Feed-in tariff for RES: As defined by Ministerial Decree no. 865 CM of June 28th, 2011, which sets the prices and conditions for purchasing electricity produced by solar technologies. The tariffs differ according to the location (main island Tahiti; or outer island that face higher costs due to remote

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locations) and the total installed capacity (0 to 50 kW_p / 50 to 500 kW_p / for higher than 500 kW_p prices have to be negotiated with the government and grid operator directly). The table below presents the tariffs as defined in the decree.

Localisation de l'unité de production	*Puissance de l'installation*	*Prix d'achat du kilowattheure injecté sur le réseau public d'électricité (en F CFP)*
Tahiti	*P < 500kWc*	*15,98*
Iles autres que Tahiti	*P < 50kWc*	*23,64*
Iles autres que Tahiti	*50 kWc < P < 500 kWc*	*15,98*

- Subsidies: To help develop renewable energies more quickly and because French Polynesia is a remote and complicated location, subsidies have been put in place, such as tax exemption (with a list of conditions to be eligible). In addition, from January 2023 to December 2026, a new fund has been allocated by France (mainland) to French Polynesia to accelerate renewable projects and support them financially to ensure project feasibility.

4. Assessment of LH & Fellow Islands Plans

In this chapter, the 9 UCs that will be tested in the LH and FI are described. The UCs' description includes a full dimensioning of the assets that will be used and a brief description of the scenarios that will be tested by each demonstrator. In addition, the information describing the status in M30 regarding the power system topology that those assets will be installed on, that has been described in the other IANOS WPs, has been taken into consideration in order to perform the pre-validation of the IEPT suite. All IANOS' UCs are listed in Table 6.

Table 6: IANOS' Use Cases.

ID	Name
Use Case #1	Community demand-side driven self-consumption maximization
Use Case #2	Community supply-side optimal dispatch and intra-day services provision
Use Case #3	Island-wide, any-scale storage utilization for fast response ancillary services
Use Case #4	Demand side management and smart grid methods to support power quality and congestion management services
Use Case #5	Decarbonization of transport and the role of electric mobility in stabilizing the energy system
Use Case #6	Decarbonising large industrial continuous energy consumers through electrification and local generation
Use Case #7	Circular economy, utilization of waste streams and gas grid decarbonization
Use Case #8	Decarbonization of heating network
Use Case #9	Active citizen and LEC engagement into decarbonization transition

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4.1 Use Case #1

The dimensioning of all assets used in the LH islands Terceira and Ameland, regarding the demonstration activities up to M30 is presented in Table 7.

Table 7: Dimensioning of assets in the LH islands for UC#1.

<table>
<tr><th></th><th colspan="2">Terceira</th><th colspan="2">Ameland</th></tr>
<tr><th>Grid Area</th><th>Components</th><th>Specs</th><th>Components</th><th>Specs</th></tr>
<tr><td>Generation</td><td>-</td><td>-</td><td>Solar Farm</td><td>1 x $6MW_p$</td></tr>
<tr><td>Transmission</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>Distribution</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="4">DER</td><td rowspan="4">PV Panels with Microinverter</td><td rowspan="4">40 x 1.5kW (5 x 300W DC/250W AC on each installation)</td><td>Residential Solar Panels</td><td>400 PVs ~1MW in total</td></tr>
<tr><td>Wind Turbines</td><td>2 x $15kW_e$</td></tr>
<tr><td>Micro-CHP</td><td>3 x $5.5kW_{th}$ (micro-CHP), 3.5kWh (battery), $1kW_e$ (solar panels)</td></tr>
<tr><td>Private Methane Fuel Cells</td><td>35 x $2kW_e$</td></tr>
<tr><td rowspan="4">Customer Premises</td><td>Heat Batteries</td><td>24 x 3.5kWh</td><td rowspan="2">Biobased Saline Batteries</td><td rowspan="2">1 x 50kW/120kWh</td></tr>
<tr><td>Electrochemical Batteries</td><td>16 x 3kW/3kWh</td></tr>
<tr><td>Smart Plugs</td><td>TBD</td><td rowspan="2">Hybrid Heat Pumps</td><td rowspan="2">135 x $20kW_{th}$ (boiler), $1.1kW_e/5kW_{th}$ (heat pump)</td></tr>
<tr><td>Electric Water Heaters</td><td>5 x 2kW</td></tr>
</table>

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As reported in D2.3, in the context of UC1 two different scenarios will be demonstrated:

1) Self-consumption maximization through optimization of behind-the-meter assets: The iVPP receives several real-time data coming from localized energy management systems and the weather forecast provider. Along with its internal data, the iVPP performs optimization of behind-the-meter assets' consumption in order to maximize self-consumption. Lastly, the iVPP sends the setpoints to the localized management systems.

2) Self-consumption maximization through P2P energy trading based on DLT: An overproduction occurs due to excess production from renewables. Prosumers sell the excess energy in a P2P market. The market will leverage on self-enforcing smart contracts to manage, in a programmatic manner, the P2P energy-trading between prosumers.

4.2 Use Case #2

The dimensioning of all assets used in the LH islands Terceira and Ameland, regarding the demonstration activities up to M30 is presented in Table 8.

Table 8: Dimensioning of assets in the LH islands for UC#2.

	Terceira		Ameland	
Grid Area	Components	Specs	Components	Specs
Generation	Wind Park	Will be used theoretically (no deployment)	Electrolyser	1 x 50kW
	Fossil Fuel Generators	Will be used theoretically (no deployment)		
	Geothermal Plant	Will be used theoretically (no deployment)	Solar Farm	1 x $6MW_p$

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	Waste Incineration Plant	Will be used theoretically (no deployment)	Solar Park	1 x $3MW_p$
Transmission	Legacy BESS	1 x 15MW/3MWh	BESS	1 x 1.5MWh
Distribution	-	-	-	-
DER	Small Scale PV Farm	Will be used theoretically (no deployment)	-	-
Customer Premises	-	-	-	-

As reported in D2.3, in the context of UC2 one scenario will be demonstrated:

1) Supply-side optimal dispatch: Performing the optimal day-ahead energy dispatch and provision of intra-day services to the grid in order to minimize energy curtailment and integrate the maximum RES by using the available flexibility on the generation side.

4.3 Use Case #3

The dimensioning of all assets used in the LH islands Terceira and Ameland, regarding the demonstration activities up to M30 is presented in Table 9.

Table 9: Dimensioning of assets in the LH islands for UC#3.

	Terceira		Ameland	
Grid Area	Components	Specs	Components	Specs
Generation	-	-	CHPs	2 x $75kW_e/110kW_{th}$
Transmission	Legacy BESS	1 x 15MW/3MWh	BESS	1 x 1.5MWh
Distribution	-	-	-	-

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DER	-	-	Fuel Cell	1 x 56kW$_e$/62kW$_p$
Customer Premises	Flywheel	1 x 100kW/3kWh	Private Methane Fuel Cells	35 x 2kW$_e$
	Electrochemical Batteries	16 x 3kW/3kWh	Private CHPs	35 x 2kW

As reported in D2.3, in the context of UC3 one scenario will be demonstrated:

1) Provision of fast ancillary services through storage systems of any-scale: The iVPP computes the optimal set-point for distributed storage technologies that provide fast ancillary services to the grid.

4.4 Use Case #4

The dimensioning of all assets used in the LH islands Terceira and Ameland, regarding the demonstration activities up to M30 is presented in Table 10.

Table 10: Dimensioning of assets in LH islands for UC#4.

	Terceira		Ameland	
Grid Area	Components	Specs	Components	Specs
Generation	-	-	CHPs	2 x 75kW$_e$/110kW$_{th}$
Transmission	Legacy BESS	1 x 15MW/3MWh	BESS	1 x 1.5MWh
Distribution	Hybrid Transformer	1 x 400kVA	-	-
DER	-	-	Fuel Cell	1 x 56kW$_e$/62kW$_p$
Customer Premises	Smart Energy Routers	2 x 5kW$_p$	Private Methane Fuel Cells	35 x 2kW$_e$

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			Hybrid Heat Pumps	135 x 20kW$_{th}$ (boiler) 1.1kW$_{e}$/5kW$_{th}$ (heat pump)
			Biobased Saline Batteries	1 x 50kW/120kWh
			Private CHPs	35 x 2kW

As reported in D2.3, in the context of UC4 three different scenarios will be demonstrated:

1) Demand-side management capable of providing slow ancillary services: The iVPP computes the optimal set-point which allows to provide slow balancing services to the grid through storage assets by using demand-side flexibility.
2) Voltage control to support power quality optimisation and congestion management services: The hybrid transformer complies with the voltage setpoint computed by the iVPP in order to ensure a continuous power.

3) Localized energy routing management capable of providing ancillary services: The iVPP calculates the optimal dispatch to the smart energy router which manages the energy transfer from and to different sources (RES generators and distribution grid), loads and storage systems in order to provide services to the grid and the consumer.

4.5 Use Case #5

The dimensioning of all assets used in the LH islands Terceira and Ameland, regarding the demonstration activities up to M30 is presented in Table 11.

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Table 11: Dimensioning of assets in the LH islands for UC#5.

	Terceira		Ameland	
Grid Area	Components	Specs	Components	Specs
Generation	-	-	Electrolyser	1 x 50kW
Transmission	-	-	-	-
Distribution	-	-	-	-
DER	-	-	-	-
Customer Premises	V2G Charging Stations	2 x 11kVA (input)/ 10kW (output)	Electric Charging Stations	10
			Municipal EVs	3
	Smart Energy Routers	2 x 5kW$_p$	Electric Buses	6
	EVs	2	Electric Bikes	1000
			EVs	TBD

As reported in D2.3, in the context of UC5 three different scenarios will be demonstrated:

1) <u>The use of V2G for power system stabilization:</u> The iVPP is connected to V2G charging stations and manages power fluxes allowing the provision of balancing services to the grid.

2) <u>The use of smart charging for power system stabilization:</u> The iVPP is connected to electric charging stations and manages power fluxes from the grid to the station considering the end-user profile and ensuring the stability of the power system.

3) <u>The use of hydrogen for mobility in order to decarbonize the transport sector:</u> The iVPP is connected to the electrolyzer and manages the hydrogen quantity which could be used to fuel hydrogen water taxis and

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the possible transport mean to transport the hydrogen to water taxis (e.g. trucks).

4.6 Use Case #6

The dimensioning of all assets used in the LH island Ameland, regarding the demonstration activities up to M30 is presented in Table 12.

Table 12: Dimensioning of assets in the LH island for UC#6.

	Ameland	
Grid Area	Components	Specs
Generation	CHPs	2 x 75kW$_e$/110kW$_{th}$
Transmission	-	-
Distribution	AWG Natural Gas Platform	410TJ/y
	Hydrogen Storage	1
DER	Fuel Cell	1 x 56kW$_e$/62kW$_p$
	Micro-CHP	3 x 5.5kW$_{th}$ (micro-CHP), 3.5kWh (battery), 1kW$_e$ (solar panels)
	Solar Farm	1 x 6MW$_p$
	Solar Park	1 x 3MW$_p$
	Wind Turbines	2 x 15kW$_e$
	Tidal Kite	1 x 500kW$_e$
Customer Premises	-	-

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As reported in D2.3, in the context of UC6 one scenario will be demonstrated:

1) Electrification of Natural gas Platform: The iVPP computes the optimal setpoint for production dispatchable assets to supply energy to all energy demanding assets present in the island (including the natural gas platform), while ensuring the maximization of renewable penetration in the power system.

4.7 Use Case #7

The dimensioning of all assets used in the LH island Ameland, regarding the demonstration activities up to M30 is presented in Table 13.

Table 13: Dimensioning of assets in the LH island for UC#7.

	Ameland	
Grid Area	Components	Specs
Generation	AHPD Digester	Won't be further developed. Instead, an alternative centralized digester or multiple smaller digesters at restaurant locations will be used.
	Electrolyser	1 x 50kW
Transmission	-	-
Distribution	-	-
DER	Micro-CHP	3 x 5.5kW$_{th}$ (micro-CHP), 3.5kWh (battery), 1kW$_e$ (solar panels)
Customer Premises	Private Methane Fuel Cells	35 x 2kW$_e$

As reported in D2.3, in the context of UC7 two different scenarios will be demonstrated:

1) <u>Green natural gas production from waste streams:</u> The iVPP computes the optimal dispatch for the electrolyzer and the small-scale digester regarding the respective amounts of gas to be supplied.

2) <u>Research on biomass processing technologies:</u> Investigate the most suitable technologies to process biomass for the remaining waste streams of the islands.

4.8 Use Case #8

The dimensioning of all assets used in the LH island Ameland, regarding the demonstration activities up to M30 is presented in Table 14.

Table 14: Dimensioning of assets in the LH islands for UC#8.

	Ameland	
Grid Area	Components	Specs
Generation	-	-
Transmission	-	-
Distribution	Hydrogen Storage	1
DER	Fuel Cell	1 x 56kW$_e$/62kW$_p$
Customer Premises	Biobased Saline Batteries	1 x 50kW/120kWh
	Hybrid Heat Pumps	135 x 20kW$_{th}$ (boiler) 1.1kW$_e$/5kW$_{th}$ (heat pump)

As reported in D2.3, in the context of UC8 one scenario will be demonstrated:

1) <u>Decarbonization of heating network:</u> Decarbonization of the heating network by installing heat and hybrid pumps, which use electricity generated by local RES. The iVPP manages the steady energy flow from the

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local RES to the heat pumps, ensuring heat and hot water is provided to the buildings.

4.9 Use Case #9

In Table 15 the amount and type of engaged citizens for both LH islands are presented, based on the progress of the project up to M30. For this UC there are not explicit scenarios defined as in the previous ones. However, in order to conduct a quantifiable CBA approach, the IEPT suite will need to collect data that quantify the local communities' and citizens' engagement to the IANOS activities. These indicators are thoroughly presented in the next chapter.

Table 15: Amount and type of engaged citizens in the LH islands for UC#9.

	Terceira		Ameland	
	Amount	Type	Amount	Type
Engaged Citizens	300	Various	600	Various
	5	Capacity Building Sessions		

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5. Decision Support Toolset Pre-Validation

For each UC, the benefits, along with the defined KPIs that are linked to the IEPT suite are presented. In addition, a screening process takes places, where from those KPIs that are linked to the IEPT suite, the ones that can be monetized through the KPI component are presented. These KPIs provide fine-grained quantified insights for the decision-makers, enabling them to better assess the smart grid interventions. The complete list of KPIs is provided in Appendix A.

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5.1 Use Case #1

Benefits[1]	Maximize self-consumption from renewable energy sources to allow the users (Terceira) or the community (Ameland) to better exploit their assets, to avoid future grid transport costs to the mainland and to alleviate the grid in periods of excess of renewable generation.
	Reduce energy curtailment by achieving the maximum renewable penetration possible.
	Avoid grid challenges such as congestion and voltage variations.
Identified KPIs[2]	T-2, T-7, T-9, T-12, EN-2, EC-11, I-4, S-1, P-1, P-2
IEPT module responsible for KPIs calculation[3]	VERIFY-D → T-2, EN-2 INTEMA.grid (for Terceira) → T-2, T-7, T-9, T-12, I-4 ESSIM (for Ameland) → T-9, T-12
Benefits Monetization[4]	T-2, T-7, T-9, T-12, EN-2, I-4

[1] The benefits are directly acquired from the objectives of each UC, as documented in D2.3. The extensive and finalized list of KPIs is also included in Appendix A.
[2] This is a list of KPIs directly linked to the particular UC (D2.3) and is also documented in D2.9.
[3] The direct link between a particular KPI and its calculation engine is reported in D3.6.
[4] This is linked to the CBA module of the IEPT toolkit, whether the particular benefit through the corresponding KPIs can be monetized or not. In case that monetization is not applicable, then the

Pre-validation comments	Most of the identified KPIs can be calculated for this UC by the IEPT suite modules. All of them can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.2 Use Case #2

Benefits	Provide flexibility on the generation-side.
	Reduce energy curtailment.
	Avoid grid challenges.
Identified KPIs	T-1, T-7, T-8, T-10, T-11, EN-2, I-1, I-4, I-5, P-2
IEPT module responsible for KPIs calculation	VERIFY-D → T-1, EN-2 INTEMA.grid (for Terceira) → T-1, T-7, T-8, I-4 ESSIM (for Ameland) → T-1
Benefits Monetization	T-1, T-7, T-8, EN-2, I-4
Pre-validation comments	Half of the identified KPIs can be calculated for this UC by the IEPT suite modules. All of them can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.3 Use Case #3

Benefits	Improve power quality and continuity of power supply.
	Reduce energy curtailment.
	Avoid grid challenges such as congestion and voltage variations.

plain technical/environmental benefits are used in the CBA process as an auxiliary input for the decision-makers.

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Identified KPIs	T-7, T-8, T-9, T-11, I-5, P-3
IEPT module responsible for KPIs calculation	VERIFY-D → - INTEMA.grid (for Terceira) → T-7, T-8, T-9 ESSIM (for Ameland) → T-9
Benefits Monetization	T-7, T-8, T-9
Pre-validation comments	Half of the identified KPIs can be calculated for this UC by the IEPT suite modules. All of them can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.4 Use Case #4

Benefits	Ensure stability of the power system.
	Minimize energy curtailment.
	Support congestion management services by utilizing demand flexibility as a means to provide slow ancillary services to the grid.
Identified KPIs	T-3, T-4, T-8, T-9, T-10, T-11, I-1, I-5, S-1, P-1, P-2, P-3
IEPT module responsible for KPIs calculation	VERIFY-D → - INTEMA.grid (for Terceira) → T-8, T-9 ESSIM (for Ameland) → T-9
Benefit Monetization	T-8, T-9
Pre-validation comments	Two of the identified KPIs can be calculated for this UC by the IEPT suite modules. Both can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

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5.5 Use Case #5

Benefits	Present a clear roadmap to decarbonize the transport sector.
	Study the potential of electric chargers, hydrogen fuelled vehicles, V2G and smart charging schemes to reach decarbonization targets.
	Offer flexibility to the electricity grid.
Identified KPIs	T-11, EN-1, EN-2, I-1, I-5, P-1, P-2, P-3
IEPT module responsible for KPIs calculation	VERIFY-D → EN-1, EN-2 INTEMA.grid → - ESSIM → -
Benefit Monetization	EN-1, EN-2
Pre-validation comments	Two of the identified KPIs can be calculated for this UC by the IEPT suite modules. Both can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.6 Use Case #6

Benefits	Maximize consumption from local RES.
	Decarbonize the industrial sector.
Identified KPIs	T-5, EN-1, EN-2, P-2, P-3
IEPT module responsible for KPIs calculation	VERIFY-D → T-5, EN-1, EN-2 INTEMA.grid (for TERCEIRA) → T-5 ESSIM (for AMELAND) → T-5
Benefit Monetization	T-5, EN-1, EN-2

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Pre-validation comments	Most of the identified KPIs can be calculated for this UC by the IEPT suite modules. All of them can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.7 Use Case #7

Benefits	Reduce the negative impact of waste streams produced on the island by reusing them to produce green energy. Foster gas and electricity grid decarbonization.
Identified KPIs	T-6, EN-1, EN-2, EN-3, EN-5
IEPT module responsible for KPIs calculation	VERIFY-D → EN-1, EN-2 INTEMA.grid → - ESSIM → -
Benefit Monetization	EN-1, EN-2
Pre-validation comments	Two of the identified KPIs can be calculated for this UC by the IEPT suite modules. Both can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.8 Use Case #8

Benefits	Decarbonize the existent heating grid in Ameland which currently mainly uses natural gas as fuel.
Identified KPIs	T-5, EN-1, EN-2, S-1, S-2, G-1, P-1, P-2, P-3
IEPT module responsible	VERIFY-D → T-5, EN-1, EN-2 INTEMA.grid → T-5 ESSIM → T-5

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for KPIs calculation	
Benefit Monetization	T-5, EN-1, EN-2
Pre-validation comments	Some of the identified KPIs can be calculated for this UC by the IEPT suite modules. All of them can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

5.9 Use Case #9

Benefits	Promoting the engagement of the local community in the islands' energy transition.
	Raising customers' environmental and energy efficiency awareness.
	Support local generation.
	Promote DSM programs.
Identified KPIs	T-5, T-12, I-2, S-1, S-6, P-1
IEPT module responsible for KPIs calculation	VERIFY-D → T-5 INTEMA.grid → T-5, T-12 ESSIM → T-5, T-12
Benefit Monetization	T-5, T-12
Pre-validation comments	Two of the identified KPIs can be calculated for this UC by the IEPT suite modules. Both can be converted into monetary benefits, providing quantifiable decision-making capabilities for the stakeholders.

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6. Interoperability validation

6.1 Operational scenarios and tests conducted

The aim of this section is to showcase the proposed methodology and the integration process by applying the IEPT tool to a testing scenario. The proposed methodology was defined in D3.6 and is also depicted in Figure 3 for a more extensive view in order to understand all the steps that are going to be described next.

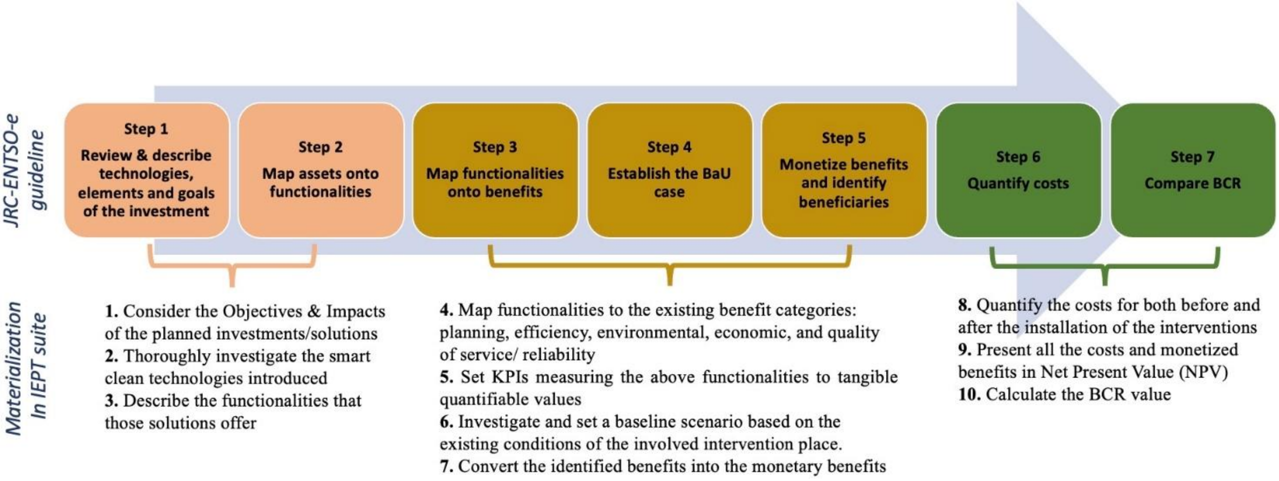

Figure 3: Extensive methodology followed for the assessment of the investment viability.

The proposed CBA methodology is based on both JRC's and ENTSO-E's methodologies. These are comprehensive frameworks to assess the costs and benefits of smart grid interventions inserted into the electricity infrastructure from the system planning perceptive. Those are materialized through the CBA module of the IEPT suite. The module defines a methodology of ten steps that leverages the KPI values, quantifying the planning, efficiency, environmental, economic and reliability benefits of the underpinning smart grid solutions measured by both INTEMA.grid and VERIFY-D.

As a testing scenario, we use the Nisyros island case, in Greece. For that purpose, the overall case description of the island is provided which will also constitute the baseline scenario. Then, the set of the interventions under consideration is defined.

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6.1.1 Baseline scenario

Nisyros is a small Greek island that covers an area of 41.6 km^2 and is situated in the Aegean Sea. It is part of the Dodecanese group of islands and has a population of around 1,100 residents. The island receives abundant solar radiation and its wind potential is one of the highest in Greece. Unlike the mainland, the Dodecanese islands are not connected to a centralized power grid and operate on independent electrical systems. Nisyros is part of the Kos-Kalymnos electric network, which functions at a frequency of 50Hz and provides electricity to a total of 9 islands, as depicted in Figure 4.

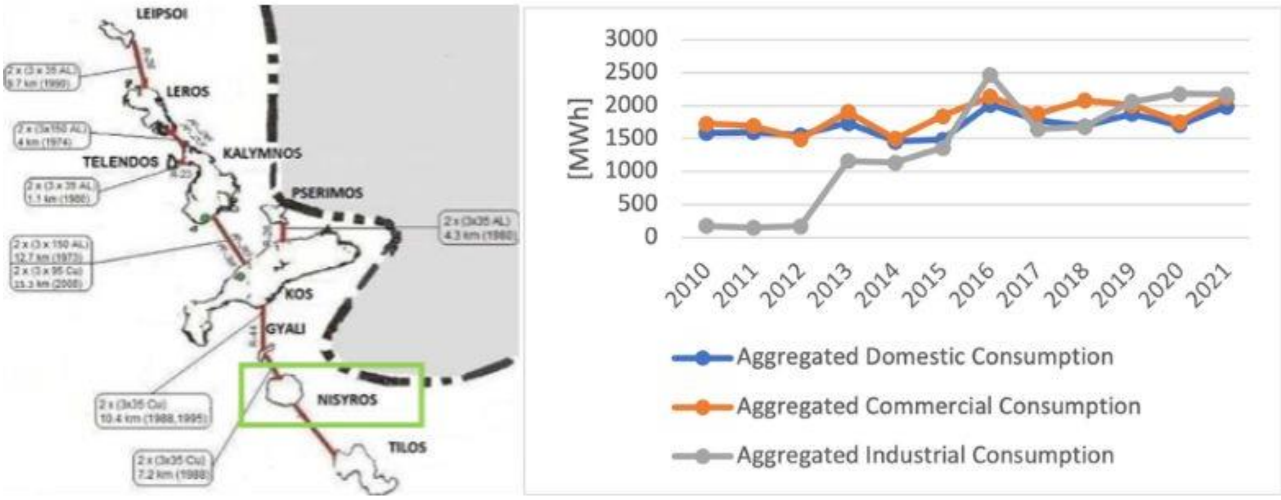

Figure 4: (a) Kos-Kalymnos transmission network, (b) Pattern for aggregated domestic, commercial and industrial electricity consumption progression.

Most of Nisyros' energy requirements are met by thermal power stations located in Kos and Kalymnos, with a combined installed capacity of 119.07 MW and 19.66 MW respectively. The Kos-Kalymnos electrical system is supplemented by 4 wind parks with a capacity of 15.2 MW, 92 photovoltaic installations with a capacity of 8.78 MW, and a small hybrid station with a capacity of 0.4 MW. These renewable energy sources are connected to the electrical system and contribute 10-20% of the total energy production across the interconnected islands.

Previously, Nisyros operated a local power station with a capacity of 1 MW. However, the power station is currently in cold lay-up and only used as a backup

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source during emergencies such as local blackouts, particularly during the peak tourist season in summer.

Nisyros has an internal electricity transmission and distribution network comprising a main Medium Voltage (MV) line with a capacity of 22 kV that originates from Kos and passes through the island communities. A series of local transformers reduce the voltage level to 400V (single phase/3-phase) for domestic and commercial use (low-voltage consumers at 230V phase to neutral), while industrial consumers (MV consumers) and the desalination plant are powered directly from the MV line through an in-house transformer (400V/3-phase).

Another MV transmission line runs from the island's capital, Mandraki, to the south of the island (area of Avlaki) via aerial lines that connect to submarine cables powering Tilos island, the southernmost part of the grid. However, the installed capacity of the Kos-Kalymnos autonomous network only marginally meets the energy demands, particularly during peak tourist season. The extended nature and complexity of the grid often results in unstable supply (voltage/frequency fluctuations), diesel generator set breakdowns and blackouts, leading to population insecurity and hindering economic growth in the region.

Previously, Nisyros had an annual energy consumption of approximately 4 GWh_e, with the majority of the demand coming from the domestic and commercial sectors. However, the installation of desalination units in 2013 and 2016 led to an increase in energy demand by 2 GWh_e, resulting in a current demand of 6.5 GWh_e.

It is worth noting that the municipality has successfully reduced its public energy consumption by 50% through various measures. These include the implementation of solar panels to power public lighting, the use of LED lamps and better energy consumption management in public buildings.

6.1.2 Scenarios' definition

Several smart grid interventions have been studied on Nisyros island to improve the stability and reliability of the electrical system, as well as to increase the

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use of renewable energy sources. One of the interventions is the installation of a photovoltaic (PV) park with a total installed capacity of 2,032 kW for the 95% self-consumption level, with lower capacities of 602 kW and 1,030 kW for the 50% and 80% self-consumption levels, respectively. The self-consumption level refers to the percentage of the electricity generated by the PV park that is used on the island, with the remainder being exported to the grid. By installing a PV park, Nisyros island is able to reduce its reliance on fossil fuel-based power generation and contribute to the reduction of greenhouse gas emissions.

Another intervention is the installation of a wind park with a total installed capacity of 2,550 kW for the 95% self-consumption level, with lower capacities of 850 kW and 1,700 kW for the 50% and 80% self-consumption levels, respectively. Like the PV park, the self-consumption level refers to the percentage of electricity generated by the wind park that is used on the island. The wind park complements the PV park in meeting the island's electricity demand from renewable sources, and it is particularly useful during periods of low solar radiation.

To improve the energy storage capacity of the grid, a grid energy storage system has been installed on the island. The grid energy storage system helps to balance the intermittent electricity production from the PV and wind parks. It has two different self-consumption levels: 80% and 95%. At the 95% self-consumption level, the storage system has a total capacity of 7,613 kWh, while at the 80% self-consumption level, it has a total capacity of 3,961 kWh. The storage system is charged when there is excess electricity generation from the PV and wind parks and discharged when there is a deficit, thus helping to maintain grid stability and reliability.

In addition, a flywheel has been installed on the island with a power rating of 100 kW and a storage capacity of 3 kWh. The flywheel is a kinetic energy storage system, which provides fast response times to grid disturbances. It is able to quickly respond to changes in the grid frequency and voltage, thus helping to improve the stability of the electrical system on the island.

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Finally, 13 public electric vehicle (EV) chargers have been installed on the island with a power rating of 22 kW each. The installation of public EV chargers is expected to encourage the adoption of electric vehicles on the island, which can help reduce the island's carbon footprint and contribute to the island's goal of becoming more sustainable. The EV chargers are available for public use and are located at convenient locations around the island, making it easy for residents and visitors to charge their electric vehicles.

6.1.3 Functionalities from the interventions

Each of the above-mentioned scenarios provide different functionalities to the involved actors, which are DSOs and local community representatives in our case. Specifically, PV parks and wind parks are designed to produce local energy. This means that the energy produced by the PV parks and the wind parks can be used to power local homes, businesses and other facilities, reducing the need for electricity from the grid.

The grid energy storage system serves several functions. Firstly, it ensures quality of supply and grid reliability. Secondly, it improves market functioning and customer service. Thirdly, it helps increase self-consumption, allowing more of the energy produced locally to be used locally.

The flywheel also serves multiple functions. It ensures quality of supply and grid reliability, by providing quick response times to changes in demand and supply, helping to maintain grid stability and prevent blackouts. It increases energy independence by storing and managing energy locally, reducing dependence on external energy sources. It is also cost-effective, environmentally friendly and has a long lifespan, making it a reliable and low-maintenance solution for frequency regulation on islands.

Finally, the public EV chargers facilitate the electrification of island transportation. By providing a charging infrastructure, the island encourages the use of electric vehicles, reducing reliance on fossil fuels and helping to reduce carbon emissions.

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6.2 Interoperability aspects

Based on the above defined scenarios, INTEMA.grid and VERIFY-D modules conducted simulations for a lifetime of 20 years to provide to the CBA module the KPIs for the assessment of the different interventions. The sequence diagram for the interoperability between the modules can be shown in Figure 5.

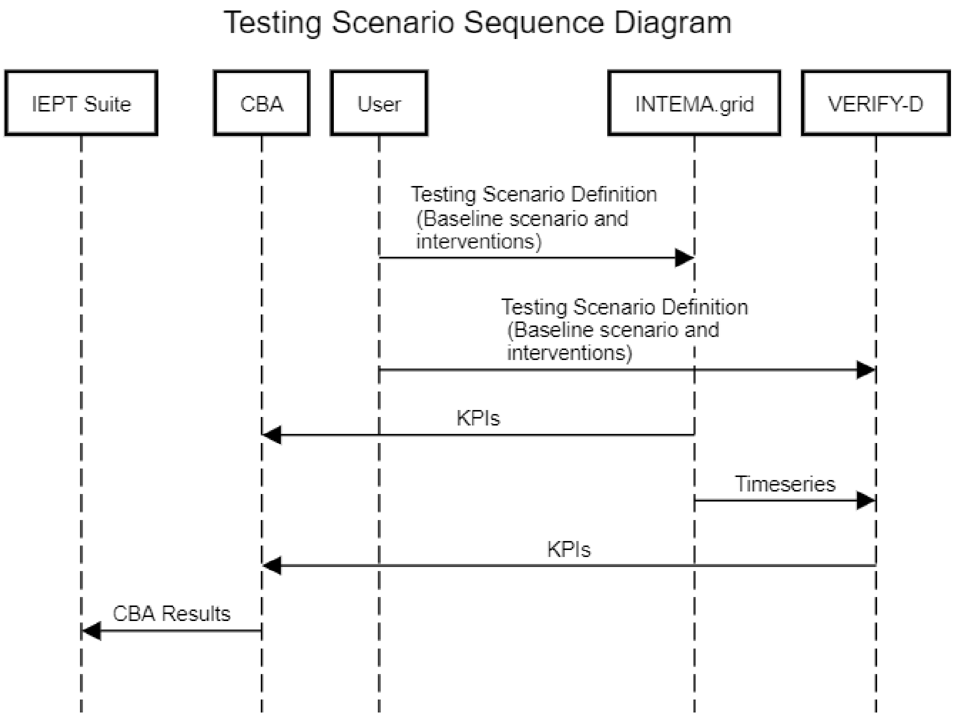

Figure 5: Testing scenario sequence diagram.

The user initially communicates to INTEMA.grid and VERIFY-D the use case definition that needs to be run. The use case includes the baseline scenario and the different interventions under investigation. After that, the INTEMA.grid simulates the different scenarios for the specified lifetime and produces the KPIs that are needed from the CBA module and the timeseries that can be of use from the VERIFY-D. At the same time, VERIFY-D simulates the different scenarios and produces the KPIs for the CBA module. All KPIs are stored in the IEPT suite's central database and can be retrieved at any time based on the unique use case ID. Next, the CBA module converts the KPIs to costs and monetized benefits and conducts the calculations for the final assessment of the investment. Finally, the results are stored into the central database and are sent to the IEPT suite's dashboard for visualization.

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6.2.1 Identified KPIs from INTEMA.grid and VERIFY-D

Table 16 shown below, summarizes the calculated KPIs per scenario and the module that was used for the calculation:

Table 16: Identified KPIs for the different scenarios under assessment.

Intervention	KPI	Module
PV Park	Increase self-consumption	INTEMA.grid
	Reduce CO_2 emissions	VERIFY-D
	Reduce electricity cost	VERIFY-D
	Lifecycle costs	VERIFY-D
	Lifecycle income	VERIFY-D
	IRR	VERIFY-D
	ROI	VERIFY-D
	Investment payback time	VERIFY-D
Wind Park	Increase self-consumption	INTEMA.grid
	Reduce CO_2 emissions	VERIFY-D
	Reduce electricity costs	VERIFY-D
	Lifecycle costs	VERIFY-D
	Lifecycle income	VERIFY-D
	IRR	VERIFY-D
	ROI	VERIFY-D
	Investment payback time	VERIFY-D
Grid Energy Storage	Reduce peak load	INTEMA.grid
	Reduce electricity costs	VERIFY-D
	Lifecycle costs	VERIFY-D
Flywheel	Decrease in frequency fluctuations	INTEMA.grid
	Reduce fuel consumption	VERIFY-D
	Reduce electricity costs	VERIFY-D
	Lifecycle costs	VERIFY-D
EV Chargers	Lifecycle costs	VERIFY-D
	Lifecycle income	VERIFY-D
	IRR	VERIFY-D
	ROI	VERIFY-D
	Investment payback time	VERIFY-D

As a note, all the KPIs that are mentioned as lifecycle costs include capital expenditure for the interventions, annual operational expenditures and the costs of possible replacements. The lifecycle income includes the annual production multiplied with the export price.

6.2.2 Benefits monetization

All KPIs that are not economic-related need to be monetized in order to be used by the CBA module. Monetizing KPIs involves quantifying the financial impact of achieving each KPI. The approach used to monetize each KPI may vary

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depending on the specific context and assumptions made. Here are some examples:

- Increase in self-consumption: This KPI measures the percentage of electricity generated by the PV or wind park that is used on the island. To monetize this KPI, we calculate the value of the electricity that is no longer imported from the mainland grid or generated by fossil fuel-based power plants. This is done by estimating the cost of electricity from these sources and multiplying it by the amount of electricity that is self-consumed.

- Reduce CO_2 emissions: This KPI measures the reduction in greenhouse gas emissions resulting from the installation of the PV or wind park. To monetize this KPI, we use the social cost of carbon (SCC), which is a measure of the economic damages caused by each ton of CO_2 emitted. The SCC can be estimated using different models and can vary depending on the discount rate, the time horizon and the assumptions made about climate impacts. Once the SCC is estimated, it can be multiplied by the amount of CO_2 emissions avoided by the intervention.

- Reduce peak load: This KPI measures the reduction in the highest electricity demand during a given period (e.g. a day or a week). To monetize this KPI, we calculate the value of the avoided cost of building or upgrading peak power plants, transmission lines or other infrastructure that is needed to meet the peak load. This is done by estimating the capital cost of the infrastructure and the cost of financing and dividing it by the expected lifetime and capacity of the infrastructure.

- Decrease in frequency fluctuations: This KPI measures the improvement in the stability of the electrical system resulting from the installation of the flywheel. To monetize this KPI, we calculate the value of the avoided cost of blackouts, equipment damage or lost productivity that can result from frequency fluctuations. This is done by estimating the cost of these events and multiplying it by the probability of their occurrence with and without the flywheel.

- Reduction in fuel consumption: This KPI measures the reduction in fuel consumption of diesel generators resulting from the installation of the flywheel. To monetize this KPI, we calculate the value of the avoided cost of diesel fuel, which can vary depending on the price of fuel, the efficiency of the generators and the maintenance and replacement costs.

It is important to note that monetizing KPIs is not always straightforward and requires making assumptions and estimating values that may be uncertain or context-dependent.

6.2.3 CBA results

Based on the KPIs stored in the central database, the CBA module calculates the NPV, the IRR, the BCR, the payback period and the cashflow of the whole investment.

Initially, we calculate the cash flow of the investment for a period of 20 years. The cash flow is the sum of the annual revenues minus the sum of the capital costs and operating costs for each year. Here is the total cash flow for all the interventions:

Year 1: -€18,932,500 (capital cost)
Year 2-20: €3,263,246 (revenue) - €1,038,302 (operating cost) = €2,224,944

To calculate the NPV, we first need to determine the discount rate. We assume a discount rate of 5%. Using this discount rate, we can calculate the NPV of the cash flows as follows:

NPV = (€2,224,944 / (1+0.05)^1) + (€2,224,944 / (1+0.05)^2) + ... + (€2,224,944 / (1+0.05)^20) - €18,932,500

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Solving the above shown equation gives us a NPV of approximately €2,494,786. This indicates that the total value of the cash inflows over the 20-year period is greater than the initial investment cost and the project is financially feasible.

To calculate the payback period, we need to determine in which year the cumulative net cash inflows equal the initial investment cost. Using the above cash flow analysis, we can see that the cumulative net cash inflows reach €18,932,500 at the end of Year 8. Therefore, the payback period is 8 years.

So, the payback period for this project is 8 years, meaning that it will take 8 years for the cumulative net cash inflows to equal the initial investment cost of €18,932,500.

To calculate the internal rate of return (IRR), we need to find the discount rate that makes the net present value (NPV) of the project equal to zero. Using the cash flow analysis, we calculate the IRR to be approximately 9.77%.

This indicates that the project has an expected rate of return of 9.77%, which is higher than the discount rate of 5% used in the NPV calculation. Therefore, the project is financially feasible and profitable, and it would generate a positive cash flow over the 20-year period.

The Benefit-Cost Ratio (BCR) is a financial metric that measures the ratio of the present value of the benefits of a project to the present value of its costs. It is calculated by dividing the present value of the benefits by the present value of the costs.

Using the cash flow analysis from before, we can calculate the BCR as follows:

PV of benefits = PV of net cash inflows over 20 years = €32,212,725

PV of costs = €18,932,500 (initial investment cost)

BCR = PV of benefits / PV of costs = €32,212,725 / €18,932,500 ≈ 1.70

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The BCR of the project is approximately 1.70, which means that for every euro invested in the project, there will be a return of €1.70 in present value of benefits over the 20-year period. A BCR greater than 1 indicates that the project is expected to generate a positive net present value, which means that the benefits outweigh the costs and the project is financially viable. In this case, the BCR of 1.70 indicates that the project is expected to generate a positive net present value, making it financially feasible.

Based on the analysis of the cash flow, net present value (NPV), internal rate of return (IRR), payback period and benefit-cost ratio (BCR), the investment appears to be worth it.

The NPV of the project is positive, which means that the present value of the cash inflows from the project is greater than the initial investment cost. The IRR is greater than the discount rate of 5%, indicating that the project is expected to generate a return that exceeds the opportunity cost of capital. The payback period of 8 years is reasonable, which means that the initial investment cost will be recovered in a relatively short amount of time. Finally, the BCR of 1.70 indicates that the project is expected to generate a positive net present value.

Overall, the project appears to be financially feasible and profitable. In addition, the project would also provide environmental benefits such as reducing carbon emissions and improving energy security on the island. Therefore, based on the analysis, the investment is worth considering.

6.3 GUI functionalities and users' satisfaction

In the registration page, users are required to enter their personal information as well as their role and the demonstration site they are interested in, as seen in Figure 6. At the time of writing, the available roles are "DSO", "Municipality" and "Community Representative" and the available demonstration sites are "Ameland", "Terceira", "Lampedusa", "Bora Bora" and "Nisyros".

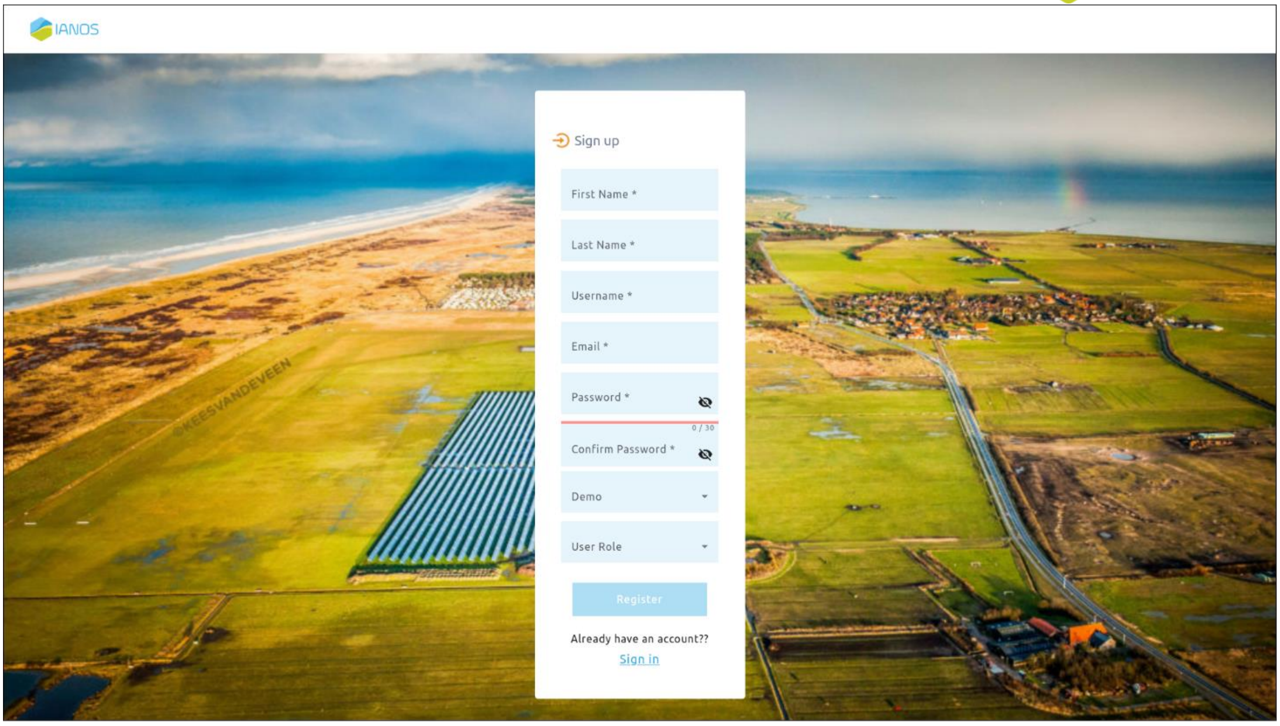

Figure 6: Registration page of the IEPT Suite dashboard.

Upon successful registration, users are able to log in, as seen in Figure 7 and access the IEPT Suite dashboard.

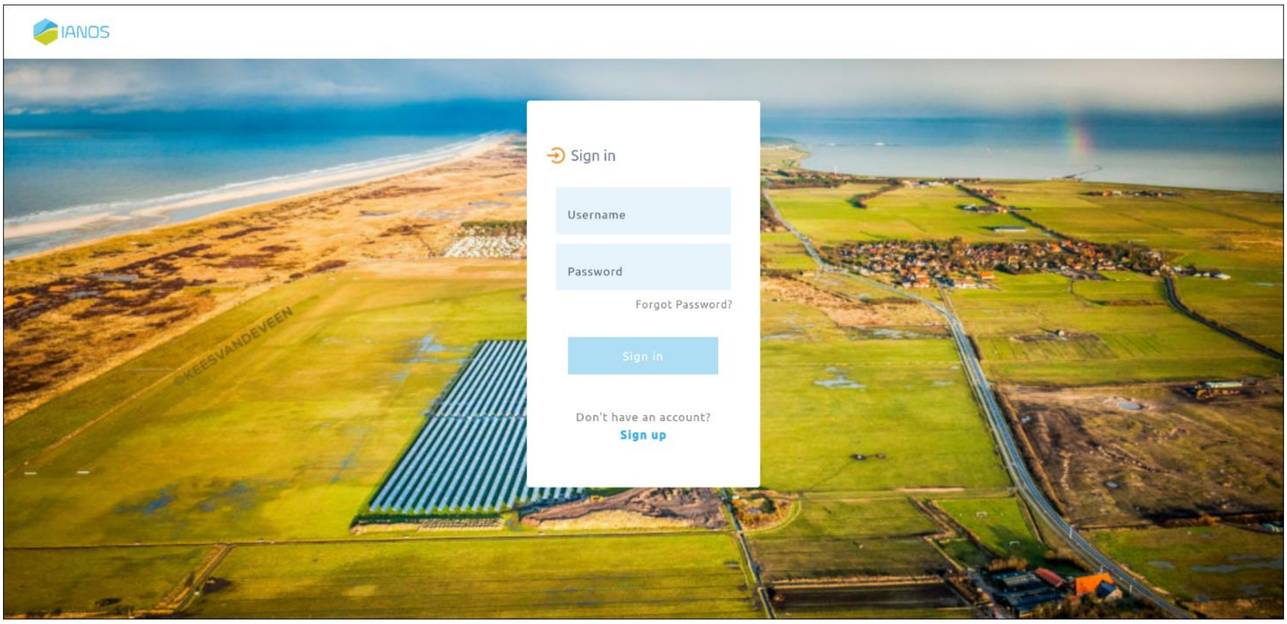

Figure 7: Login page of the IEPT Suite dashboard.

Upon successful login, the user can have an overview of the CBA module results. Specifically, the user can see information about the demonstration site, the actors

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involved in the investments, the use case that the user has selected and the specific assets that were added into the CBA. The CBA outcome includes values, such as NPV, IRR, etc., a graph with the cashflow of the investment and the final conclusion of the CBA. There is also a list of the technical benefits that the actors will achieve with the addition of the assets. The results can be depicted in Figure 8.

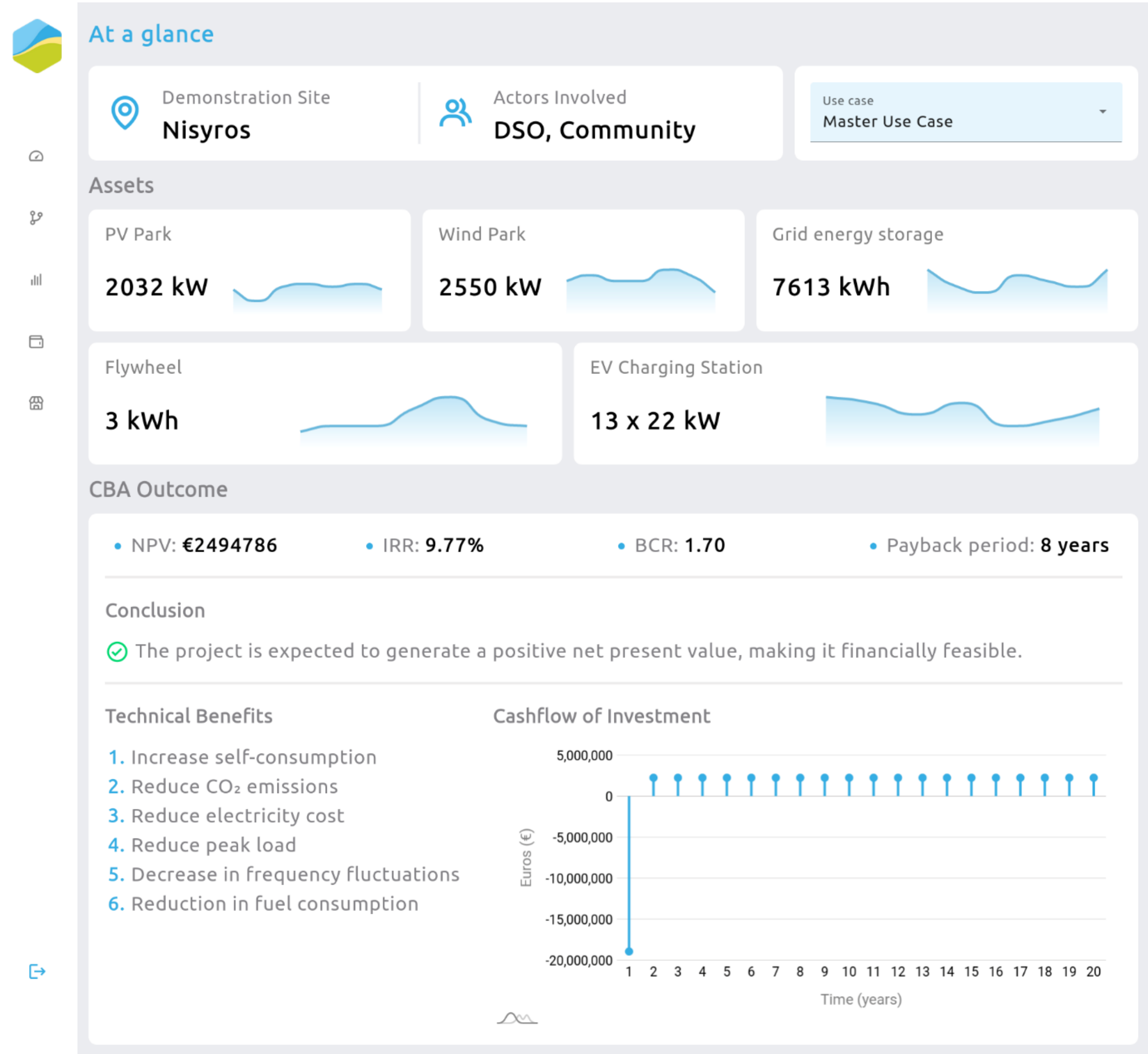

Figure 8: IEPT Suite's dashboard main page.

Overall, the GUI appears to be a well-designed and user-friendly interface. The internal testing has helped to iron out any issues and it seems that users will be satisfied with the experience of using the GUI.

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The layout is clear and easy to navigate, with intuitive menus. The GUI is also responsive, with fast load times and quick response times to user inputs.

The GUI also appears to handle errors gracefully. When a user enters incorrect information into the registration or login form, the GUI provides clear feedback on what went wrong and how to fix it. This error handling mechanism is essential for ensuring that users don't get frustrated or confused when using the GUI.

7. Conclusions

This deliverable (D3.8) is an updated version of deliverable D3.7, linked to Task 3.4. Important information was documented, providing the environment that the IEPT suite will be running on, based on all available information up to M30 of the project. Hence, two dimensions were investigated: the regulatory one and the level of fitness to the project's demonstrators. This was achieved through extensive research on the regulatory barriers and investment frameworks of each island and the exact dimensioning of all assets that will be used in the demonstration areas. The establishment of the environment that IEPT will be running on was completed by a mapping process of the KPIs identified for the IANOS UCs to the CBA module, along with a brief description of the scenarios that will be tested in each UC.

The interoperability of the components comprising the IEPT suite was validated through a verification test that was conducted for Nisyros FI, showcasing the way IEPT is leveraged for assessing investment plans. In this test, different operational scenarios were defined for the selected interventions (i.e., PV park, wind park, etc.) and compared to the baseline scenario. The CBA results indicated that the defined investment plan for Nisyros is financially feasible, profitable and absolutely worth considering.

Lastly, the IEPT suite's GUI functionalities were presented, showcasing the steps a user needs to follow to access the interface and the available CBA results that are visualized, along with some comments regarding the user-friendliness aspects of the interface.

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8. Appendix A – IANOS KPIs list

Table 17: IANOS finalized KPIs list.

Categories in D2.9	***KPI Name***
T-1	*RES Generation*
T-2	*Energy Savings*
T-3	*System Average Interruption Frequency Index (SAIFI)*
T-4	*System Average Interruption Duration Index (SAIDI)*
T-5	*Degree of energetic self-supply by RES*
T-6	*Percentage of total amount of waste that is used to generate energy*
T-7	*Storage capacity of the energy grid per total island energy consumption*
T-8	*Reduced energy curtailment of RES and DER*
T-9	*Peak load reduction*
T-10	*Accuracy of energy supply and demand prediction*
T-11	*Unbalance of the three-phase voltage system*
T-12	*Peak photovoltaic power installed per 100 inhabitants*
EN-1	*Reduced Greenhouse Gas Emissions*
EN-2	*Reduced Fossil Fuels consumption*
EN-3	*Electrical and thermal energy produced from solid waste or other liquid waste treatment per capita per year*
EN-4	*Air quality index (Air pollution)*
EN-5	*Reduction in the amount of unsorted waste collected*
EN-6	*Primary Energy Demand and Consumption*
EC-1	*Total investments*
EC-2	*ROI*
EC-3	*Total annual costs*
EC-4	*Payback period*
EC-5	*Total annual revenues*
EC-6	*Financial benefit for the end- user*
EC-7	*Minimum electricity price for companies and consumers*
EC-8	*Internal Rate of Return (IRR)*
EC-9	*Cost of Fossil Fuel purchased from mainland*
EC-10	*Cost of electricity purchased from mainland*
EC-11	*Energy poverty*
I-1	*Increased system flexibility for energy players*
I-2	*Data privacy - Data Safety & Level of Improvement (Improved Data Privacy)*
I-3	*ICT Response time*
I-4	*Increased hosting capacity for RES, electric vehicles and other new loads*
I-5	*Increased reliability*
I-6	*Number of sensors integrated/devices connected*
I-7	*Improved cyber security*
I-8	*Integrated Building Management Systems in Buildings*

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S-1	*People reached*
S-2	*Thermal Comfort*
S-3	*Job creation*
S-4	*Percentage of citizens' participation in decision-making*
S-5	*Number of interactive social media initiatives*
S-6	*Increased citizen awareness of the potential of smart islands projects*
G-1	*Involvement of the island administration*
G-2	*Smart island policy*
G-3	*Micro-grids legal framework*
G-4	*Suitable Energy Storage Regulation*
P-1	*Social compatibility*
P-2	*Technical compatibility*
P-3	*Ease of use for end users of the solution*

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