Deliverable 8.1: Baseline Analysis Report and 'BD-4-DER' Large Scale Pilots Preparation

WP8 – "BD-4-DER" Large Scale Pilots: Optimizing the Management of Assets (DER-Distributed Energy Resources) Connected to the Grid

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Preface

BD4NRG focuses on addressing emerging challenges in big data management for the energy sector with an innovative open holistic solution for smart grid-tailored, near real time, energy-specific and AI-based open Big Data Analytics modular framework. The vision is to deliver holistic services for techno-economic optimal management of Electric Power and Energy Systems value chain. Services range from optimal risk assessment for energy efficiency investments planning, to optimized management of grid and non-grid owned assets, improved efficiency, and reliability of electricity networks operation, while at the same time contributing to achieve fair energy prices to the consumers and laying the foundations for an EU-level energy-tailored data sharing economy. The BD4NRG Toolbox will be implemented and validated in real-life pilots in 12 large-scale demo sites across 8 countries for:

- Increasing the efficiency and reliability of the electricity network BD-4-NET

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- Optimising the management of assets connected to the grid BD-4-DER
- De-risking investments in energy efficiency and increasing the efficiency and comfort of buildings BD-4-ENEF

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Abbreviations & Acronyms

Acronym	Description
AAS	Asset Administration Shell
AC	Alternative Current
ANN	Artificial Neural Network
API	Application Programming Interface
BESS	Battery Energy Storage System
BMS	Building Maintenance System
BO	Business Objective
CI/CD	Continuous Integration/Continuous Delivery
CHP	Combined Heat and Power
CPV	Concentrated Photovoltaic
CSV	Comma-Separated Values
DaaS	Data as a Service
DAS	Data Acquisition System
DC	Direct Current
DER	Distributed Energy Resources
DL	Deep Learning
DNI	Direct Normal Irradiance
DR	Demand Response
DSO	Distribution System Operator
EV	Electric Vehicle
FSP	Full Service Provider
HTTP	Hypertext Transfer Protocol
IT	Information Technology

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JSON	JavaScript Object Notation
KPI	Key Performance Indicator
LSP	Large Scale Pilot
LSTM	Long Short Term Memory
LTE	Long Term Evolution
LV	Low Voltage
M&V	Measurement & Verification
MDP	Markov Decision Process
ML	Machine Learning
MV	Medium Voltage
NZEB	Near Zero Energy Building
O&M	Operation & Maintenance
POV	Proof of Value
PV	Photovoltaic
RES	Renewable Energy Sources
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SQL	Structured Query Language
SVM	Support Vector Machine
TCP	Transmission Control Protocol
TS	Transformer Station
UC	Use Case
UV	Ultraviolet
VPN	Virtual Private Network
WP	Work Package

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Executive Summary

This report provides an overview of the "BD-4-DER" Large Scale Pilots (LSPs) and concludes the work of the first task for WP8, Task 8.1. Aim is to establish a report, which provides a comprehensive and consistent overview of the baseline of the Key Performance Indicators (KPIs) associated with the use cases in the "BD-4-DER" cluster. It also provides an overview of the preparation per associated LSP and the further proceedings of WP8 activities.

The joint focus of all pilots is the optimization of the management of assets, which are connected to the grid. This is done by leveraging available data, providing insights on energy demand and flexibility. The baseline analysis for the pilots assists in the self-assessment process and establishing learning and preparatory opportunities across the different pilots. In addition, the pilot preparations for each LSP focus on three areas: infrastructure outline, deployment preparations and data-analytics services description.

By leveraging the preparatory steps each LSP has undertaken in relation to deployment and demonstration activities, the report sets the scene for follow up exploration of the commonalities and learning experiences that can be taken and utilized as a way of sharing insights from the further validation of BD4NRG interventions. Utilizing the entirety of pilots will support activities related to the harmonization across LSPs to enhance knowledge sharing during the next phase of BD4NRG pilot validation activities at the cross-section of WP8 & WP6.

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1 Introduction

This report is the first deliverable of WP8 of the BD4NRG project dealing with the so called "BD-4-DER" Large Scale Pilots (LSPs); that is pilots whose objective is to optimize the management of assets connected to the grid, and specifically those identified as Distributed Energy Resources (DER). In particular, this report concludes the work of the first task for WP8, Task 8.1, which has been running since early stages of the BD4NRG project and in parallel with the general preparatory and planning activities of Task 6.1. The latter has already released the Pilot Operations, Engagement and Measurement & Verification (M&V) plan (D6.1) where the processes to be followed by all BD4NRG pilots for the deployment and validation of the BD4NRG tools and services are defined. Nevertheless, this plan should be adjusted to the specificities of the pilots and their use cases that are within the "BD-4-DER" cluster. Hence the existence of this report.

1.1 Purpose of this report

The purpose of this report is to provide a comprehensive and consistent overview of the baseline of the Key Performance Indicators (KPIs) associated with the use cases within the "BD-4-DER" cluster as already identified and mapped within D6.1. Furthermore, this report aims also at describing the preparations already undertaken per associated LSP and in so doing setting up the scene for the rest of the WP8 activities.

1.2 Intended Audience

The intended target audience of this report is primarily the project's pilot coordinator (NTUA) and its technology partners as a means of providing them with the information necessary from all associated LSPs to perform the activities of continuous tracking of the pilot progress on one hand, and understanding of current state of affairs on the other.

Additionally, this report can provide useful information to the BD4NRG EU project officer and reviewers supporting them in their efforts to better understand the progress achieved thus far and of course its results and potential impact.

Last but not least, this report being public can also support similar stakeholders as the BD4NRG partners in their own endeavours of optimising the management of DERs, by providing them insights in terms of potential replication & assessment options.

1.3 Dependencies & Handovers

This report largely depends on the guidelines and processes already put in place by the activities of Task 6.1: templates and KPIs list and mapping to the "BD-4-DER" LSPs have been adopted as described within *D6.1 - Pilot Operation, Engagement and M&V Plan.* Naturally, it also feeds back to the ongoing activities of this task in support of the finalization of the pilot deployment plan.

With the completion of this report task 8.1 hands over to the remaining tasks of WP8, Tasks 8.2 – 8.6, where the actual deployment and demonstration activities are taking place, having established both the associated KPIs baseline and the preparatory steps for said activities.

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1.4 Structure of this report

The remainder for the report is structured as follows:

- Chapter 2 provides a comprehensive overview a6nd analysis of the baseline associated with the pilots within the BD-4-DER cluster; identifying both potential common denominators and specific differentiators.
- Chapter 3 presents the current state of affairs in terms of preparatory steps for the deployment of the identified BD4NRG services to each LSP within the BD-4-DER cluster.
- Chapter 4 concludes this report along with a summary of next steps within the activities of WP8 towards deployment and validation.

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2 Baseline Analysis

Following the guidelines and timeline of the pilot operation, engagement and M&V plan as defined in D6.1, this chapter proceeds with detailing the baseline information per KPI associated within the BD-4-DER cluster.

The thread that connects all pilots within this cluster is the focus on optimizing the management of assets connected to the grid by leveraging available data including, "behind the meter data", to gain insights on energy demand and flexibility.

Details on LSPs within this cluster are also found in report D2.1: Big Data Value Chain and Requirements. Table 1 provides an overview of all pilots within this cluster for ease of reference.

Table 1: Overview of all pilots within the BD-4-DER cluster.

Pilot	LSP Description	Leader Partners	Location
LSP 5	Cross-stakeholder Transfer Learning for Flexibility Assets Forecasting	CENTRICA	Belgium
LSP 6	Coordinating grid-owned and behind-the-meter assets management prediction for improved grid operation and near real time power market operation settlement	EKL, BORZEN & CS	Slovenia
LSP 7	Predictive Analytics Forecasting of storage optimized operation for improved market reserve participation	ENELX	Italy
LSP 8	Predictive Demand and Generation Forecasting for Optimized Local Energy Community Management	UNIWA	Greece
LSP 9	Collaborative aggregated energy generation prediction	ENERC	Portugal

2.1 General KPIs

All LSPs within the BD-4-DER cluster address the general KPIs as presented in D6.1 and here below repeated along with their definition for convenience (Table 2). For details, please refer to the aforementioned BD4NRG deliverable.

Table 2: General KPIs addressed by all BD-4-DER Large Scale Pilots.

KPI	Definition
G01: Seamless and smooth data transition from different types of sensors	The different types of sensors that will be used to collect data.
G02: Seamless and smooth data transition from different types of data resources	The different type of data resources that will transmit data to the BD4NRG platform.
G03: Resources	The number of resources used from the data sources.
G04: Type of data sources	The number of the different data sources to be used in BD4NRG.

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G05: Identification and interoperability with well-known open data sources	The number of open-source data sources that will be used in BD4NRG.
G06: Datasets used	The number of datasets that will be used to develop the analytics services of BD4NRG.
G07: Digital technologies integrated in the energy system	The number of digital technologies after the development of the analytics services that can be integrated in the energy system.
G08: Big data availability for real life research	The amount of data that will be used overall in BD4NRG.

The baseline indication for each KPI per BD-4-DER LSP is shown in Table 3.

Table 3: Baseline indication per Oct 2021 for each general KPI per BD-4-DER Large Scale Pilot.

KPI	LSP5	LSP6	LSP7	LSP8	LSP9
G01	Residential demand-response assets: frequency meter, voltage meter, power meter, Grid measurements: reactive and active power, voltage, total harmonic distortion (THD), current	10 surface temperature sensors, 10 transformer's oil temperature sensors, 10 temperature sensors for ambient temperature	1 AC grid meter – 1 DC BESS meter – 1 DC PV meter – 1 AC Load meter – 1 BMS battery system	2 PV Production Sensors – 7 Sensors for Pump Consumption – 1 Sensor for the whole consumption of Tilos Island	389 Inverters (each one has Power DC/AC Current, DC/AC Voltage, frequency); 388 CPV sun trackers (azimuth angle, elevation angle); 1 Weather station (temperature, humidity, irradiation - Global, Direct, Diffuse, precipitation, wind direction and velocity, pressure, UV intensity); Total number of 778 devices.
G02	Data of residential demand response assets, grid data	Weather, electricity consumption and devices (installed technology on the power network) properties	PV Production – Load Power consumption – Battery exchanged power – Grid power	Energy Production – Energy Consumption (Total & subsystems' consumption) & weather data from UBIMET	4 (2 weather data type sources, 1 energy sensor data type source, 1 Sun tracking data type source)
G03	Demand response assets (power, frequency, voltage, SoC, asset availability, power setpoint), Grid data	AC meters (10 parameters), current and forecast weather data (7)	AC meter (22 parameters) - DC meter (11 parameters) - BMS battery system (20 parameters) - Load	2 Energy Production (PVs), Energy 1 Consumption (Water Pumps) – 4 Weather	Weather station (9 parameters), Inverters (6 parameters), Trackers (2 parameters),

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KPI	LSP5	LSP6	LSP7	LSP8	LSP9
	resources (reactive power, active power, voltage, THD, current, DSO assets grid location, yearly residential production volume, standard year volume)		Simulator (13 parameters) - PV Plant (16 parameters)	(Temperature, Wind Speed, Solar Radiation, Cloud Coverage) from UBIMET	weather satellite (6 parameters), Solar Lab (5 parameters)
G04	Historical residential demand response asset metering data and historical grid data	Historical meter data, real time meter data, current weather, weather forecast data, real time temperature data, electrical current and voltage data	CSV/JSON	4 (PV data, historical weather data, weather forecast data, pumps consumption)	6 (Solar Edge API, CPV data, local weather station, historical satellite weather data, weather forecast data, Solar Lab energy data)
G05	n/a	n/a	n/a	n/a	n/a
G06	Historical residential demand response asset metering data and historical grid data	Several data sets, estimated more than 10, e.g. electrical basic values A, V in real time, energy real time, asset’s data, location, ...	5 (PV Production, Load Power consumption, Battery exchanged power, Grid power)	3 categories of data used (PV Production, Island Total Consumption, Pumps Consumption)	4 (CPV dataset, local weather station dataset, historical satellite weather dataset, Solar Lab dataset)
G07	0	Real time analytics tools	0	No digital technologies / analytics services	0
G08[1]	8750 GB	4MB per day, incl. only the pilot locations[2]	4.2 GB of historical data (2 years)	10GB of historical data	6-7 GBs for CPV generation data, 0.5 GBs for weather data

In the following sections KPIs specific to each LSP within BD-4-DER cluster are presented.

[1] The data reported in the baseline of KPI G08 “Big data availability for real life research”, concern the internal data that LSPs have available for use. The total amount of data that will be used in the project and provide the evaluation of the KPI G08, will be consisted of additional databases (such as open-source data, weather data), which will complement the LSP data and be reported in later deliverables of WP6-9.

[2] The size of streaming gathered data, limited to the entire pilot site, is estimated at 7 MB/day.

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2.2 Pilot Specific KPIs

2.2.1 LSP5: Cross-stakeholder Transfer Learning for Flexibility Assets Forecasting and dispatching – Belgium

Residential flexibility that is valorised on multiple energy services is becoming increasingly interesting. Residential assets such as electric vehicles, electric boilers, micro-CHPs or heat pumps are an untapped potential of flexible energy to integrate renewable energy in our energy systems by providing balancing services and mitigate grid congestion.

In order to control the assets efficiently, flexibility providers are building models of the assets to optimise their control actions. This can be a labour-intensive and time-consuming process that limits scalability. This challenge is approached by leveraging on data-driven algorithms in a Markov Decision Process (MDP) setting, such as reinforcement learning algorithms.

Flexibility providers, such as aggregators have access to very granular data over each individual asset such as power and voltage at fine-grained timescales (in the minutes to seconds range) through proprietary metering solutions.

LSP5 is focused on demonstrating the developed analytics services on transfer learning and grid-secure dispatching. The KPIs defined for the proposed use cases (UCs) aim at providing insights to different challenges. Regarding UC1, training data-driven models needs a considerable amount of data and can take time to converge to an optimal policy. Cross-context transfer learning is explored in this project as a solution and will be demonstrated in a real-life pilot. Regarding UC2, aggregators data can be leveraged in a cross-domain context to perform DR in a grid friendly way, by performing demand response in a way that supports the grid, mitigating voltage and congestion issues.

Following KPIs have been put in place to assess the pilot:

BO4 "DER Flexibility": This KPI will show the benefits of the transfer learning approach applied in the pilot test for control policy training compared to the state-of-the-art approach, for the first year of operation. With the state-of-the-art approach, an effective control policy is in place 315 days of the first year, as 50 days of that year are needed to train the policy. This means that only for 85% of the first operational year, an effective control policy is in place. This number is expected to increase after applying transfer learning, as less days will be needed to train the policy.

KPI 5101 "Number of days of historical samples required for training to fulfil the minimum cost saving target or related threshold": The efficiency of training is amongst others determined by the size of the dataset. Typically, 50 days of data are needed to train an effective control policy for an asset. This number is expected to reduce by the application of transfer learning.

KPI 5102 "Number of transfer learning agents deployed in staging / production environment": So far, no transfer learning agents have been deployed. This KPI tracks the number of assets with transfer learning agent deployed.

KPI 5201 "Number of grid secure disaggregation agents deployed in staging / production environment": So far, no disaggregation agents have been deployed. This KPI tracks the number of assets with transfer learning agent deployed.

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Table 4: KPIs Baseline specific to LSP5.

KPI	Definition	Unit	Related Use Case	Baseline
BO4: DER Flexibility	The aim of the KPI is to identify increase in DER flexibility that can be unlocked additionally with transfer learning, compared to Centrica's current services	% per year	UC1	85%
5101: Number of days of historical samples required for training to fulfil the minimum cost saving target or related threshold	To validate the added value of transfer learning, the number days required for training a control policy with and without knowledge transfer is compared	# Days of training data	UC1	50
5102: Number of transfer learning agents deployed in staging/production environment	For monitoring the pilot progress, the number of trained agents deployed in production (i.e., on a real asset in the field) is monitored	Number of assets	UC1	0
5201: Number of grid secure disaggregation agents deployed in staging/production environment	For monitoring the pilot progress, the number of grid secure agents deployed in production (i.e., on a real asset in the field) is monitored	Number of assets	UC2	0

2.2.2 LSP6: Coordinating grid-owned and behind-the-meter assets management prediction for improved grid operation and near real time power market operation settlement – Slovenia

The first use case is focused on providing data from the DSO infrastructure and the second UC, is about the independent aggregator flexibility activation, quantification and settlement. Both cases will define indicators as follows:

KPI 6101 is about the improvement of the electricity quality indicators. Improved quality parameters lead into improved reliability and efficiency of the power network. The legislation requests from the DSO to calculate the SAIDI and SAIFI, but both indicators give information for the entire grid. In our case, we

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will calculate this KPI for the observed part of the grid, as for lack of supplied energy and as reduction of the overloads at the observed transformer stations.

KPI 6102 is about cost reduction for management and maintenance of the power network assets. This is a technical indicator and it will be available when the pilots will be up and running.

KPI 6103, this indicator will give information about the increased number of the flexible prosumers.

KPI 6104 is about a number of innovative, data driven business models. DSO scope is to have this indicator for each MV/LV transformer station (TS). Under business models it is meant that for instance identified flexible prosumers offer through decreasing or increasing their consumption or production a support to the grid.

KPI 6201 is in relation with the second use case. Exploring this specific case, it is about the difference in the financial outcome for the consumer/producer for the corresponding models.

KPI 6202 will give an answer on a possibility, that the proposed models will be implemented for a larger number of end users, comprising many MV/LV transformer stations, much larger area then the pilot will consist of.

Table 5: KPIs Baseline specific to LSP6.

KPI	Definition	Unit	Related Use Case	Baseline
6101: Reliability and efficiency of the power network	Improvement of the electricity quality indicators regarding level of undelivered electricity, in terms of reliability and the reduction of the MV/LV transformer overloads.	#	UC1	Will be defined later, namely the SAIDI, SAIFI parameters are calculated on the level of a complete distribution grid
6102: Cost reduction for management and maintenance of the power network assets	This indicator will be available when the pilots will be up and running and is in relation with SAIDI.	%	UC1	6%
6103: Number of flexible prosumers	This KPIs will be an assessment of the increase of flexible prosumers, as this pilot will be the start of flexibility potential evaluation.	#	UC1	0,125
6104: Contracted/activated flexible power	This KPI will be about several innovative, data driven business	#	UC1	0,1

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KPI	Definition	Unit	Related Use Case	Baseline
provided to cover the DSO needs	models per MV/LV transformer station.			
6201: Impact on final asset (consumer / producer) for different possible models	The difference in the financial outcome for consumer/producer for the corresponding models	€	UC2	0
6202: Scalability of models (including equipment needs)	The possibility of implementing models for a larger number of end users	#	UC2	0

2.2.3 LSP7: Predictive Analytics Forecasting of storage optimized operation for improved market reserve participation – Italy

LSP7 is focused on creating Battery Energy Storage System (BESS) predictive maintenance tool and providing related maintenance procedures in order to identify under-performance cases and predict critical events thus to improve BESS reliability and, consequently, improve plant performance while reducing operating maintenance costs. The service takes in input multiple data sources (real-time and historical data) collected through a Data Acquisition System (DAS).

An overall description and baseline values for each specific KPI of LSP7 follows below:

KPI EI01 "Cost of asset maintenance and management": the baseline value will be defined at a later stage as it will depend on the market scenario, which is still under evaluation.

KPI 7101 "Number (percentage) of DAS measures collected by physical equipment": based on previous experiences, the robustness of Data Acquisition System architecture in terms of data backup routines joined with data caching procedures developed into the physical devices and good network connectivity in terms of data packet transfer, led to collect more than 95% of daily sensors data.

KPI 7102 "BESS under performance areas identification": it represents all the conditions in which BESS behaviour differ from nominal one, for instance internal temperature higher than nominal one. The baseline value has been defined by considering literature values defined on different ML approaches for anomaly detection.

KPI 7103 "Reaction time before system under performance event": it represents the time in which an under-performance area will be identified before a critical event could occur. The baseline value has been defined by considering literature values defined on different ML approaches for anomaly detection.

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Table 6: KPIs Baseline specific to LSP7.

KPI	Definition	Unit	Related Use Case	Baseline
EI01: Cost of asset maintenance and management	Reduction of annual cost for asset maintenance and management	€	UC1	**TBD**[3]
7101: Number (percentage) of DAS measures collected by physical equipment	This KPI measures the number of daily measures produced by physical sensors and collected into the Data Acquisition System.	%/day	UC1	>=95%
7102: BESS under performance areas identification	This KPI measures the number of BESS under-performance areas identified before system critical alert notification.	%	UC1	>=65%
7103: Reaction time before system under performance event	This KPI measures the time identification before system under-performance event (according to BESS under performance areas identified).	Hours	UC1	>=3h

2.2.4 LSP8: Predictive Demand and Generation Forecasting for Optimized Local Energy Community Management – Greece

In order to identify the baseline value assessment for the specific KPIs of LSP8 a specific process has been conducted for each one. The analysis for each KPI is presented below:

KPI EI04 "Network management improvement": For KPI EI04, the baseline value is not applicable as there were no predicted metered network loads as of now. During the BD4NRG project, the metered network loads will be predicted through the analytics services and the AI-based models in order to reach the target value set.

KPI EI05 "Use of renewable energy": RES penetration of the Kos-Kalymnos electricity system is in the order of nearly 15%. The applications under LSP8 will put forward maximum exploitation of RES-based self-consumption schemes for the envisaged pool(s) of loads, further supported by the development of tailored data-driven management strategies.

[3] As of writing the baseline of this KPI cannot be reported. Further analysis is necessary going beyond the scope of this deliverable. Subsequent report within WP6 (D6.2) will provide the result of such analysis.

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KPI 8101 "Specific Cost Savings": For KPI 8101 the specific cost savings upon deployment of BD4NRG services will be evaluated. Two different cost approaches are used. The first is based on standard utility tariffs (retail prices) and the second one, assuming the application of dynamic pricing based on wholesale prices. On average, production cost (wholesale) of the Kos and Kalymnos system where Tilos island belongs to, spans between 100 and 180 €/MWh (no overheads included), depending on oil prices and loading factors of the dispatched units, whereas utility tariffs normally range in the order of nearly 0.2€/kWh and offer a distinction between daytime and nigh time tariffs (e.g., Winter: 02:00 – 08:00 and 15:30 – 17:30, Summer: 23:00 – 07:00). At the same time, and for certain loads, such as municipality ones, discount tariffs may apply, that may drop to even 10cents/kWh. For this Use Case, the normal tariff of 0.2€/kWh is considered as the baseline.

KPI 8102 "Load Demand Volatility": For KPI 8102 the load demand volatility upon deployment of BD4NRG services will be evaluated. Measure of volatility will be influenced by data-driven peak shaving / load curve smoothing strategies. The latter will be supported by load shifting of flexible loads and via increased dispatchability of local PV generation (apart from scale aspects, power profile parameters like the panels' tilt angle will be investigated). For this Use Case, the baseline value of the volatility of load demand (through the standard deviation) on an hourly level, is calculated from 12 months of historical data (from May of 2020 until May of 2021). The value measured is 148.4kW.

KPI 8103 "Availability of Renewable Energy Sources": For KPI 8103, the availability of RES upon deployment of BD4NRG services will be evaluated. Depending on the use case examined and available PV capacity, an optimal matching between local PV power generation and load demand, assuming self-consumption and looking at both individual end-users and aggregated use, exploiting the complementarity between different demand profiles. This is expected to reduce hours of otherwise curtailed power and thus increase capacity factor of envisaged units. Based on two grid-connected PV stations (4.93kWp and 3.36kWp respectively), maximum annual capacity factor ranges between 17% and 20%, which, depending on the use, shall be increased by lowering the mismatch with the load profiles involved.

KPI 8104 "Annual RES Shares": The baseline is based on local PV generation and different end-user and load pool cases. The latter will reveal cases of different complementarity levels between local PV generation and different load profiles. By analysing a one-year data sample (May 2020 – May 2021) of the pump operating hours, the annual RES share for the operation of the pumps is 44%.

KPI 8105 "Specific CO2 Savings": For KPI 8105 the reduced CO2 emissions will be calculated. As Tilos' electricity mix consists of fuel and renewable sources, the CO2 reductions will be evaluated after the deployment of BD4NRG's analytics services. The fuel mix of the overall Kos and Kalymnos system, to which Tilos belongs, is described by an annual CO2 factor in the order of 700kg CO2/MWh, owing to the use of oil.

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Table 7: LSP8 - Specific KPIs Baseline Values

KPI	Definition	Unit	Related Use Case	Baseline
EI04: Network management improvement	Improvement of network management through reduced gap between predicted and metered network loads	%	UC1	n/a
EI05: Use of renewable energy	Increased use of renewable energy measured as amount of RES-based generated energy integrated in the grid network by leveraging on predictive load and generation forecasting	%	UC1	15%
8101: Specific Cost Savings	This KPI measures the specific cost savings achieved in the island of Tilos due to better allocation of energy uses (e.g., water pumps), resulting in improved alignment between the energy produced and the energy consumed.	Euros/MWh	UC1	0.2€/KWh
8102: Load Demand Volatility	This KPI measures the load demand volatility in the island of Tilos on an hourly level. Indicatively, peak shaving services have been implemented to support less volatile energy consumption patterns across the day.	% decrease of the standard deviation of the energy consumption	UC1	148.4 KWh
8103: Availability of Renewable Energy Sources	This KPI measures the ability of energy management systems to accurately detect and monitor anomalies in renewable energy production sources,	% increase in annual operating hours	UC1	900h

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KPI	Definition	Unit	Related Use Case	Baseline
	namely photovoltaic plants.			
8104: Annual RES Shares	This KPI measures the recovery of RES (PV or wind) curtailments achieved through the implementation of ML forecasting methods and load shifting DR strategies for a versatile pool of flexible loads.	% increase in annual RES (wind) shares	UC1	44%
8105: Specific CO2 Savings	This KPI measures the specific CO2 savings achieved in the island of Tilos due to a better penetration of renewable energy sources (e.g., PV plants), resulting in less losses.	(kg CO2/MWh)	UC1	700 kg CO2/MWh

2.2.5 LSP9: Collaborative aggregated energy generation prediction – Portugal

The pilot-specific KPIs of LSP9 are meant to measure: the number of maintenance interventions (equipment faults, replacements, repairs); the optimization of the cleaning operations and resources activation; the reduction in energy losses; how many types of components at the CPV plant are integrated in an edge architecture; the number of digital twins set up; and the number of data streams per type.

An overall description, goals and baseline values for each specific KPI of LSP9 follows below:

KPI EI01 "Cost of asset maintenance and management" - This KPI is intended to compare annual cost of asset maintenance and management. This is intended to evaluate the changes in costs of O&M after the BD4NRG analytical services are deployed. The baseline value of 25€/kW/yr is an industry average for CPV plants O&M annual costs because currently this value is not available. In the future, if this value is determined it can be compared with the industry average.

EIO6 "Energy efficiency increase" - This KPI measures the increase in energy efficiency after predictive maintenance is implemented. Since the BD4NRG analytical services haven't been deployed this baseline value is 0%.

9101 "Number of equipment faults" - This KPI measures the reduction of faults occurrence (inverters, CPV trackers, cells, etc.) after predictive fault monitoring is implemented through the BD4NRG analytical services. The recorded average number of faults per site is 9-10 per year.

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9102 "Number of maintenance interventions" - This KPI measures the change in the number of maintenance interventions (e.g., cleaning, plant system resetting, electric board, physical damage) after predictive maintenance is implemented through the BD4NRG analytical services. The recorded average number of maintenance interventions per site is 36-39 per year.

9103 "Number of replacements and repair interventions" - This KPI measures the change in replacements and repair interventions (e.g. inverters, CPV trackers, string, cells, etc.) after predictive fault monitoring is implemented through the BD4NRG analytical services. The recorded average number of replacements and repair interventions per site is 2 per year.

9104 "Number of cleaning operations and the related resources activation optimisation" - This KPI measures the change in the number of cleaning operations after predictive maintenance is implemented through the BD4NRG analytical services. This KPI is intended to evaluate the optimization in the cleaning cycles, including scheduling. The recorded average number of cleaning operations per site is 2-3 per year.

9105 "Number of enabled edge components" - This KPI intends to assess how many types of components installed were integrated in an edge architecture model (e.g., inverter, tracker, datalogger, gateway). Since, at the moment, no edge architecture has been deployed yet this baseline value is 0. The BD4NRG analytical services are expected to be deployed in an edge-enabled architecture.

9201 "Digital twins setting up and performance optimisation" - This KPI measures the digital twin's set-up to enable data share from available data sources. The baseline value for this KPI is 0 at the moment.

9202 "Data streams (energy production, energy consumption, building energy efficiency, energy related carbon footprint)" - This KPI intends to assess how many different data streams are offered per type for the digital twins. The baseline value for this KPI at the moment is 2 (energy production, energy consumption).

Table 8: KPIs Baseline specific to LSP9.

KPI	Definition	Unit	Related Use Case	Baseline
EI01: Cost of asset maintenance and management	Compare annual cost of asset maintenance and management	€/year	UC1	25€/kW/year
EIO6: Energy efficiency increase	Measure the increase in energy efficiency after predictive maintenance is implemented	%/year	UC1	0
9101: Number of equipment faults	This KPI measures the reduction of faults occurrence (inverters, CPV trackers, cells, etc.)	#faults/year - %	UC1	9-10 per site/year

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KPI	Definition	Unit	Related Use Case	Baseline
	after predictive fault monitoring is implemented			
9102: Number of maintenance interventions	This KPI measures the change in the number of maintenance interventions (e.g., cleaning, plant system resetting, electric board, physical damage) after predictive maintenance is implemented	#interventions/year - %	UC1	36-39 per site/year
9103: Number of replacements and repair interventions	Measure the change in replacements and repair interventions (e.g. inverters, CPV trackers, string, cells, etc.) after predictive fault monitoring is implemented	# replacements and repair interventions /year - %	UC1	2 per site/year
9104: Number of cleaning operations and the related resources activation optimisation	Measure the change in the number of cleaning operations after predictive maintenance is implemented, evaluating the optimisation in the cleaning cycles (including scheduling)	#interventions/year - %	UC1	2-3 per site/year
9105: Number of enabled edge components	Assess how many types of components installed were integrated in an edge architecture model (e.g., inverter, tracker, datalogger, gateway)	#edge components	UC1	0
9201: Digital twins setting up and	Optimal setting of architectures	# of digital twins	UC2	0

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KPI	Definition	Unit	Related Use Case	Baseline
performance optimisation	integrating systems enabling data share from available data sources			
9202: Data streams (energy production, energy consumption, building energy efficiency, energy related carbon footprint)	Assess how many different data streams are offered	# of data streams per type	UC2	2

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3 Pilot Preparation

3.1 Step-by-step approach

This section provides information related to the preparatory steps each LSP has been undertaking in anticipation of the demonstration activities, while getting their pilot ready for deployment of the identified services. In order to provide a uniform and consistent overview of the pilot preparatory activities, the Task 8.1 team opted for following the guidelines as initially drawn up within Task 6.1 with the focus on deployment preparations.

In the subsequent sub-sections of this report, each LSP provides an overview of their efforts on pilot preparations by focusing on 3 areas: (i) infrastructure outline, (ii) deployment preparations and (iii) data-analytics services description.

Step 1: Outline of the infrastructure according to the following guidelines:

- The communication interface or protocols via which data may be accessed. BD4NRG platform will be able to accommodate diverse and interoperable type of data under its premises. In that context, data infrastructure and existing methods are important to be taken under consideration at this early level.
- Dedicated APIs to access data infrastructure along with relevant documentation
- Standardized data model currently being used (i.e., SAREF, FI-WARE). BD4NRG platform will also rely on standardized data models. This is aligned with the AI4EU project and relevant activities that could help share AI resources produced in European projects.

Step 2: *Description of preparations for initial deployment,* with starting point based on Pilot Deployment Information as provided from on-going activities within Task 6.2 on pilot monitoring and coordination. Table 9 focuses on the topics that are related to initial deployment actions and further elaborated for each LSP in its respective sub-section.

Table 9: Related topics to initial deployment actions.

Topic	Sub-topic	Description
Readiness	**Deployment diagram**	**Summary of the necessary steps for deployment**
	Deployment preparation	**Description of the requirements for the components and the underlying infrastructure**
	Deployment assessment	**Assessment of the completeness of the preparation and the mitigation of the possible identified risks**
Data Handling	**Data Population**	**Description of the process for populating the databases required for the operation of the services**

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Topic	Sub-topic	Description
	Algorithm Training	**Description of procedures for ML/AI training with the relevant datasets, include validation mechanisms**

Step 3: *Description data-analytics services* to be deployed in a narrative form to show how the pilot is realizing the use case's vision.

3.2 LSP5: Cross-stakeholder Transfer Learning for Flexibility Assets Forecasting and dispatching – Belgium

3.2.1 Infrastructure

The infrastructure of LSP5 consists of residential demand response assets of Centrica (EVs, heat pumps, electric boilers, etc.). The assets are connected to a gateway containing the local control logic of the asset and communicating with the pool controller that determines the control policy per asset. The control policy per asset depends on asset-specific data. The local control logic in the gateway receives measurements from the local measurement devices. These measurements are related to the power grid (e.g., frequency and voltage). Moreover, the activated power and other measurements are sent via the local gateway to the pool controller for validation of the executed control.

3.2.2 Deployment preparations

Deployment diagram

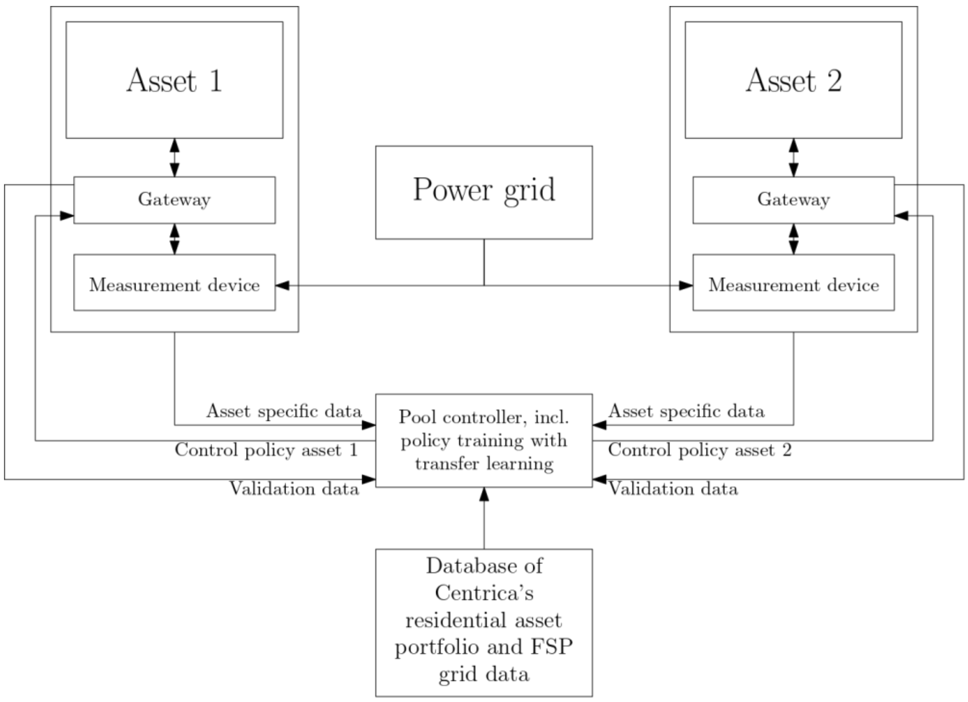

Figure 1: LSP5 Deployment Diagram

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Deployment preparation

The gateways and measurement devices are in place at the assets' location. The infrastructure to communicate securely with the gateways is also in place. The main development is needed in the policy training with transfer learning block, the interaction with the database of Centrica's residential asset portfolio and FSP grid data, and possible changes in the existing communication between the local gateway and the adapted pool controller.

Deployment assessment

Assessment of the solution involves comparing measurements of the activated power signal at the asset level with power signals to be expected according to the grid measurements and the trained control policy.

Data Population

The data that will populate the databases will be coming from Centrica's portfolio of residential assets and grid data collected by the flexibility service provider.

Algorithm Training

The service will involve a variety of AI-based techniques, such as reinforcement learning and transfer learning, to learn adequately control policies for residential assets.

3.2.3 Data-analytics services

The services to be developed in LSP5 aim at improving the efficiency of learning control policies for residential assets to provide flexibility and energy services to the system in a grid-friendly way.

The proposed methodology is based on the concept of transfer learning. To generate accurate models via data-driven techniques a lot of (labelled) training data is needed, preferably recorded in very similar circumstances to the use case at hand. Applying models trained for similar applications but in different exogenous conditions is typically not straightforward. Instead, a lot of effort and time is required to build up new site-specific training data sets and retrain the models, limiting scalability. For this reason, we want to apply transfer learning to be able to leverage data obtained for similar assets but deployed in different locations and in different external conditions to boost the training of models and agents for specific (new) use cases. Different applications can benefit from the developed solutions, e.g., the derivation of optimal policies to control flexible assets in different countries, but with different conditions regarding user habits, climate, grid constraints, etc.

The service collects historical data of Centrica's residential asset pool in different countries and contexts, and the grid-data collected by the flexibility service provider. The collected data by the flexibility provider will be leveraged in a cross-domain context to perform demand response in a grid friendly way, e.g. by performing demand response in a way that supports the grid, mitigating voltage and congestion issues. Algorithms will be trained on Centrica's residential portfolio. The trained algorithms will be tested on part of Centrica's residential portfolio.

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3.3 LSP6: Coordinating grid-owned and behind-the-meter assets management prediction for improved grid operation and near real time power market operation settlement – Slovenia

3.3.1 Infrastructure

The Slovenian pilot consists mainly of the existing DSO's assets, the electricity distribution grid assets. But following the two use cases defined in previous chapters, Elektro Ljubljana will install more equipment in the field. We plan to select at least 10 locations; a location is a point where the distribution grid operator has a MV/LV transformer station. At each location we will install additional meters such as meters for temperature. So, the pilot site will comprise the LV grid, completely observed by metering equipment. So, we will use the data from the existing smart meters and the data coming from the new installed devices.

3.3.2 Deployment preparations

Data gathered for installed devices are going to be processed. The pilot will result in the design of rules and complementary toolbox for implementation of the demand-response services and settlement among the involved and impacted parties. The idea of use case one is, that the pilot will involve near real time predictions of transformer overloads, based on historical and near-real time data from smart meters and other relevant data such as temperature measurements. In the second use case data from the meters and analytical tools will be used to demonstrate settlement within the power market using different models for implementation of flexibility.

3.3.3 Data-analytics services

Reliable and near real-time DSO assets data, comprising smart meters and temperature sensors, providing information via a reliable information transfer (LTE), weather data, etc. All these data will be used in the analytical tools (prediction of the available balancing/flexible capacity, estimation of volumes of realized activated energy, assessment of effectiveness of activation on a physical level). Other data analytics tools will be specified just after completion of already planned equipment installations on the field.

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3.4 LSP7: Predictive Analytics Forecasting of storage optimized operation for improved market reserve participation – Italy

3.4.1 Infrastructure

The infrastructure of LSP7 consists of Energy Storage Systems, PV plants, End user data and AC/DC meters.

The overview of the data is the following:

1. Energy Storage System profile data with a granularity of 1 second and collected using Modbus RTU protocol in CSV/JSON file.
2. PV Power production profile data with a granularity of 5 seconds and collected using Modbus RTU protocol in CSV/JSON file.
3. Load power consumption simulated profile with a granularity of 1 second and collected using Modbus TCP protocol in CSV/JSON file.
4. AC/DC Meters data with a granularity of 5 seconds and collected using Modbus RTU protocol in CSV/JSON file.

Each electrical parameter will be stored in a No-SQL database, accessed by VPN and username/password, and contained into Enel X Database Cluster.

3.4.2 Deployment preparations

Deployment diagram:

Development & Deployment Plan:

As shown in Figure 2, the Development and Deployment plan can be organized into 6 activities:

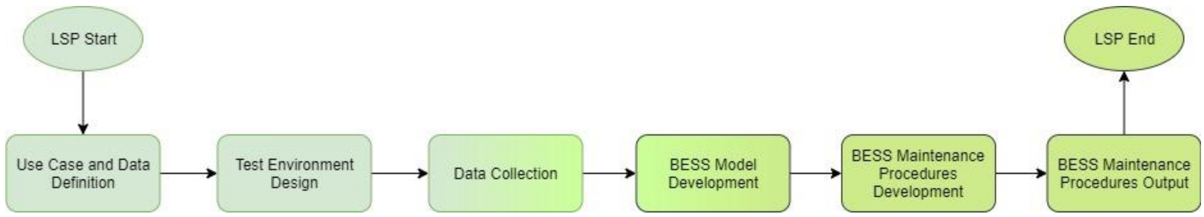

Figure 2: Development & Deployment Plan for LSP7

1. Use Case and Data Definition: this activity represents the starting point of the LSP7 and consists of defining the use case and the necessary input data, for each step, in order to provide the final output.
2. Test Environment Design: represents the preparation of the test environment. This activity includes:

- Asset definition in terms of device/electrical instruments able to provide the data defined in the previous item, and their physical installation.
- Interfacing between assets and Data Acquisition System through communication protocol.
- Database Cluster development in terms of database installation and structure definition according to the data provided by the assets.

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3. Data Collection: represents the data gathering process thanks to the implementation of device connectors (Python programming language) in order to read asset registers and store the information into the No-SQL database.
4. BESS Model Development: represents the core activity of the whole project. A BESS model will be developed using machine learning techniques and the input data collected in order to identify BESS under-performance areas.
5. BESS Maintenance Procedures Development: after under-performance areas identification, this activity aims to define the maintenance procedure in order to preserve BESS integrity.
6. BESS Maintenance Procedures Output: this activity represents the final point of the LSP7 and consists of providing final output produced by the model developed in the previous item.

Envisioned System Architecture:

The test environment that will be used for LSP7 will be composed of a stand-alone energy storage system (250kW/500kWh) equipped with additional sensors able to validate the data collected by BMS and ESS that can be coupled with a 300kW Load/PV simulator.

Figure 3 describes the integration, among each component, necessary to provide input/output data.

Each physical component is interfaced with the Data Acquisition System through an external gateway directly connected. According to the kind of asset, the connection with the external gateway could be implemented using two different Modbus protocols:

- Modbus TCP using ethernet connection
- Modbus RTU using serial connection

In particular, Energy Storage System (with additional sensors), PV plants and AC/DC meters will be connected via Modbus RTU while Electronic Programmable loads will be connected via Modbus TCP.

Each external gateway will therefore have two interfaces, the first one, as described before, will be used for Modbus connection with the physical component and the second one will be used, for the connection with Data Acquisition System via LAN through the Enel X Internal Process Network.

In addition to the parameters read by the physical equipment (Energy Storage System, PV Plants, Electronic Programmable Loads), other electrical parameters are available through external AC/DC Meters in order to measure AC power exchanged at the grid connection point, DC power produced by PV plants, internal DC power related to the batteries.

Each data collected by the external gateway will be stored in the Database Cluster, composed by 3 servers, which contains the instance of No-SQL Database (MongoDB) for the data storage. The data storage process involves Data Acquisition System and Database Cluster also connected through the Enel X Internal Process Network.

All the parameters stored into MongoDB database will be the inputs for the BESS model that will be developed into the Application Server.

The output of the model, representing maintenance procedures aimed to preserve BESS integrity, will be provided through API interface as CSV/JSON files. In order to allow the API to be reached from external networks, a Server Proxy will be installed to allow the communication between Enel X Process Network and the BD4NRG environment.

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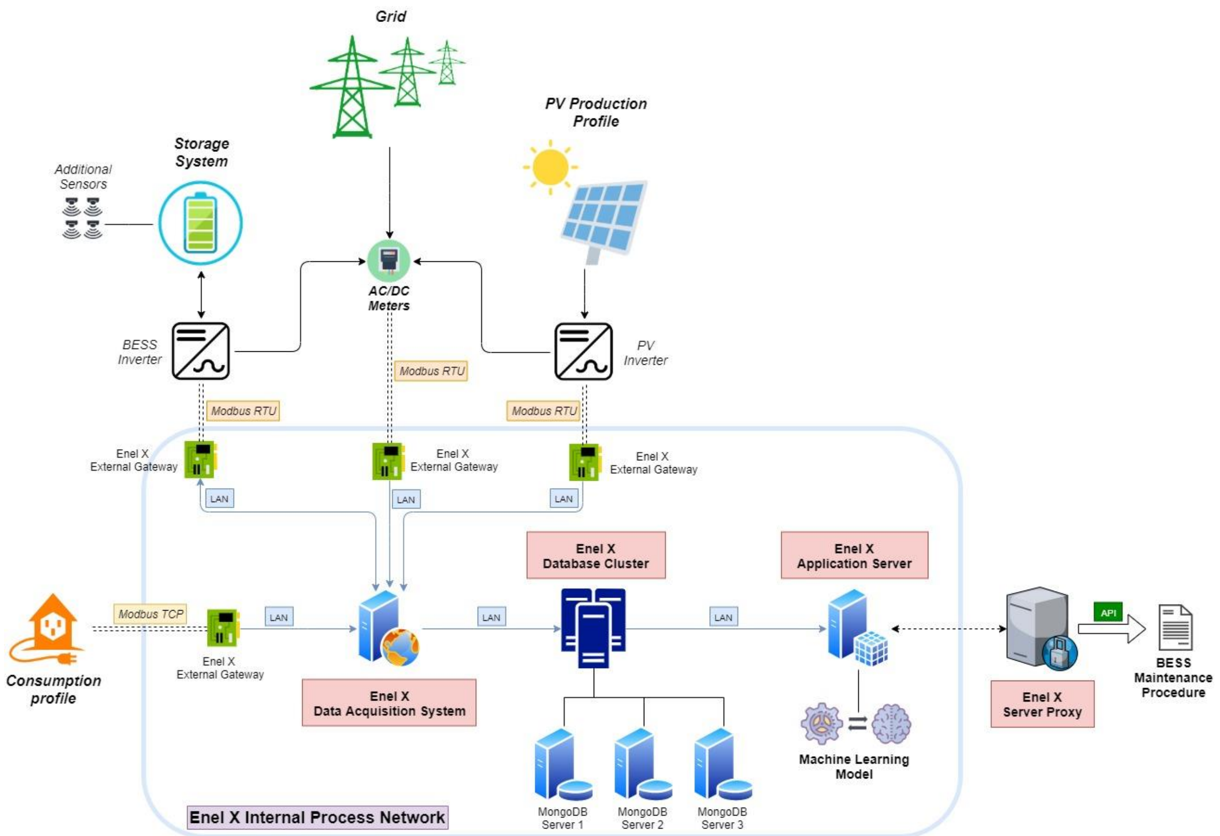

Figure 3: Data Architecture

Deployment preparation:

Following the plan described in Figure 2, first step is to prepare the test environment in terms of Energy Storage System installation and Data Acquisition System development.

For the Data Collection process, we will mainly use Python programming language in order to develop:

- communication interfaces installed into the external gateways
- data storage into Data Acquisition System
- BESS Model development using Machine Learning libraries such as Tensorflow, Keras, etc…

Once previous items have been developed and tested, docker will be used, which is a virtualization platform to deliver software in packages called containers.

Deployment assessment:

The assessment of the deployment will be performed in a later stage, when the architecture will be implemented. The key points we will focus on are asset data availability, data storage, BESS control through power set-points and secure connection between Enel X Process Network and BD4NRG (Server Proxy for output APIs).

Data population:

The inputs necessary as dataset for the development of BESS model come from external AC/DC Meters, BESS inverters coupled with PV inverters, Electronic Programmable loads that define simulated consumption profiles and historical real consumption profiles.

The data are gathered through external gateways connected via Modbus TCP/RTU to the aforementioned sources.

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Algorithm Training:

The ML model used to provide the outputs will be developed using a variety of AI-based techniques such as SVM, LSTM, Regression, Unsupervised/Semi-supervised Learning.

The output will be provided through an API interface as CSV/JSON files.

3.4.3 Data-analytics services

Below a description of the service defined for LSP7.

BESS predictive maintenance tool and related procedures.

The service aims to create a BESS predictive maintenance tool and provide related procedures, starting from condition-based monitoring, in order to identify under-performance cases and predict critical events. The goal is thus to improve BESS reliability and, consequently, improve plant performance while reducing operating maintenance costs.

The service takes as multiple data sources with different sampling rates such as AC/DC Meters power measures (5 seconds availability), energy storage system profiles (1 second availability), PV power production simulated profile (5 seconds availability), Load power consumption profile (1 second availability) and identifies under-performance areas through a BESS model, real-time and historical data.

3.5 LSP8: Predictive Demand and Generation Forecasting for Optimized Local Energy Community Management – Greece

3.5.1 Infrastructure

The infrastructure of LSP8 consists of PV plants, water pumping components, energy demand from end users and weather data. The granularity of the data varies between 15 minutes and 1 hour. Historical data of up to 2 years will be utilised, in order to create the services. The overview of the data is as follows:

- RES Production, and specifically PV production from local plants. The measurements will have granularity of 15 minutes and 1 hour. As of now a sample of data is available in CSV files.
- Electricity load at the community (island) level, as well as from water pumping components and end users. The measurements are hourly, and a sample of data is available in CSV files.
- Weather data (Solar Irradiance, Temperature, Cloud coverage, Wind Speed, Wind Direction). The weather forecast is available of up to one week and the data are provided, through a Restful JSON API

As of now the communication protocols exist for the weather data. Grafana application is available for the water pumping components through its interface and the relevant architecture that will provide the infrastructure to streamline the data (sensors, communication protocols, dedicated APIs and security protocols) are under design. No standardised data models are being utilised but instead

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custom data models for research use.

3.5.2 Deployment preparations

Deployment Diagram

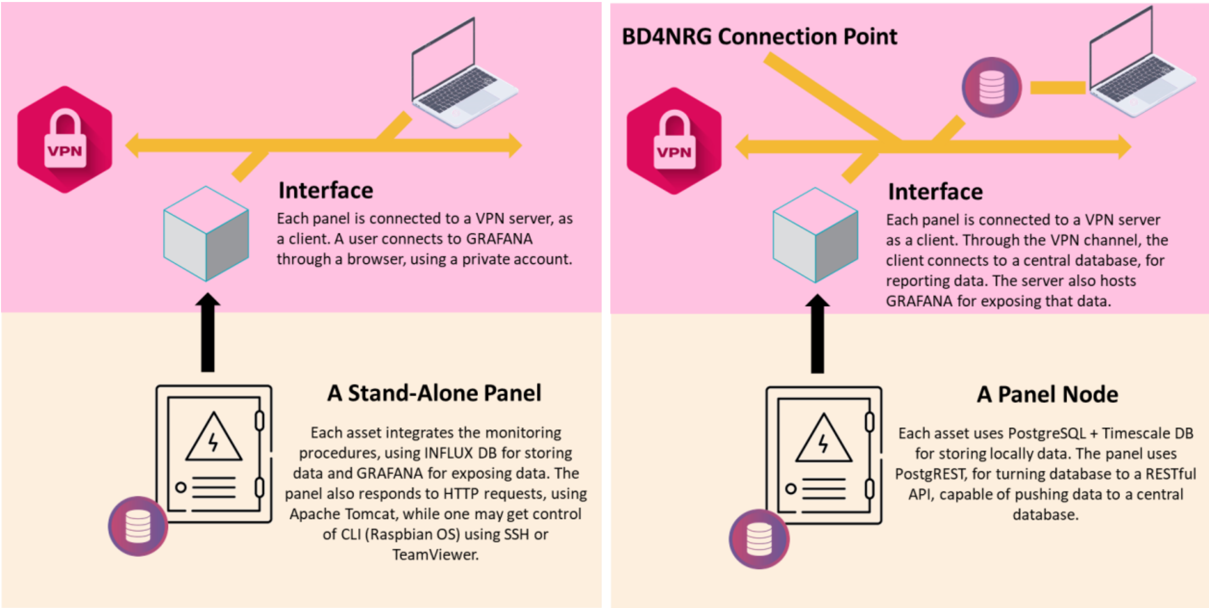

Figure 4: LSP8 Deployment Diagram (De-centralised mode/envisioned centralized mode)

The existing architecture for data gathering, processing and sharing is depicted in the above figure and relies on a decentralised system. Each stand-alone panel encapsulates its monitoring and data gathering procedures using InfluxDB and GRAFANA. InfluxDB is a time series platform which is used for storing the panel's data, while GRAFANA is an open observability platform which is for the assets' data exposure and visualization. Access to data is given for each asset through HTTP requests using Apache Tomcat. Another option is the direct connection to the Raspbian OS CLI with remote control through SSH or TeamViewer. Each panel is directly connected to a VPN server, where authorised users may connect to GRAFANA in order to inspect data through a browser.

Deployment Preparation

The envisioned architecture which is being implemented for the purpose of the project is based on a centralised mode. In this case, each asset will store the produced datasets locally, with PostgreSQL and Timescale DB, which is a database scheme for time series data. A central database is being created where data from different nodes will be pushed through a RESTful API using PostgREST. The interface of this architecture will rely on a VPN server as in the decentralised mode. The clients will be able to connect to the central database in order to report and inspect data, while the GRAFANA solution will be incorporated to the server. The central database will, finally, be connected to the BD4NRG database, where data will be collected for processing and analytics implementation.

Deployment Assessment

The assessment of the deployment will be performed in a later stage, when the architecture is designed, and the infrastructure is deployed. The key points that will be addressed are, sensors' downtime being minimised, data streamlining in the desired granularity, data cleansing and secure

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connection between BD4NRG and LSP8 (VPN connection both for Grafana application and the dedicated APIs).

Data Population

The data that will populate the databases will be coming from the local RES production plants (PV panels), energy intensive infrastructures, end-users' and community-level load demand, and weather data.

Algorithm Training

The service will involve a variety of AI-based techniques, depending on the context and the particularities of the modules it consists of. Electricity load forecasting and RES production forecasting modules will exploit advanced ML models, namely ANNs and Regression Trees (e.g., XGBoost and Random Forests). Peak shaving and load shifting modules will exploit heuristic and fuzzy logic algorithms.

3.5.3 Data-analytics services

The services to be developed in LSP8 aim to support peak shaving and load shifting decisions for a community pool of diverse electricity loads based on electricity demand and RES production forecasts.

The service collects historical data of energy intensive infrastructures and end-users (e.g., pumping stations, public buildings, and EV charging stations) as well as weather data and predictions (e.g., temperature) and provides electricity demand forecasts for the upcoming day(s). Similarly, the service collects available historical data of local RES production plants (e.g., PV stations, wind parks) as well as weather data and predictions (e.g., radiation, wind speed) and provides RES production demand forecasts for the upcoming day(s). Based on the forecasts produced, load peaks are identified and shifted, where possible, to better match expected production on an intra-day level.

The proposed methodology is based on two pillars:

The first pillar is the development of two forecasting models. Several techniques and approaches will be taken under consideration, based on the requirements of the Use Cases. The first model being developed by NTUA, aims towards the prediction of the energy production of the photovoltaic panels, taking as input the PV production historical data and weather data and using ML/DL algorithms. A second approach for the energy production as well as forecasts of power generation, where forecasts are calculated with physical models and optimised statistically by ML algorithms, is being developed by UBIMET. Provided data can be used to calculate the current and future load of power grid to avoid curtailments and to allow settlements of redistributed power generation. The second model will provide forecasts for the total energy consumption of the island of Tilos, by taking into consideration the historical data, weather data and analyse the patterns of electricity use from various end points.

The second pillar is a pattern extraction method developed in order to calculate the total operating hours of each load component examined (e.g., water supplying system), exploiting the operating schedule during previous years. The abovementioned methods are combined in order to create an integrated scheduling plan for the asset(s) each time examined aiming to achieve peak shaving in high energy demand hours and the exploitation of locally generated RES.

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3.6 LSP9: Collaborative aggregated energy generation prediction – Portugal

3.6.1 Infrastructure

The infrastructure of LSP9 consists of a 4MWp Concentrated Photovoltaics (CPV) plant and a Near Zero Energy Building (NZEB) Research & Innovation Infrastructure – *Solar Lab*. The CPV plant is divided into 3 sites, each one for a different CPV technology. All these sites are composed of CPV strings, inverters and solar tracking systems. The Solar Lab is composed of an 11.7 kWp self-consumption system, a battery storage system of 6 kWh, an EV charger, a weather station and smart home appliances (oven, refrigerator and freezer). The overview of the data is the following:

- RES production and trackers system, specifically from one of CPV sites. The measurements will have granularity of 5 minutes. A sample of data was already made available in a CSV file.
- RES production, energy storage and electricity load consumption from Solar Lab. A sample of data is available in XML files for the inverter data and in CSV files for the remaining data.
- Weather data (Solar Irradiance, Temperature, Wind Speed, Wind Direction, UV index, pressure and precipitation) coming from the local weather station at Solar Lab with a granularity of 1 minute and made available with CSV files.

The existing communication protocols are for the Solar Lab self-consumption data, weather data and energy forecast data. The self-consumption data is accessed via the inverter's manufacturer Restful API (*Solar Edge* API) while the weather data and energy forecasts are accessed by a Restful JSON API. The latter is an API prototype by UBIMET. The remaining communication interfaces and protocols that will be used for the rest of the data are currently being determined. Because of this no standardized data model are being utilized but their use is being considered and most likely will be used.

3.6.2 Deployment preparations

Deployment diagram:

Development & Deployment Plan:

For the LSP9 the generic development and deployment workflow (from Harvard Computing Group) is shown in Figure 5.

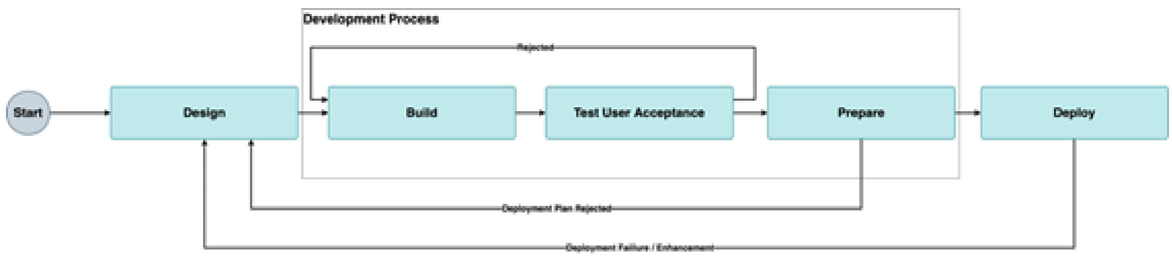

Figure 5: Development & Deployment Process Flow

Figure 5 indicates that the Development & Deployment Process Flow involves three main activities, namely:

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- Design: this is where the requirements of the solution are established, and specifications created.
- Development: this is where the solution is developed taking into account the specifications. The activity can be further split into tree sub-activities:
- Build: it involves the development and integration of the components that are part of the final solution.
- Test User Acceptance: it involves the testing of the developed solution. A negative output of this activity means returning to the build activity.
- Prepare: after a positive result during the user acceptance tests, this activity can start. It involves the final adjustments and necessary configurations to the source code of the solution enabling the deployment within a production environment. Documentation is also part of this activity.
- Deploy: it is the activity of managing the final solution into production. Any failure and/or enhancement identified during this activity/stage will be used as input to the Design activity in a continuous process of design-develop-improve.

Envisioned System Architecture:

The envisioned system architecture for LSP9 is shown in Figure 6.

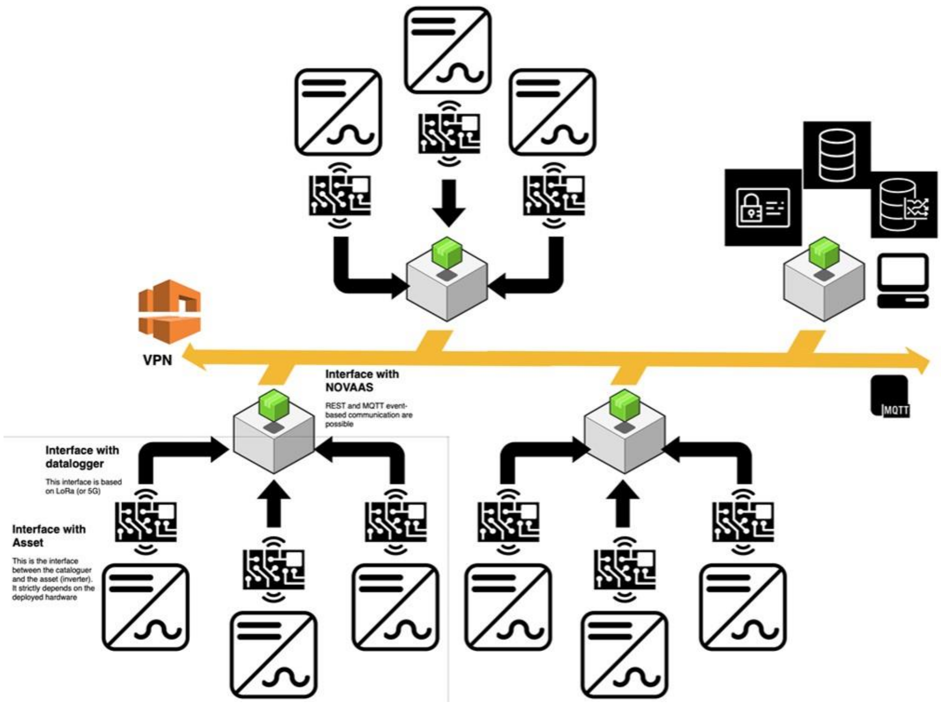

Figure 6: LSP9 Envisioned System Architecture

Figure 6 shows at a very high-level the logical organization of the envisioned components as well as a snapshot of the way they interact i.e., the relationships between them. The main idea behind the LSP9 system model is to develop a fully compliant Industry 4.0 (I4.0) Edge data platform that allows data collection, pre-processing, streaming, analysis and storage at the edge. The platform is designed using the broker topology model where asset events are broadcasted to a lightweight message broker. The component responsible for collecting the data from the physical assets is designed according to the I4.0 specifications and takes the name of Asset Administration Shell (AAS). The AAS will be also responsible to hold standard digital models for of the underlying physical assets. Finally, connected to

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the broker several services are envisioned ranging from data analytics to data persistence and querying passing through the IoT management platform. At the current stage, not all the components will be developed and released. In fact, for the first technological release a simplified version of the architecture in Figure 7 will be developed and used as a "Proof of Value" (POV).

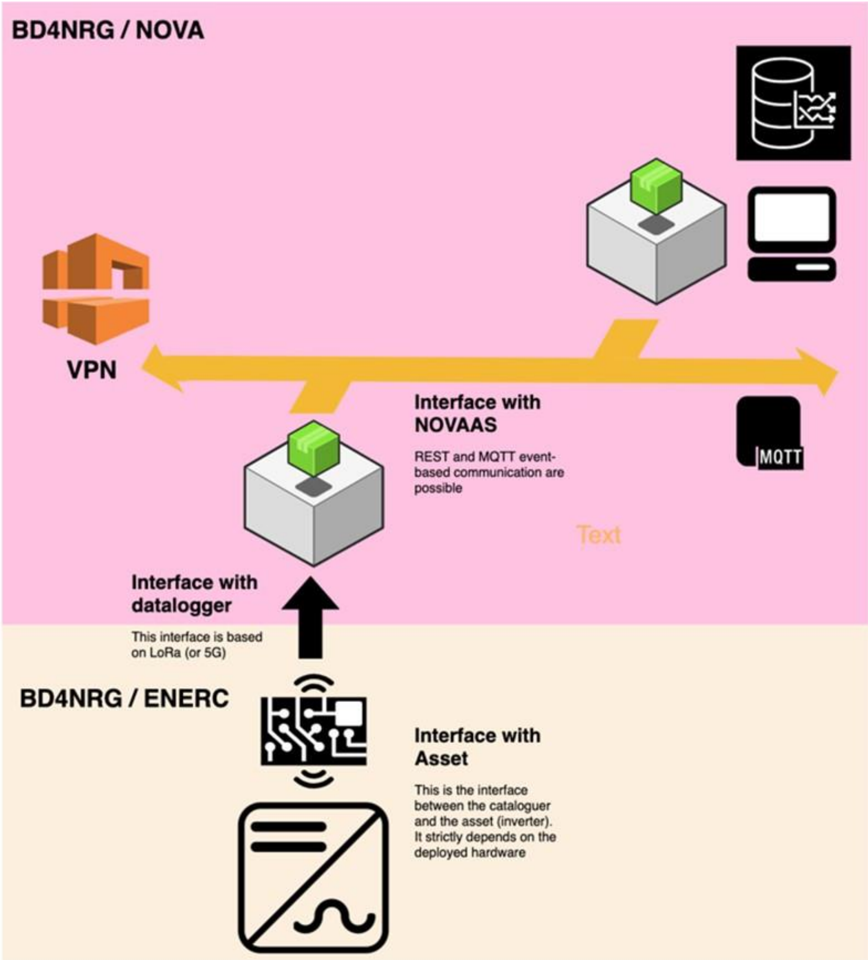

Figure 7: Envisioned Architecture for the First Technological Release

The release will provide an implementation of the AAS component based on NOVAAS[4]. NOVAAS is an open-source AAS Server and will be responsible to provide – from one side – a "living instance" of the AAS itself, and – from the other side – a digitalization of the physical asset connected to it. Data from the physical asset will be collected by a data logger and NOVAAS will in turn collect data from it. The data logger is already installed and deployed within the production environment. To facilitate the visualization of the data coming from NOVAAS and show the value of the new set-up an IoT platform will be also deployed within the POV.

The full list of components and responsible partners is included within Table 10.

Table 10: First Release Components and Responsible Partners

Component	*Responsible Partner*
Infrastructure	ENERC/UNINOVA

[4] https://ieeexplore.ieee.org/document/8927081

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NOVAAS	UNINOVA
Broker	UNINOVA
Connector between NOVAAS and data logger	ENERC/UNINOVA
Asset Digital Model	UNINOVA/ENERC
IoT Platform	UNINOVA

Once the POV has been deeply tested and exploited the same configuration will be replicated to all the other assets within LSP9. In addition, within the future release, machine learning (ML) and artificial intelligence (AI) algorithms will be deployed to show fast data analysis and Servitization at the edge.

Deployment preparation:

A modern IT infrastructure for supporting the DevOps strategy

One of the main objectives of LSP9 is the usage of advanced Information Technology (IT) methodologies, strategies and related tools to improve enterprise agility in very conservative industries. In particular, the solution will be built on a technical infrastructure to ensure the implementation of a DevOps strategy, i.e. to close the loop between development and operations while enhancing monitoring, testing and software delivering. The strategy is built around Continuous Integration/Continuous Delivery (CI/CD) principles and requires a complete technological shift. The infrastructure, the tools and the CI/CD processes for LSP9 are shown in Figure 8.

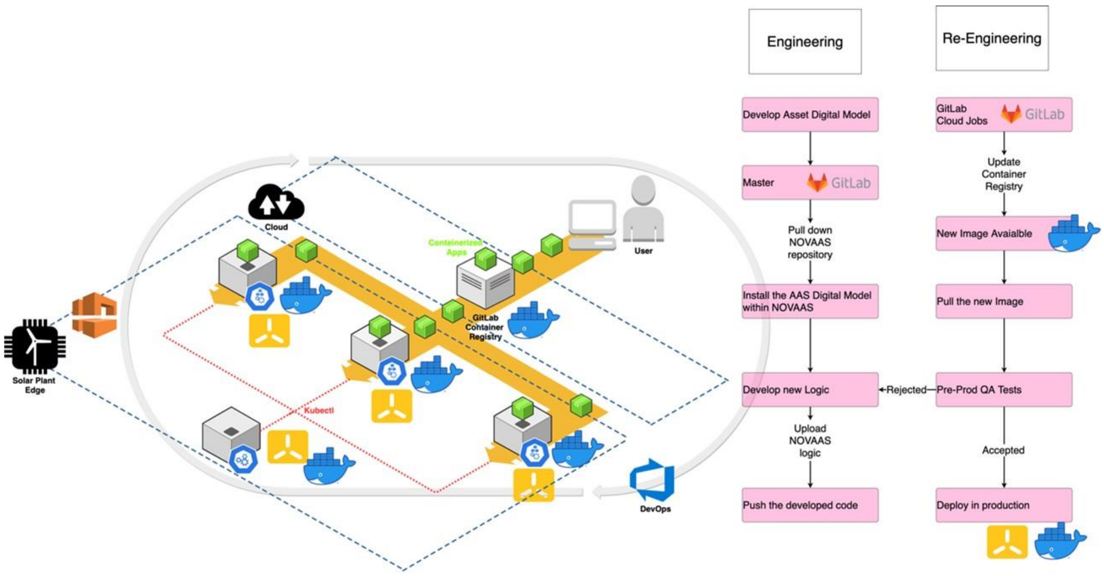

Figure 8: LSP9 IT Infrastructure for DevOps CI/CD strategy

The selected toolchain for the infrastructure is the following:

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- **GitLab**: is a web-based DevOps lifecycle tool that provides a Git repository manager providing wiki, issue-tracking and continuous integration and deployment pipeline features, using an open-source license, developed by GitLab Inc.
- **Docker**: is a set of Platform-as-a-Service products that use OS-level virtualization to deliver software in packages called containers. Containers are isolated from one another and bundle their own software, libraries and configuration files; they can communicate with each other through well-defined channels.
- **Kubernetes/K3S**: is a highly available, certified Kubernetes distribution designed for production workloads in unattended, resource-constrained, remote locations or inside IoT appliances.
- **Portainer**: is a universal container-as-a-service solution that works with Docker and Kubernetes. It helps organizations manage and deploy cloud-native applications and can be deployed on top of any Kubernetes distro in the cloud, on-premise, and at the edge.

Deployment assessment:

We're still at an initial stage of defining the system architecture to deploy.

Data population:

The data necessary to populate the databases will come from the CPV's inverters and tracking system through a datalogger installed at the edge. The datalogger is connected to a gateway which streams the data when accessed through a monitoring platform (cloud access or local access).

Algorithm Training:

UBIMET is intending to utilize autoML frameworks such as TPOT (based on SCICit Learn) or KERAS (Deep Learning Framework based on Tensorflow) for its machine learning tasks. These frameworks will help tackle challenges of data preparation, feature engineering, selection of appropriate models and specifically hyperparameter optimization challenges.

To leverage autoML capabilities, that heavily rely on the exploration of a large set of potential possible pipelines – an infrastructure needs to support process parallelization with common frameworks such as dask, as well as GPU Acceleration.

In order to deploy and validate the ML and DL training process, NTUA's first step is the identification of the datasets needed and their connection with the pilot requirements and Use Cases. For LSP9, the performance of CPV and the potential maintenance actions to be implemented is being examined. The datasets that are identified to be used are the historical production data from the plants, along with the electrical measurements (Voltage, Current, Frequency, etc.). Weather data are also needed to combine with the CPVs data and forecast the future production. To this end, two scenarios are proposed for testing and deploying:

The first scenario is the forecasting module, which is being under implementation. Several designs to test the accuracy of several ML and DL models is being evaluated, as well as the definition of resources needed for the training process.

The second scenario consists of the maintenance actions, in which the optimal dates that maintenance could be performed will be evaluated. This process requires the identification of the constraints, both technical (fault detection) and operational (personnel capacity and minimization of downtime of the CPV production). The forecasting module will be used in this scenario too, providing insights in the

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future CPV's production and using this information as a decision criterion. In addition, this scenario involves the classification of the detected functional anomalies into discrete classes which is in design stage. The most common malfunctions of CPVs are being analysed, along with their impact on the CPV's functions. The detection of the recorded patterns of the production and electrical measurements will lead to the interpretation of the type of anomaly that has been occurred in the CPV.

The validation process is two-fold; first the design of the algorithms and their accuracy will be evaluated in the general context of the LSP. This will be validated through the KPIs, by determining if the proposed solutions can achieve the target values. Secondly, when the KPI targets are met, the specifications and resources needed for the ML/DL training process will be evaluated and optimized in order to achieve the most efficient way to implement and deploy the solutions. To this end, for the forecasting module, transfer learning techniques are under development, which can reduce the training time and the resources needed for the training process.

3.6.3 Data-analytics services

For LSP9 there are 4 services envisioned, 3 services for UC1 and 1 service for UC2. Below follows a description of these services.

- Forecasts of power generation for renewable energy plants on plant level (UC1):

The service uses weather model data and plant-specific data (location, technical properties of renewable plants) and calculates the current possible energy production as well as forecasts of power generation. Forecasts are calculated using physical models and optimized statistically by machine learning algorithms. The service provides current and future power production at any point of interest as time series via an API interface (or csv file). Provided data is used to calculate the current and future load of the power grid to avoid curtailments and to allow settlements of redistributed power generation. Forecast horizon is up to 48 hours.

- Predictive Fault Monitoring (UC1):

This service will be for O&M activities and aims to detect and prevent system and equipment faults (detect irregular operation and act to prevent failures). It also aims to identify and classify faults with gathered data to speed up maintenance intervention, even when faults are prevented. This service will use system equipment historical and live data (from inverters, trackers, switches, breakers, etc.), plant-specific data (location and technical properties of renewable energy plants), historical production data and live production data.

- Optimal scheduling of maintenance operations (UC1):

This service will be for O&M activities and aims to decide the best scheduling for them. For CPV there is only generation under Direct Normal Irradiance (DNI). Detecting lower generation than forecasted may indicate that the panels need cleaning. This service intends to schedule the most optimal period to conduct this cleaning. Other O&M activities will also be scheduled accordingly. Periods of non-generation (cloudy and rainy) will be considered, when possible, to minimize generation losses. This service will use numerical weather model output, plant-specific data (location and technical properties of renewable energy plants), historical production data, live production data.

- Energy-oriented Digital Twin for Buildings (UC2):

This service intends to be a DaaS for public and private buildings and aims to: aggregate energy

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production/consumption at municipal and individual building level; monitor building energy efficiency; improve energy resource management; creation of a consumption electricity map and energy related carbon footprint; leverage the historical data available, identify new services, and explore possibilities of data spaces integration.

Energy data from buildings will be gathered through smart sensors connected to a platform that will enable an Edge driven digital twin capable of streaming the historical and live data as well as other energy related indicators (e.g., energy efficiency, carbon footprint). The Digital Twins will be grouped to make a local energy map.

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4 Conclusions & Outlook

This report has aimed at setting up the scene for the demonstration and validation activities of the LSPs within the BD-4-DER cluster. It has done so by introducing the related pilots that focus on the optimization of asset management and specifically those assets that are identified as DER. The report further acts as a joint overview of the baseline of the associated KPIs and also in describing the shared journey to discuss the preparations undertaken by the LSPs within this cluster.

Initially this report provides a baseline analysis of KPIs per LSP which leads towards generating a shared background and understanding. Following the baseline analysis is a description and self-assessment of pilots and their preparatory steps.

A key aim of this report is to bring together all the pilots involved within BD-4-DER and provide the opportunity for self-assessments and by this highlight shared experiences. By each pilot discussing their development track and focusing on the three areas of infrastructure outline, deployment preparations and data-analytics services description, the circumstances are framed to enable knowledge sharing.

By capturing the self-assessment and knowledge of best practices in deployment preparations, it introduces the next steps to follow. Each pilot brings a unique vantage point to the report and through self-assessment of the associated KPIs baseline and preparations is able to provide insights both in terms of challenges and opportunities. These challenges and opportunities can be harnessed for all pilots within WP8 and may provide a way forward to build upon each other.

A key outlook is to enhance the synergies amongst the pilots and take on the knowledge transfer, leading eventually to best practices for demonstration and validation activities of the pilots within the BD-4-DER cluster. In doing so, this report can be leveraged by on-going tasks within WP6 on the evaluation of the BD4NRG interventions in providing valuable insights into the optimization of the management of assets connected to the electricity grid.

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