BD4NRG
Big Data for Next Generation Energy

Deliverable 9.1: Baseline Analysis Report and 'BD-4-ENEF' Large Scale Pilots Preparation

WP9 – "BD-4-ENEF" Large Scale Pilots: De-Risking investments in Energy Efficiency and Increasing the efficiency and comfort in buildings

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www.bd4nrg.eu

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Preface

BD4NRG focuses on addressing emerging challenges in big data management for 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

Who We Are

	Participant Name	Short Name	Country Code	Logo
1	ENGINEERING – INGEGNERIA INFORMATICA SPA	**ENG**	IT	
2	NATIONAL TECHNICAL UNIVERSITY OF ATHENS	**NTUA**	GR	
3	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	**RWTH**	DE	
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5	INTERNATIONAL DATA SPACES EV	**IDSA**	DE	
6	EUROPEAN NETWORK OF TRANSMISSION SYSTEM OPERATORS FOR ELECTRICITY AISBL	**ENTSO-E**	BE	
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9	FUNDACION CARTIF	**CARTIF**	ES	
10	UNIVERZA V LJUBLJANI	**UNILJ**	SL	
11	ENEL X SRL	**ENELX**	IT	
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Abbreviation & Acronyms

Acronym	Description
AI	Artificial Intelligence
BO	Business Objective
EC	European Commission
EE	Energy Efficiency
EPC	Energy Performance Certificate
EU	European Union
GA	Grant Agreement
ICT	Information Communication Technology
KPI	Key Performance Indicator
LSP	Large Scale Pilot
M&V	Measurement & Verification
ML	Machine Learning
UC	Use Case
WP	Work Package

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Executive Summary

The adoption of Energy Efficiency measures is increasingly recognised as a means not only to achieve a sustainable energy supply, reduce energy consumption and greenhouse gas emissions, improve security of supply and reduce import bills, but also to promote the competitiveness of the EU. It is well known that more than a third of the total final energy consumed in the European Union is consumed in buildings in the residential and tertiary sector. Therefore, it is important to increase the energy efficiency in buildings, but always taking into account the comfort of the users. In addition, there is a need to increase investments in energy efficiency measures, which can be achieved by decreasing the risk of investments, in particular through reliable prediction and monitoring of energy savings. The BD-4-ENEF Large Scale Pilots (LSP) focus on increasing the efficiency and comfort of buildings, as well as reducing the risk of energy efficiency investments at the same time, due to the interrelation of both aspects.

This deliverable covers the activities carried out in Task 9.1 - "Pilots' Detailed Specifications and Preparation". These activities have focused on the preparation of the Large-Scale Pilots related to Energy Efficiency, expanding and improving the information offered in a previous deliverable (D6.1 - "Pilot Operation, Engagement and M&V Plan). The Large-Scale Pilots included in BD-4-ENEF are the following: (i) LSP 10, Predictive and Prescriptive Analytics for improved Energy Performance Certificates Reliability; (ii) LSP 11, Weather-enhanced building thermal comfort prediction to enable energy efficiency reliable forecasting; and (iii) LSP 12, Predictive Analytics for Energy Efficiency Investments de-risking.

In this document, firstly the Key Performance Indicators (KPIs) that will be used to evaluate the BD-4-ENEF LSPs have been explained, presenting the targets values and also the baseline values already calculated. After that, the first version of the deployment diagram and the infrastructure expected for each LSP are described.

The work presented in this report will help in the future will in the WP9 - ""BD-4-ENEF" Large Scale Pilots: De-Risking Investments in Energy Efficiency and Increasing the Efficiency and Comfort of Buildings", in which the analytics services will be implemented in the LSPs, and validated in the different WP9 tasks, in order to assess the benefits experienced in the pilots.

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1 Introduction

The purpose of this deliverable, the structure of the document, and the connection with other work in the project is presented in the following subsections.

1.1 Objectives of the Deliverable

The objective of this deliverable is to present a first view of the demonstration activities to be carried out in WP9 - ""BD-4-ENEF" Large Scale Pilots: De-Risking Investments in Energy Efficiency and Increasing the Efficiency and Comfort of Buildings". These demonstration activities are related to integrating energy efficiency financing risk assessment with real life energy and comfort monitoring and trade off.

The deliverable aims to provide a deeper vision of the KPIs related to each BD-4-ENEF Large-Scale Pilots. The first identification of the KPIs to be used in these LSP was made in WP6 - "Pilot Requirements and Assessment "and reflected in D6.1 - "Pilot Operation, Engagement and M&V Plan". Here, the KPIs to be used are explained in more depth, including how they should be measured. Also, the target and the baseline have been set; being the target the value to be achieved at the end of the project and the baseline the value that is currently assured.

In addition to the KPIs, information regarding the initial preparation in terms of infrastructure, deployment operations of the LSPs and data-analytics services to be implemented are presented.

1.2 Structure of the Document

The document is divided into two main blocks: a section with the analysis of the KPIs and the baseline values (section 2) and other section with different information on the Pilots preparation (section 3).

In section 2, the analysis of the baseline values of the KPIs is performed for each pilot in the WP: LSP10-Predictive and Prescriptive Analytics for improved Energy Performance Certificates Reliability; LSP11-Weather-enhanced building thermal comfort prediction to enable energy efficiency reliable forecasting; and LSP12-Predictive Analytics for Energy Efficiency Investments de-risking.

In section 3, the infrastructure, aspects about the deployment in the BD4NRG platform and the implementation of the services involved is presented, also for each pilot.

Section 4, provide the summary and the next steps after the submission of the deliverable.

1.3 Connection with other Work Packages

Deliverable D9.1 - "Baseline Analysis Report and 'BD-4-ENEF' Large Scale Pilots Preparation" is closely connected with WP6 - "Pilot Requirements and Assessment", and, specifically, with Task T6.1 Pilot planning, requirement and KPIs, as it takes as input the identified KPIs, both General and Pilot specific in order to provide the baseline value and the calculation methods.

As it also provides information regarding the initial activities and preparations for the deployment of BD4NRG tools and services on each pilot, it is also connected with the technical WPs of BD4NRG, WP3 - "Data Governance and Management", WP4 - "Data Modelling & Open Modular AI-based edge-level Analytics Toolbox" and WP5 – "Marketplaces for realizing EU-level Energy Data Economy".

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2 Baseline Analysis (as-is KPIs calculation)

In deliverable D6.1 - "Pilot Operation, Engagement and M&V Plan" the KPIs selected for measuring the impact of the project were indicated and described. For some of them target values were defined. In this deliverable, a step forward is taken, all the targets are defined and also an analysis of the values of theses KPIs at the current situation is done.

2.1 General KPIs

The energy efficiency is the common link of the three BD-4-ENEF LSPs. So, aspects such as reduction of demand and consumption energy, maintaining (or even increasing) the comfort will be taking into account in the pilots. The LSPs that are involved in this WP are those indicated in Table 1.

Table 1: List of LSP in BD-4-ENEF

Pilot	LSP Name	Leader Partners	Location
LSP 10	Predictive and Prescriptive Analytics for improved Energy Performance Certificates Reliability	CAR, VEOLIA	Spain
LSP 11	Weather-enhanced building thermal comfort prediction to enable energy efficiency reliable forecasting	AJSCV, VEOLIA	Spain
LSP 12	Predictive Analytics for Energy Efficiency Investments de-risking	LEIF	Latvia

For the three Pilots, the general KPIs are listed first, and then the specific KPIs for each LSP are indicated. The description of the General KPIs can be seen in Table 2 and more information about these KPIs can be found in deliverable D6.1 - "Pilot operation, engagement and M&V plan".

Table 2: General KPIs definition

KPI	Definition
G01: Seamless and smooth data transition from different types of sensors	The different type 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.
G05: Identification and interoperability with well-known open data sources	The number of open-source data sources that will be used in BD4NRG.

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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 following table presents the baseline values of the General KPIs for each LSP.

Table 3: General KPIs Baseline

General KPIs Baseline			
KPI	**LSP10**	**LSP11**	**LSP12**
G01: Seamless and smooth data transition from different types of sensors	2 (Indoor temperature sensor, humidity sensor)	2 (Temperature sensors, humidity sensors)	6 (Temperature sensors, heating sensors, electrical sensors, CO2 sensors, CO sensors, humidity sensors)
G02: Seamless and smooth data transition from different types of data resources	2 (Building information, Public EPCs)	3 (Weather information, Building Indoor conditions, BEMS information)	3 (Building information and weather information, financed energy efficiency projects)
G03: Resources	43 (several types of resources, 26 from Spanish cadastre, 17 from EPCs of Castilla y Leon)	76 (several type of resources, such as outdoor/indoor temperatures, energy consumption, system temperatures, wind speed, indoor humidity, motion conditions from three separate buildings)	12 (3 from building information, 3 from weather information, graphical information, technical design documents, images, financial information, reports, documents)
G04: Type of data sources	2 (Spanish Cadastre information, Regional Register of Castilla y Leon)	1 (Data from three separate buildings)	3 (KPFI – Climate Change Financial Instrument, EKII – Emission Allowance Auction Instrument, Buildings' information)
G05: Identification and interoperability with well-known open data	2 (Spanish Cadastre information, EPC Regional Register of Castilla y Leon)	0	2 (KPFI, EKII)

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sources			
G06: Datasets used	4505 (Weather datasets, building information datasets, EPCs datasets, public buildings energy consumption information)	28 (BEMS information, Sensor measurements)	10 (Energy Consumption, smart meters from buildings, KPFI datasets, EKII datasets)
G07: Digital Technologies integrated in the energy system	0	0	0
G08*: Big data availability for real life research	13.2GB of historical data(1 year of Cadastre data and EPCs data)	33.33 MB of historical data (Building related data and weather data, 3 years and 925.65 kB/month)	283GB (235GB from KPFI, 48GB from EKII)

**The data reported in the baseline of KPI G08 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 WPs 6-9.*

2.2 Pilot Specific KPIs

The KPIs analysis is explained in the following subsections for each pilot of the BD-4-ENEF pillar.

The specific KPIs of each pilot will serve to validate the achievement of the objectives, monitor the performance of the proposed analytics control the evolution throughout the process. In the case of the "BD-4-ENEF" Large Scale Pilots, specific KPIs have been defined, and also KPIs belonging to the Business Objectives and General categories will be monitored, as detailed in the following sections.

2.2.1 LSP10 (CARTIF & VEOLIA): Predictive and Prescriptive Analytics for improved Energy Performance Certificates Reliability

The main objective of LSP10 is to increase the reliability in Energy Performance Certificates as an element to determine the degree of improvements of buildings energy performance. In this LSP, a large number of datasets will be used in order to validate EPCs values comparing with real data with estimations done using analytics applied to the set of data. Besides, an analysis of the energy conservation measures recommended for each building will be done, taking into account the changes not only the present but also the behaviour of the building with future condition taking into account climate changes.

In the following table the list of the pilot specific KPIs for LSP10 are presented. It is noted that for the pilot specific KPIs, concern the analytics services to be developed during BD4NRG project. In that respect, the applicability of BD4NRG services will be evaluated with previously unused indicators.

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Table 4: LSP10 Pilot Specific KPIs Baseline

KPI	Definition	Unit	Use Case	Baseline Value
B06: EPC gap reduction	EPC gap reduction between the predicted and the actual energy efficiency performance	%	UC1	N/A
10101: EPCs calculated	Number of estimated EPCs that can be calculated using the service developed for LSP10	#	UC1	0
10102: Building typologies included in the next generation EPCs	Number of different building typologies that can be found in the estimated EPCs	#	UC1	0
10103: Trust on Energy Performance Certificates	This KPI measures the increase in the trust on Energy Performance Certificates through the Energy savings verification deployed in LSP.	Likert Scale	UC1	N/A
10104: Maximum refresh rate reached	Refresh rate for data used by the service. It is important to note that different sources could have different refresh rate.	number of updates/units of time	UC1	-

Below for each KPI, the calculation method is provided where needed.

BO6: EPC gap reduction

At the end of the project, it is expected to have a GAP reduction of 20% between the predicted and the actual energy efficiency performance (in the energy demand and consumption). The idea of this indicator is to measure the degree of improvement of the EPC calculation when applying the set of analytic services selected for LSP10. There is no previous methodology to achieve this gap reduction, then no baseline value can be provided. This value will be calculated once the analytics are applied.

10101: EPCs calculated

With the services operating in LSP10, the objective is to estimate EPCs (demand, consumption and CO2 emissions) for 1000 buildings. This could be a district of a city in the region, or a set of municipalities. No EPCs have been estimated yet.

10102: Building typologies included in the next generation EPCs

At least 6 building typologies will be characterized by the service developed here at the end of the project.

10103: Trust on Energy Performance Certificates

A main objective of the pilot is to improve the trust on the Energy Performance Certificates. This indicator will measure this increment on the trust. For this, feedback before and after the application of the service from different stakeholders will be collected. Currently we are developing a method to

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collect the trust on Energy Performance Certificates in the present.

10104: Maximum refresh rate reached

The data from the different monitoring systems should be collected with a refresh rate of at least one per hour.

2.2.2 LSP11 (AJSCV & VEOLIA): Weather-enhanced building thermal comfort prediction to enable energy efficiency reliable forecasting

LSP11 aims to promote new private-oriented business models in order to implement building energy retrofitting actions at district and city level, prioritizing the thermal comfort of the occupants. Building-level solutions can be easy to tackle, however, the difficulty increases as the scale gets larger, down to the district and city levels. Current Energy Performance Contracts (EPCs) are static, regardless of dynamic energy data or contextual information. BD4NRG aims to bridge this gap, by using ML algorithms that make it possible to model comfort levels, while trading with energy efficiency. Big Data techniques provide new opportunities to overcome these barriers, enabling scalable integration and management of large heterogeneous amounts of data across domains and stakeholders in a harmonised way, from real-time smart meters to relevant contextual information The main benefit realized will be a more detailed and accurate thermal comfort prediction, considering possible changes in fuel consumption energy and how this could be reflected in the energy efficiency of buildings.

In the following table the list of the KPIs with their baseline value is presented.

Table 5: LSP11 Pilot Specific KPIs Baseline

KPI	Definition	Unit	Use Case	Baseline Value
B05: Building comfort conditions	Increase of thermal comfort	%	UC1	30%
1101: Energy Savings from Thermal Comfort Actions/Measures	This KPI measures the decrease in energy consumption due to the conducted analysis on heating management in the examined buildings, while also maintaining the quality of life of tenants in high levels.	%	UC1	114kWh per working day (for spring period)
1102: Energy Efficiency Measures Proposed	This KPI measures the number of measures proposed towards energy efficiency on buildings based on real social housing energy consumptions.	#	UC1	0
1103: Number of Buildings Involved	This KPI measures the number of buildings that participate in the thermal comfort scenarios.	#	UC1	1

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Below for each KPI, the calculation method is provided where needed.

B05: Building comfort conditions

The building comfort conditions have been estimated with the available historical data at the moment. The indoor temperatures have been studied. The ratio between the hours in which the temperature has been in the range of 21 to 25 °C and the total working hours of the Sant Cugat Town Hall building has been calculated.

1101: Energy Savings from Thermal Comfort Actions/Measures

This KPI will measure the energy savings from thermal comfort actions/measures to be implemented. The average energy consumption will be measured in order to identify the saving obtained after the analytics services are implemented. It should be noted, that the sensor installations are recently deployed, and the winter months are not available for calculations as of now, where the heating energy is expected to be higher. So it is expected that the actual baseline energy consumption would be increased as reference. However, based on 2 months (April and May) the average consumption is 114kWh per day.

1102: Energy Efficiency Measures Proposed

This KPI will measure the number of energy efficiency measures to be proposed. As the analytics services will be developed and deployed during the project, there are no energy efficiency measures proposed as of now.

1103: Number of Buildings Involved

Initially, 3 buildings are envisioned to be used as demonstrators in this pilot. (Sant Cugat Town Hall building, school of Pins del Valles and a culture centre named Casal Mira-Sol). As of now, data are collected in full scale from 1 building.

2.2.3 LSP12 (LEIF): Predictive Analytics for Energy Efficiency Investments de-risking

The Latvian Environmental Investment Fund ("the Fund") deals with energy efficiency and environmental protection topic for the last 20 years. The Fund has participated in implementation of more than 3000 projects in this field. The decision to finance the project implementation mostly was made based on the expertise of the technical documentation. After projects were realized it was found out, that many projects do not reach the planned energy savings and the funding needs to be refunded.

Also, in some projects, investment was not made in the most efficient energy savings activities. The pre-analysis and investment risk assessment would decrease in most cases investment risks and project failure.

The vast Fund experience shows that predictive analytics for energy efficiency investments de-risking is very important tool in energy efficiency projects. It is important for all – government, investors, stakeholders, municipalities and other clients.

The data analysed in LSP is from the energy efficiency projects in which The Fund had participated in implementation. The data allows to compare the situation before and after the project realization.

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The pilot will reduce the uncertainty linked to energy efficiency investments, which can be attributed to the lack of relevant skills and ability to assess investments. It will strengthen debt and equity financing of energy efficiency projects. More specifically, the platform will provide investors/financiers and project developers the opportunity to: evaluate quickly and easily key performance indicators for projects (analysis and assessment techniques for projects and companies, benchmark tools, financial performance indicators for investors, special indicators "Green barometer", written analysis); Explore past and future projects (project history, synopsis, projects/companies more attractive to investors); Make a profound risk measurement and evaluation (implement key indicators, such as debt service coverage ratio, integrate a cross-check for legal requirements of environmental laws and regulations).

Table 6: LSP12 Pilot Specific KPIs Baseline

KPI	Definition	Unit	Use Case	Baseline Value
B07: Energy efficiency investment de-risking	This KPI will measure the de-risking on energy efficiency investments	%	UC1	490€/MWh
12101: Investment in energy efficiency	This KPI measures the most effective investments for energy consumption reduction	kWh/€/year	UC1	0.96
12102: Grant financing in energy efficiency	This KPI measures the most effective grant financing for energy consumption reduction.	kWh/€/year	UC1	1.95
12103: Investment CO2 efficiency	This KPI measures the most effective investments for CO2 reduction.	kgCO2/€/year	UC1	0.26
12104: Grant financing CO2 efficiency	This KPI measures the most effective grant financing for CO2 reduction.	kgCO2/€/year	UC1	0.52
12105: Renewable energy efficiency	This KPI measures the most effective investments for renewable energy	kgCO2/€/year	UC1	3.17
12106: House heating / cooling efficiency	This KPI measures the house heating or cooling efficiency.	kWh/m2	UC1	69

Below for each KPI, the calculation method is provided where needed.

B07: Energy efficiency investment de-risking

Based on the financed projects, selected buildings that utilises smart meters will be analysed. In these buildings, the average energy consumption before the energy efficiency measures is calculated. The financing of these measures is also calculated in order to provide the cost of energy efficiency investments per MWh. This value for the selected buildings is 490€/MWh. The analytics

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services to be developed will enable to calculate the cost reduction hence allowing to de-risk energy efficiency investments, based on the calculation of the predicted and the actual energy consumption and the actual cost of reduction of the implemented projects.

12101: Investment in energy efficiency/12102: Grant financing in energy efficiency/12103: Investment CO2 efficiency/12104: Grant financing CO2 efficiency

Baseline KPIs have been calculated in accordance with real investment in projects where the Fund has participated in implementation. Funding per kilowatt-hour of energy saved shall not exceed 4 euro per year and funding per ton of carbon dioxide equivalent saved per year shall not exceed 15 848€.

12105: Renewable energy efficiency

Renewable energy efficiency KPI has been calculated as produced energy (thermal, solar) to technology costs (solar plants, heat pumps).

12106: House heating / cooling efficiency

Building's heating efficiency is defined by Regulations Regarding the Latvian Construction Standard LBN 002-19, Thermo-technics of Building Envelopes. Minimum Permissible Level of Energy Efficiency of Buildings for Renewal and Rebuilding of Buildings is 80-90 kWh/m2 per year (for residential buildings) and 90-100 kWh/m2 per year (for non-residential buildings).

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3 Pilot Preparation

This section provides details on the preparation of each of the pilots. The approach is to be able to answer two main questions: on the one hand, the readiness of the pilot, on the other, how the data handling is carried out.

In the case of infrastructure, a description of the existing and planned infrastructure is provided. The integration of the data into the platform is explained, highlighting the communication interfaces or protocols used, if there are databases that will be connected or dedicated APIs, existing data models that are being used, etc. This information is intended to complement the technical descriptions provided in other documents.

For the deployment, the method to implement the service in each pilot is explained, considering all the elements of the BD platform infrastructure that will come into play. For that, the sub-topics regarding Readiness and Data handling described in the next table are defined for each pilot.

Table 7: Pilot preparation strategy

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
	Algorithm Training	Description of procedures for ML/AI training with the relevant datasets, include validation mechanisms

In the last subsection the analytics that will be implemented in the pilot are explained, taking into account the work previously done in WP2 – "System Requirements and Specifications".

3.1 LSP10 (CARTIF & VEOLIA): Predictive and Prescriptive Analytics for improved Energy Performance Certificates Reliability

This section includes details about the preparation of the LSP10: the infrastructure used, how the services will be implemented, and the main objective of each one of them.

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3.1.1 Infrastructure

The data used in the LSP10 have different nature and origin.

Considering the update frequency, we can find:

- Semi-static data that is updated annually (building information from the Spanish cadastre)
- Semi-static data that is updated daily (public EPCs of the regional registry of Castilla y León)
- Semi-static data that is updated monthly (energy consumption in public buildings, from the Energy DataHub of Castilla y León)
- Dynamic data, which is updated every fifteen minutes (BEMS/HEMS/DEMS information)
- Dynamic data with different configuration options (weather information)

Considering the format in which the information is provided, three types of main data sources can be found: web APIs, flat files and databases with historical information.

- The cadastre data can be used in flat file format, given its static nature. It can be downloaded from the web through an ATOM service (there are a link for downloading a file for each municipality of Spain). Due to the low update frequency, there is no need to update the information of the cadastre regularly, so this information will be previously downloaded and stored in a local database.
- The public EPCs of the regional registry of Castilla y León and the information from the Energy DataHub of Castilla y León can be obtained through an API and also it can be downloaded, in different formats (JSON, CSV, XLSX). The connection with the API will be analysed, but for the first version of the service developed for the LSP10 the public EPC dataset will be downloaded in advance.
- For accessing BEMS/HEMS/DEMS information on buildings provided by VEOLIA (private data), CARTIF is working on the development of a driver for data access.
- Weather information with the desired granularity can be consulted through an API.

3.1.2 Deployment of BD4NRG Platform

Deployment diagram

Figure 1 shows a first version of the deployment diagram for LSP11.

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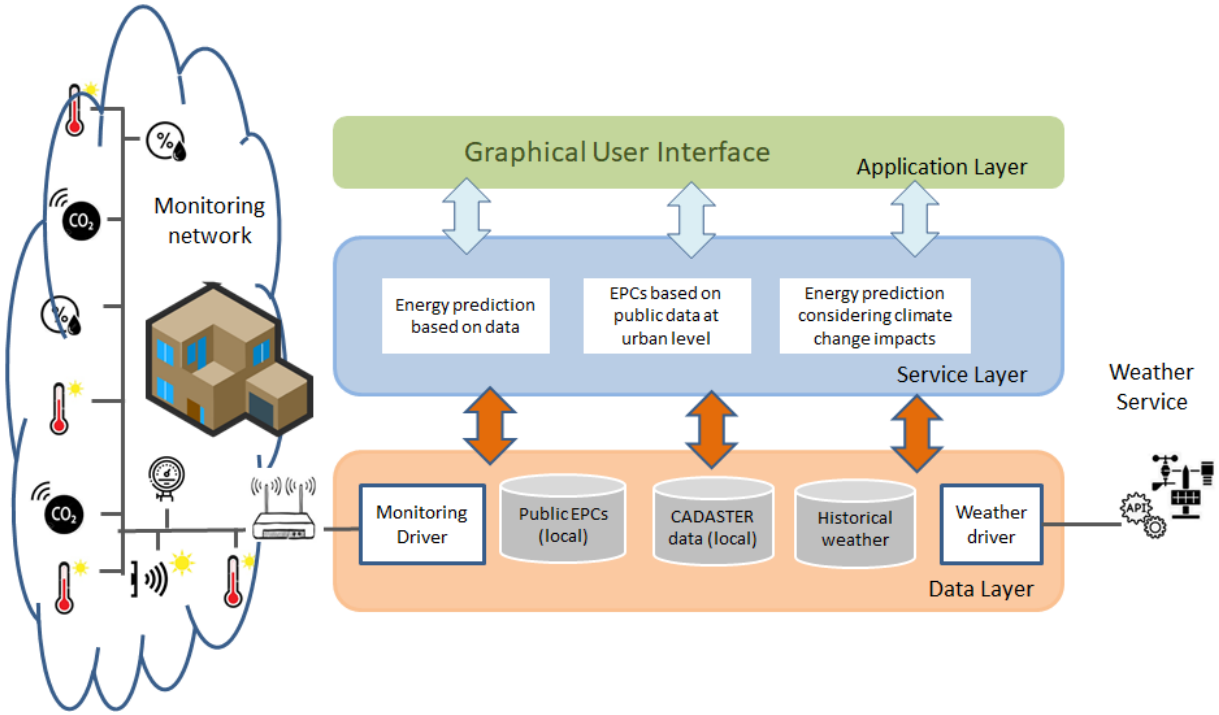

Figure 1: LSP10 deployment diagram.

Deployment preparation

As explained in section 3.1.1, some of the data will be previously downloaded and stored in local databases. Besides, information will be collected from the monitoring systems and a weather service thanks to some drivers developed for the project. This is represented by the Data layer in Figure 1.

In the service layer, the service will use the data coming from the data layer in order to calculate the analytics. There are three services in the LSP11, more details of the analytics are included in section 3.1.3.

The user could use the functionalities through the graphical user interface of the application service.

Deployment assessment

The deployment assessment will be performed at a later stage, when the infrastructure is implemented. The topics to be assessed will be:

- Data collection
- Drivers operation
- Data storage
- Analytics operation
- GUI operation

Data population

The data to be used has a different nature, as has already been highlighted: open or private data available from an API web interface or ATOM services, to private monitoring data such as those provided by BEMS / HEMS / DEMS or plain text documents. Currently, and for simplicity, the first

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tests are being carried out with plain text files, but all the information could be integrated into the database.

- Cadastral data is available through ATOM services. Given the low information update rate (yearly), the simplest procedure is to download it through a controller and then work with files.
- The data of the regional registry of Castilla y León can be directly integrated into a database through a procedure for this, which carries out periodic consultations through the API. For the early stages, the data will be previously downloaded in order to work directly with the files.
- Meteorological information (meteorological data, Copernicus) can be directly integrated by developing a procedure for it, which makes periodic information requests through the API.
- To dump information from BEMS / HEMS / DEMS, CARTIF is working on the development of a communication controller that accesses the information and can dump it into a database, with the desired update rate.

Algorithm Training

Three scenarios are identified to develop and train the models to use within the analytic services.

- The energy prediction based on data will be based on different ML algorithms. A forecasting module needs to be implemented, including different algorithms, to make it possible to compare the accuracy of different models.
- The energy performance calculation based on public data can use different techniques (EPBD-based algorithms, classification techniques).
- The energy prediction considering climate change impacts uses different statistical downscaling algorithms and regression techniques for bias correction

3.1.3 Data-analytics services implementation

The analytics that will be developed within the LSP10 aim to improve confidence in Energy Performance Certificates from a predictive and prescriptive approach. Three services have been identified that will work together for this purpose: data-driven energy prediction, EPC calculation based on public urban data, and energy prediction considering the impacts of climate change.

Energy prediction based on data

This service will implement data-driven energy prediction applications to adjust energy demand based on monitored information. The final objective is to incorporate advanced forecasting methods and monitored information in the EPCs.

- Several types of information are used as input in order to provide energy predictions (weather data and indoor temperature if available, smart meters information, etc.), considering different granularity.
- Different machine learning algorithms and AI-based techniques will be tested in order to find the approach that best suits.
- Predictions with high reliability and precision will be offered to feed different parameters contained in the EPCs or to compare with them, and provide relevant insights from the data.

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Energy Performance Calculation based on public data at urban level

This service will provide an estimate of some of the parameters contained in the Energy Performance Certificates (heating and cooling demand, consumption and CO_2 emissions based on data from public sources. This approach allows estimating the EPC values of buildings in a specific location, as well as the detection of inconsistencies in existing and new EPCs.

- Different types of information are used as input in order to estimate the different parameters contained in the EPCs (i.e., data from cadastre, public EPCs, weather information).
- Different techniques (i.e., EPBD-based algorithms) will be explored for these calculations.
- EPC labels will be estimated for the performance of building in a given location and used for different purposes (such as planning tasks, detection of inconsistencies, or comparison of building performance).

Energy prediction considering climate change impacts

This service will provide medium-long term estimation of the energy demand of buildings based on future climate data under different RCPs (Representative Concentration Pathways), in order to be able to anticipate the impacts of climate change. There estimations serve as a basis for decision-making in the definition of feasible retrofitting scenarios. Nowadays, the basic parameters collected by open EPCs do not collect anything about this type of information. A new enriched version of them would suppose its amplification with a very important added value.

- Different types of information are used as input in order to provide energy estimations (detailed building geometries and the future climate data under different RCPs that are available at Copernicus C3S).
- Different GIS methods (i.e. interpolation, modelling), statistical downscaling algorithms and regression techniques for bias correction will be tested in order to find the approach that best suits.
- Future estimations of energy demand in buildings will be offered to make it possible to anticipate the impact of climate change.

3.2 LSP11 (AJSCV & VEOLIA): Weather-enhanced building thermal comfort prediction to enable energy efficiency reliable forecasting

This section includes details about the preparation of the LSP11: the infrastructure used, how the services will be implemented, and the main objective of each one of them.

3.2.1 Infrastructure

Two of the three buildings of the LSP11 are currently under renovation, with the installation of their own renewable energy production systems and a BEMS for their control and monitoring. This is the case of the School of Pins del Valles and the Mira-Sol Cultural Center buildings. On the other hand, the third of the buildings, the Sant Cugat Town Hall building, already has a self-production system of renewable energy managed by an outdated and out-of-market BEMS.

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Data sources for each building are:

School of Pins del Valles

The future architecture of the monitoring system will provide dynamic data associated with the new installation. This installation includes sensors in the building (room temperature, windows, presence, temperature...) and data from the PLCs of the energy production and distribution systems (temperatures, heat energy meters, electric meters, fluid flows, etc.). The frequency of the data is variable, from 1 to 15 minutes and they are stored in a BEMS solution stored on the cloud. The data can be viewed from a web portal and downloaded in CSV and XLS format.

Sant Cugat Town Hall building

- BEMS: Dynamic data, which can be flexibly updated, nowadays every 1 hour. Data includes weather variables (temperature and humidity), operating temperatures for building uses and spaces, operating temperatures for each HVAC machine and lighting manager. Data is saved in a SQL database, but it can also be downloaded in XLS format from BEMS. The BEMS is not friendly, out of the market and limited in terms of the operability of the installation.
- RES production: Semi-static data, the renewable energy production data can be consulted and downloaded via a web portal or through an API specialized in the monitoring of photovoltaic installations. The data can be obtained with variable frequency (daily, weekly, monthly or yearly) and the download of the historic values generates a XLS file.
- Energy consumption: Dynamic data. 2 electric meters measure the electricity consumption of the building. The data is stored on local servers and there is no application for real-time visualization. Data download allows exporting in XLS or CSV format.

Mira-Sol Cultural Centre

The future architecture of the monitoring system will provide dynamic data associated with the new installation. This installation includes sensors in the building (room temperature, windows, presence, temperature, etc.) and data from the PLCs of the energy production and distribution systems (temperatures, heat energy meters, electric meters, fluid flows, ..). The frequency of the data is variable, from 1 to 15 minutes and they are stored in a BEMS solution stored on the cloud. The data can be viewed from a web portal and downloaded in SCV and XLS format.

3.2.2 Deployment of BD4NRG Platform

Deployment diagram

Figure 2 shows a first version of the deployment diagram for LSP11.

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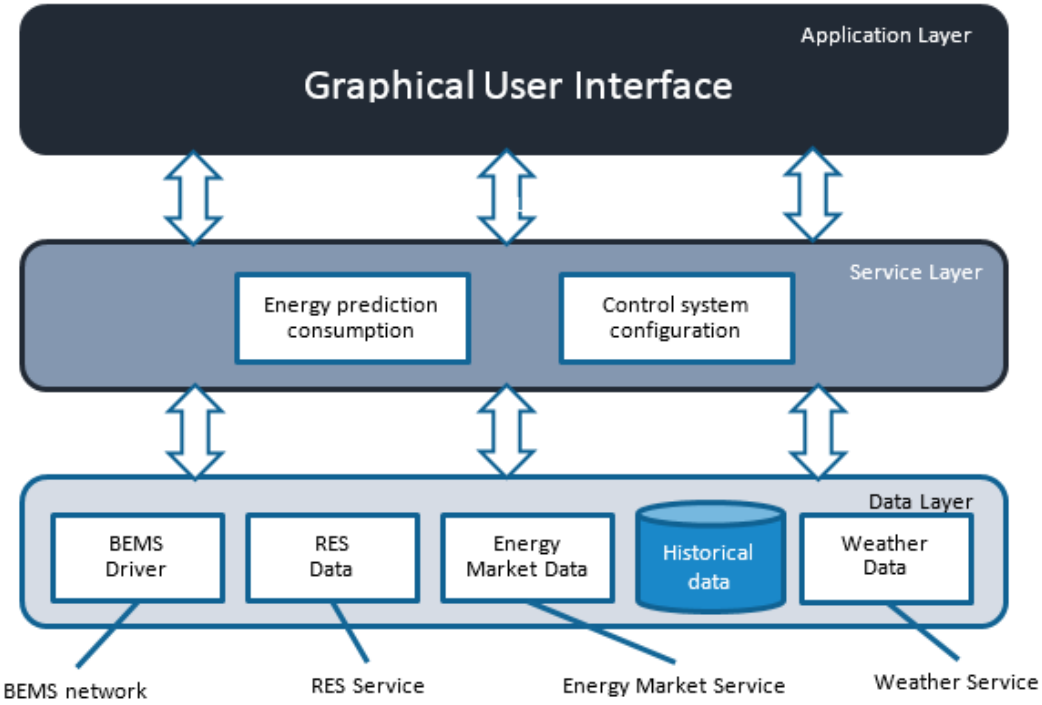

Figure 2: LSP11 deployment diagram.

Deployment preparation

The deployment of the tools and services of BD4NRG it is required that the components and infrastructure can respond to the following points:

- Definition of the KPIs related to the thermal comfort of the users of the three buildings and those related to energy efficiency.
- Download and analysis of historical data
- Real-time download of building control sensors.
- Download in real time the working parameters of the energy production systems.
- Harmonisation of the data obtained by each of the technologies of the three buildings.
- Act remotely on the energy control parameters of the BEMS of the town hall building.
- Propose new energy control parameters for the BEMS of the Pins del Vallès school and the Mira-Sol Cultural Centre.

Deployment assessment

The technical capacity of the different components of the three buildings, their infrastructure and the possibility of integrating the different technologies will be a key element in the implementation. If the acquisition of new components, services or modification of the installation is necessary, it can be a very slow public administrative procedure (public tender) that can delay the implementation. In that case, the possibility of discarding a building and / or working with another municipal building

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should be considered.

Data Population

There is a diversity in the type of data that will feed the database. These come from different technologies and structures and should be harmonized. In addition, the database will be dynamic, updating with the data that is obtained in real time and generating a history that will be necessary to feed the AI algorithms and their predictive models.

Algorithm Training

AI algorithms should work in the following scenarios:

- Prediction of the energy consumption needs of each of the buildings based on their needs and also on the weather forecast to meet the objectives of thermal comfort and energy efficiency.
- Ability to propose the most efficient control parameters for each of the facilities.
- Action on the control parameters of the town hall building.
- Review and validation of the KPIS for thermal comfort and energy efficiency for each building

3.2.3 Data-analytics services implementation

Based on the analysis of the operating data of the thermal installations of three municipal buildings, the services to be implemented will aim to offer the optimum operation set point for these buildings and for any other with similar characteristics. In turn, and using predictive models, it must be able to predict what the consumption of similar facilities will be, the operating cost of the facility and its ability to save energy as a result of weather forecasts. It should also be able to forecast operating costs based on the variability of the electricity market.

The service must be able to interact with the real-time operation of the three facilities and even control the installation of one of the buildings.

Consequently, the service will be oriented to answer the following questions.

Comparison between buildings and facilities

Based on the data collected from three buildings, with different construction characteristics and with different energy production systems, foresee what the consumption and cost of future installations will be according to their design. This will allow us to respond to the economic viability of the new project by comparing possible alternatives.

Different systems on a single platform

Although there are already systems dedicated to the energy control of a building (BEMS), the analysis will allow the manager of several facilities with different technologies to view the status of all the facilities on a single platform. The harmonization of the data obtained from different service providers will facilitate the operational management of the facility and its responsiveness.

Scalable future consumption prediction

Obtaining real operating values combined with meteorological forecasts as a consequence of climate change, will allow obtaining forecasting models of consumption and operating costs in the management of similar buildings. In turn, these consumption forecasting models will be scalable at

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the district or city level, extrapolating the forecasts on a larger scale.

Transparency

The data on the state of operation of the facilities collected must be partially public to promote transparency in public management.

3.3 LSP12 (LEIF): Predictive Analytics for Energy Efficiency Investments de-risking

This section includes details about the preparation of the LSP12: the infrastructure used, how the services will be implemented, and the main objective of each one of them.

3.3.1 Infrastructure

Energy efficiency projects monitoring system data is dataset file. Data consists of information on project activities, energy and CO2 emission consumption before and after, project general information and project costs. No communication interface or protocols are in place for energy efficiency projects monitoring system. All datasets are available in XLSX file format throw web page interface. No dedicated API have been developed and no standardized data model is used for Energy efficiency projects monitoring system before.

There will be new predictive/declarative service to de-risk funding in energy efficiency investments in the building sector by analysing previous performance. The output of this service will provide to suggest possible actions. Result visualization can be provided to suggest user-friendly analysis.

3.3.2 Deployment of BD4NRG Platform

Deployment diagram

Figure 3 shows a first version of the deployment diagram for LSP11.

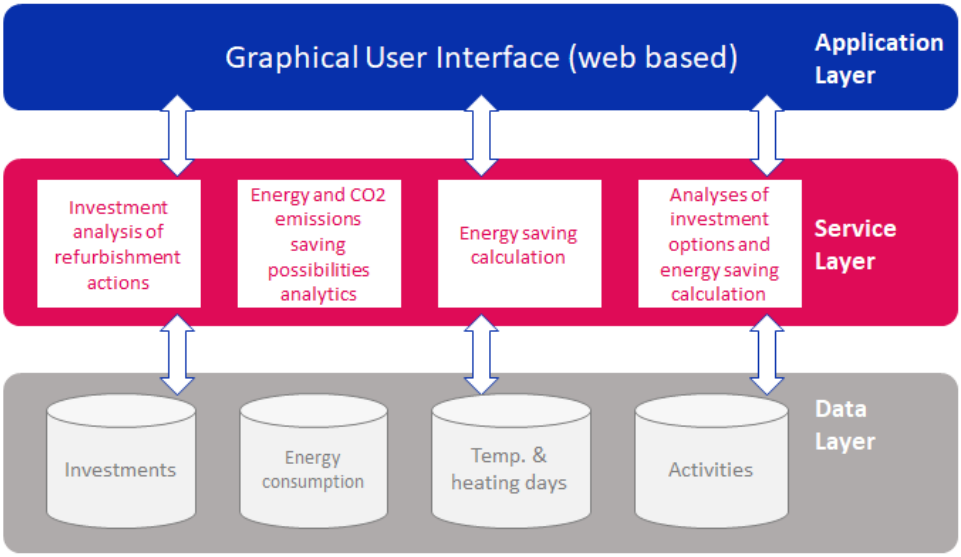

Figure 3: LSP12 deployment diagram.

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Deployment preparation

It is necessary to define the requirement for the successful launch of the platform in the pilot:

- KPIs, energy performance, investment risk, cross-domain financial and energy consumption analytics should be calculated
- Data set should have historical operation data
- Systems need availability of contextual data
- Systems need availability of building information
- A list of the Energy Efficiency Measures must be defined
- Average costs of energy efficiency measures must be defined
- Data harmonization, orchestration and synchronization should be performed
- Systems must receive and analyse smart meters data for IoT
- All data (energy and financial) collection should apply security aspects for data accessing. These data are available on databases, which should be protected.

Deployment assessment

For the successful launch of the platform in the pilot project, it is necessary to ensure that all the requirements are met. Checklist must be completed. It is necessary to consider the possibility of excluding projects in which the result has not been achieved and which can cause risks of incorrect operation of the platform while preparing a database based on implemented projects.

Data Population

The platform database should not be built on a one-time data integration basis. The database must be updated as new data on completed projects becomes available. Thus, the platform will be periodically replenished with up-to-date data. Also, the database must constantly receive data from smart meters, which provide hourly information about energy consumption. It is recommended to provide for the removal of obsolete data from the database, which cannot be up to date after a specified period.

Algorithm training

It is necessary to develop a verification mechanism to validate the platform's working state. The check must be carried out once a year. A project that has recently been completed with the achieved result should be taken as a standard. Validation of the analytical methodology of the platform must be done by checking the implemented project. Evaluate the quality of AI training according to pre-prepared evaluation criteria.

3.3.3 Data-analytics services implementation

The service gathers previous implemented projects of renovation and analyses them. It then combines weather data and projections in order to suggest possible actions. Service will use previous projects investment information, energy consumption, heating days, temperature, CO_2 emissions, type of actions implemented in projects. Analysis also will incorporate specific characteristics of buildings to identify performance of these actions, thus enabling optimal funding and performance

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assessment.

Investment information

This kind of information provides investment analysis of various refurbishment actions. The investment index is often the basis for a client's decision on project implementation. The analysis of this data cannot be made only on the basis of historical data. For an accurate analysis, it is necessary to take into account inflation in the construction sector and other factors affecting the volume of investments.

Energy consumption and CO_2

This kind of information provides energy and CO_2 emissions savings possibilities. A large amount of data by completed projects contains information of energy consumption before the implementation of projects and after implementation. Analysing this data allows to get the fairest information on energy savings. In this way, the analytics of these data protects the client from not achieving the goal and as a result of ineffective investment in an energy efficiency project.

Heating days and temperature

This kind of data is not informative for the user, but it is extremely necessary for the analytics of all other data. Temperature and heating season data are the corrective factor for energy savings calculation. All previous data were obtained under specific conditions and in order for them to be applied in analytics, it is necessary to correct for weather conditions and the duration of the heating season. Only by this correction it is possible to apply the analytics of historical data to the expected object.

Type of action

Analytics of type of action is an important aspect when deciding whether to increase energy efficiency. This is the data on which investment options and energy savings calculations are made. Each activity has a specific cost and impact on energy efficiency indicators. Analysing activities for a specific project can identify a list of effective activities with a high KPI, which in another project will not be such effective or even cause risky investment.

Each of the above parts analytics is unique and necessary to improve predictions of energy efficiency improvement. However, only in a comprehensive analysis of all these parts it is possible to achieve an accurate result with a high KPI and minimal investment risk.

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4 Summary and next steps

The work presented in this document provided the preparatory activities for the BD-4-ENEF Large Scale Pilots (i.e., LSP10-Predictive and Prescriptive Analytics for improved Energy Performance Certificates Reliability; LSP11-Weather-enhanced building thermal comfort prediction to enable energy efficiency reliable forecasting; and LSP12-Predictive Analytics for Energy Efficiency Investments de-risking).

The first part of the deliverable introduced the objectives of the deliverable, the structure of the document and the connection with other Work Packages.

The next section provided the general and Pilot Specific KPIs for each Large-Scale Pilot, indicating the expected values expected at the end of the project (named as Target) and the current figures (named as baseline) also providing explanations for both values.

Later on, the document has defined aspects related with the pilot preparation for each LSP, providing information on three topics: (1) infrastructure, (2) preparation for deployment and (3) implementation of data-analytics services. For the infrastructure, a description is included accompanied by details on how the data will be integrated into the platform. For the deployment, the method to implement the service in each pilot has been explained, together with the process to populate the databases and also a description about the procedures to train the algorithms. Finally, the analytics that would be implemented in each LSP have been explained.

All in all, this deliverable will kick-start the pre-pilot cycle (M11-M13), whose general progress in BD-4-ENEF Pilots will be tracked at the end of the cycle (M13). This M13 tracking of all pilots will be analysed two months later from WP6 - "Pilot Requirements and Assessment", in particular, in D6.2 "BD4NRG Pilots Synergies, Evaluation and Feedback – First Release" (M15).

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