This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 957047.

H2020-LC-SC3-EE-2020-1/LC-SC3-B4E-6-2020

Big data for buildings

Building Information aGGregation, harmonization and analytics platform

Project Nº 957047

D6.2- First evaluation of the BIGG pilots results on use cases

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Document Reference:	D6.2
Dissemination Level:	Public
Version:	Final Draft
Date:	31/05/2022

Executive Summary

The BIGG project aims at demonstrating the application of big data technologies and data analytic techniques for the complete buildings life-cycle of more than 4000 buildings in 6 large-scale pilot test beds.

The document provides an overview of the pilots' progress at M18 (mid project) and the challenges encountered by each pilot. During the first half of the project the work focused on setting up the different pilots (also known as business cases) and preparing the necessary infrastructure to measure and monitor them, as well as, defining the methodology to evaluate their progress.

The tasks carried out by the pilots during the first 18 months started by the definition of the datasets that each one provided with a detailed description of their pilots. The detailed description was then used by work package 2 (WP2) task 2.1 and task 2.2 to define the technical requirements of each pilot, for the technical teams (WP2-5). The second task was the definition of key performance indicators (KPIs) to analyse all the aspects of the pilots' implementation, from the technical quality of the tools developed by BIGG, to data acquisition and user interactions. The third task was the pilot setup of all necessary elements to manage each pilot, from data gathering systems to hosting platforms. The fourth and final task is the continuously ongoing monitoring of the pilots to manage each pilot and gather the necessary data from them.

The report starts with an introduction of the pilots work package, an overview of the progress of the cross-cutting technical components and the methodology for the evaluation of the current report.

The description of the pilots (also referred as Business Cases) is shown in section III. The section presents each of the 6 Business Cases divided into the different use cases analysed each with their objectives, expected improvements from BIGG and summary of the results so far.

Section IV presents the results of the pilots divided among the 6 Business Cases using the KPIs methodology developed in the second task of WP6. The analysis section explains the current state of each pilot, at the detail level of the individual use case, using the developed KPIs, which also help to show the future path of each pilot for the actions that have not started yet. The section also describes the challenges faced by each pilot (if there are any) in the form of limits detected and modifications of the initial data sets, either by adding new sources of information to expand the current ones or removing data sets deemed not useful or accessible due to the evolution of the pilots.

Finally, conclusions, lessons learned and next steps are included, showing the path forward for each pilot between the current mid project report (M18) and the end of the project (M36).

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Table of Acronyms and Definitions

Acronym	Definition
AI	Artificial Intelligence
BIM	Building Information Modelling
BMS	Building Monitoring System
BPC	Building Performance Certificate
BSO	Building Stock Observatory
CDD	Cooling Degree Day
CMMS	Computerized Maintenance Management System
DEEP	De-Risking Energy Efficiency Platform
DR	Demand Response
DSO	Distribution System Operator. Acts as a neutral market facilitator for flexibility services
ECM	Energy Conservation Measure
EEFIG	Energy Efficiency Financial Institution Group
EEM	Energy Efficiency Measure
EIU	Energy Intensity Use (kWh/m^2)
EPC	Energy Performance Contract
EPC	Energy Performance Certificate
ESCO	Energy Service Co. knowledgeable in EPC contracts.
EUBSO	European Union BSO
FCU	Fan Coil Unit
HDD	Heating Degree Day
HVAC	Heating Ventilation and Air Conditioning
ICT	Information and Communication Technology
INSPIRE	Infrastructure for Spatial information Europe

IPMVP	International Performance Measurement & Verification Protocol.
IXON	Remote service & IoT solution for industrial machines. An end-to-end solution with remote access, data logging, dashboards, alarms…
KPIs	Key Performance Indicator
PA	Public Authority
SIME	Energy accounting tool used for centralized purchasing in Public Catalan Administration
UC	Use Case
UTM	Universal Transverse Mercator, coordinate system that divides the world into 60 north-south zones, each 6 degrees of longitude wide.

I. INTRODUCTION

I.1. Purpose and organization of the document

This report describes the work carried out by the BIGG pilots during the first half of the project (18 months). The report focuses on three aspects of the BIGG business cases.

First a description of the projects and their main objectives and expected improvements to get from BIGG. Secondly the results obtained up until May 2022 as well as, any challenges or limits faced. And lastly, the conclusions of the work with a focus on lessons learned and future plans towards the second half of the project.

The document is organised as follow:

- Section II describes the progress of the whole technical development of BIGG in a summarised format
- Section III presents the 6 Business Cases and the 15 Use Cases of BIGG with their objectives and expected improvements to obtain by the end of the project.
- Section IV describes the main result obtained during the first half of the project using key performance indicators (KPIs). This section also introduces, if there are any, the limitations encountered during the project for each Business Case.
- Section V provides the conclusions for the pilots of the BIGG project, the lessons learned and the future work.

I.2. Scope and audience

The BIGG project aims at demonstrating the application of big data technologies and data analytic techniques for the buildings life-cycle of more than 4000 buildings in 15 different large-scale pilot test-beds.

This deliverable is the first public document of Work Package 6, which objectives are the following:

- First, to coordinate and align pilots in terms of objectives and evaluation;
- Second, to prove and test the applicability of the designed BIGG solutions to support diverse real-world business scenarios in terms of: (1) defining KPIs consistently across pilots, (2) ensuring that monitoring infrastructure is in place to measure the KPIs, and (3) collecting monitoring information to check KPIs are met.
- Third, to perform cross-pilot evaluations of the different business scenarios.

The scheme of Figure 1 shows how work package 6 (WP6) is in connection to the work packages of the project, to put in place all pilots:

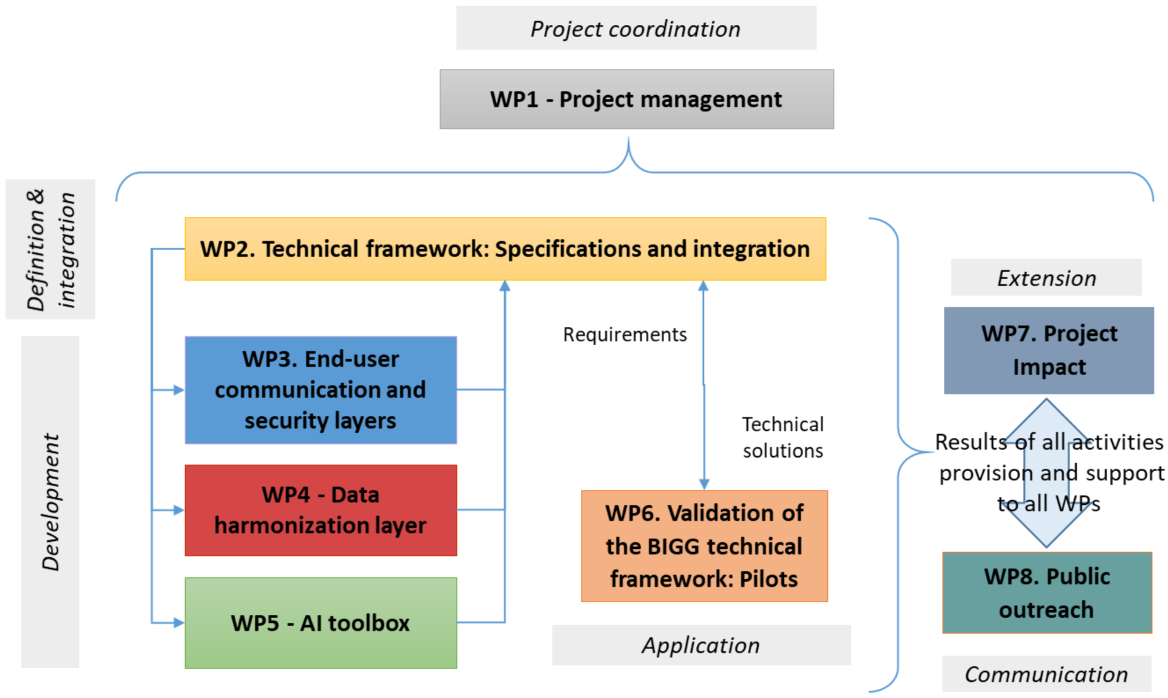


Figure 1 - Scenario of relation between WP6 and other WPs of BIGG project

At the beginning of the project WP6 described the 6 different Business cases and the available datasets, this description was then used by WP2 to elaborate the technical requirements of the project and coordinate with WP3, 4 and 5 to develop all the necessary tools to fulfil the needs of each Business case. The developed technical solutions have been returned to WP6 and are under analysis in this report, which will provide the first round of feedback for the technical WP.

The technical development objectives are defined based on the goals of the six different business cases defined in section III. Each business case has two or more use cases that aim to cover all the aspects necessary to fulfil the business case.

With respect to the audience, the results of this deliverable are relevant to all project partners, policy makers working on the field of buildings and energy efficiency, ESCO companies, building owners (small and large) that aim to improve the energy efficiency of their building stock and the public in general that is interested in following the latest trends in building, Bigg Data and energy efficiency. This is the first of two reports on the progress of the Business cases of BIGG, the second report will be produced by the end of the project (M36, November 2023).

I.3. Methodology for evaluation

The current report divides the pilots' information into three sections. First section III presents a summary of the business cases, explains its main objectives and the expected improvements to obtain from BIGG.

Section IV presents the main results of the evaluation of the BIGG pilots results on use cases, obtained to the date of producing this report (May 2022). The section will analyse the progress of the BIGG project by using both the developed KPIs for each UC and also taking into account the expected improvements described in section III. The aim of the analysis is to explain all the technical improvements that help to reach the goals of each UC from the architecture in WP2 to the AI tool box developed in WP5. To help in the analysis, the developed KPIs will provide a static picture of the current state, they were defined with the goal to track the progress of the whole project, which covers aspects from data quality checks to number of devices installed. If any of the KPIs does not display current value at M18 it means that it still has does not have enough data or the subject of analysis is not rellevant yet. The section will end with a summary of the work carried out in each BC aiming to define 2 key aspects of the project to be taken into account during the second half of BIGG:

- The detected limits to each BC
- Reasoning behind the inclusion/exclusion of certain data if there have been changes during the duration of BIGG

The final section for the BC is section V which summarised the conclusions of the report, lessons learned and the plans towards the end of the project.

II. PROGRESS ON THE CROSS-CUTTING COMPONENTS

The BIGG project has 4 technical work packages developing the solutions needed to fulfil the 6 Business cases of the project. The technical WP are working towards the continuous development of their solutions, which are then tested by the pilots (as shown in Figure 1). The technical development of BIGG has been described in the WP2-5 deliverables, specifically the public deliverables D2.2 “Initial technical specifications and preliminary design of BIGG Architecture building blocks”; D.3.1 “Description of the preliminary end-user communication and security layers”; D4.1” Description of the preliminary harmonization layer”; and D5.1 “Initial Description of the BIGG Artificial intelligence toolbox”. A summary of the progress and development so far is presented below regarding these public deliverables with the aim to describe the progress towards the Business cases (https://www.bigg-project.eu/deliverables/).

The roadmap set for the BIGG project to achieve its targets is, as defined in D2.2: 1) The Open Source BIGG Data Reference Architecture 4 Buildings for collection/funnelling, processing and exchanging data from different sources (smart meters, sensors, BMS, existing data sets); 2) An interoperable buildings data specification, BIGG Standard Data Model 4 Buildings, based on the combination of elements from existing frameworks and EC directives, such as SAREF, INSPIRE, BIM, EPCHub that will be enhanced to reach full interoperability of building dates; 3) An extensible, open, cloud-compatible BIGG Data Analytics Toolbox of service modules for batch and real-time analytics that supports a wide range of services, new business models and support reliable and effective policy-making. All these goals depend on the collaboration of the different technical WP, starting by the arquitecture (WP2) and ending with the AI toolbox (WP5).

Work package 2 is developing the BIGG Architecture which will require to confront the envisioned architecture options by the different business realities of the different consortiums’ partners. One of the key findings of BIGG is that, in order to fulfil all requirements from pilots, the BIGG architecture shall not be exclusively a cloud-based system. The proposed solution must be modular and flexible in terms of BIGG components deployment choices. Actually, BIGG components must be deployable locally on partners infrastructures where BIGG components can be close to the place where data-to-be-exploited resides. Therefore, the BIGG technical specifications are a “pick and choose” system describing components that end-users may take and unitary deploy and some architectural guidelines proposed to present state-of-the-art ways to organize these components’ interactions.

The modularity and versatility requirements of the BIGG components, due to the multiple business cases, lead to structuring the different components code in several layers: (1) the business logic core, embedded in (2) an exposing interface (CLI, Web service or event messaging) which is (3) constrained using Docker technology. The components codes and deployment artifacts need to be centralized in a repository shared among users. Every user is then able to pull the components versions that fits the best his local architecture and update the components for future shared improvements. Further descriptions of the BIGG arquitecture can be found in D2.2.

Work package 3 is developing three different aspects of the project, the communication layer, the graphical user interfaces and the security layer development. Out of the three tasks the most relevant towards this report is the communication layer development, in which, WP3 is developing the ingestors needed by BIGG. However, the work of WP3 is closely linked to the WP4 harmonisation and BIGG data model for buildings. The data model developed by WP4 will be used by WP3 to ingest and harmonise the data from external source into the BIGG format. The data ingested through the communication layer (Task 3.1) will pass through the harmonization process, the harmonized data will go through the AI Toolbox (WP5, which is the actual user of the data) and be stored or displayed to the user (Task 3.2). All of these steps will happen in a secure way (Task 3.3). Storing data before or after harmonization can optionally be done depending on the use case.

In the following figure there is a schematic of all the components of BIGG and the external sources, divided by the WP responsible of developing each part. The communication layer is developing the necessary components to **ingest** and **expose** all types of building data. Regarding the state-of-the-art reference architecture framework (RAF) which has been designed in WP2 (see D2.2), the communication layer components are laying in the northbound and in a southbound of the architecture as presented in the following simplified schema:

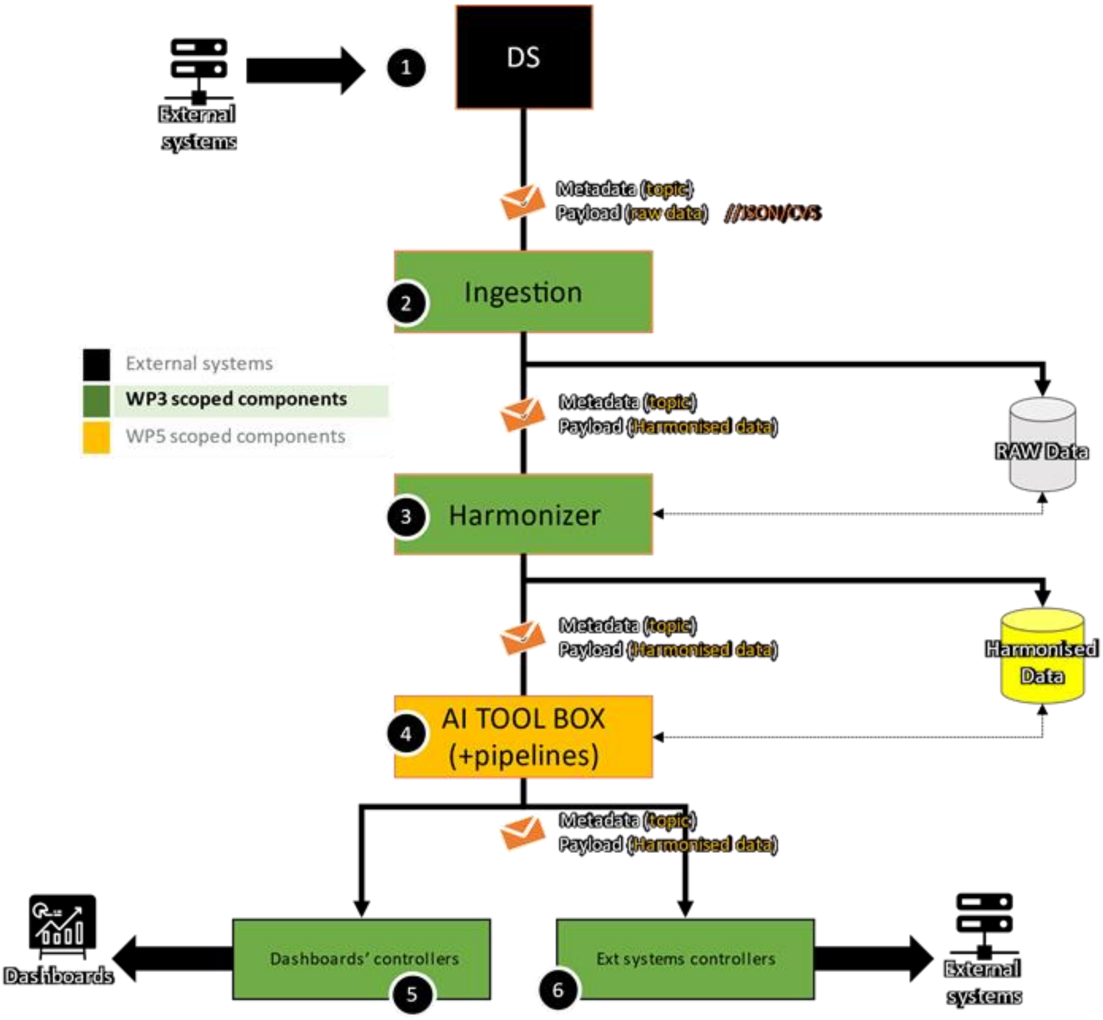


Figure 2 - Simplified communication layer architecture

Next to the Northbound (top of the figure, outside the scope of BIGG) of the BIGG architecture, technical services of external systems are responsible of exposing endpoints to inject datasets (see 1 in Figure 1) in the BIGG pipelines (to provide the data needed by BIGG). The backbone of the overall BIGG workflow is a messaging system using Kafka to exchange data between the different components. Nevertheless, BIGG components are designed in such a way that, if required, they can be used independently in a less integrated manner (cf. D2.2).

To collect raw data, **Ingestion components** (see 2 in Figure 1) have been designed to support various protocols (HTTP, MQTT etc.). Ingested raw data get pushed on the BIGG streaming bus system and get intercepted to be stored in raw-data-dedicated stores and to trigger **harmonization components** which transform raw data into harmonized data following WP4 specifications (see 3 in Figure 1). The harmonized data get published on the messaging system and can be stored in harmonized-data-dedicated stores and/or can be synchronously intercepted by configured AI toolbox components that process it to activate specific pipelines and create knowledge out of it. Insight data created by AI toolbox can then be broadcasted in the BIGG system to be intercepted by **dashboard controllers** formatting this data for representation in specific custom dashboards or **external system controllers** intercepting this data to push it back to specific external systems. These communication southbound components are to be adapted to fit every specific customer requirement (see section III of D3.1 for further details).

Work package 3 worked on the harmonisation process using the BIGG Standard Data Model 4 Buildings developed in WP4. It enables the semantic exchange of data between external data hubs and the BIGG internal components. WP3 generates the harmonized data ready to be used by the AI toolbox in WP5, ensuring at the same time the direct interoperability between external data collections that can use the BIGG infrastructure (standard data model, mappings, transformations, APIs) and align their datasets.

The work until now of WP4 has focused on the development of the BIGG Standard Data Model 4 Buildings in the core of the harmonisation process that provides the semantics and structure of the data and enables their adequate allocation in databases and use in analytics services. The work started with the analysis of the data requirements over the BIGG Use Cases and the available datasets from the pilots, which lead to the identification of data concepts and relations between them (read D4.1 for further details). In parallel, a preliminary analysis of existing ontologies identified models' correspondences with the BIGG data concepts that could be reused. On the base of these analyses, the initial BIGG data model was created in iterative steps of revisions, addition, and reorganisation of the data. The BIGG Standard Data Model 4 Buildings is comprised by detailed definition of classes, attributes, data types, relations, and a UML class diagram. In the initial phase, the data model was used as a common reference for mapping of the available data sources in order to enable the elaboration and testing of the first version (V1) of the pilot solutions and the AI Analytics Toolbox.

The AI toolbox developed in work package 5 can be found in the GitHub of the BIGG project (https://github.com/biggproject) where all the tools are explained and defined. The AI toolbox has focused its developments on solving the specific requirements of the BIGG business cases. Therefore, the development followed a bottom-up approach where the needs were defined based on each of the BC with a special focus on providing answers to the challenges presented by the BC. Each Function Block identified during the BC needs problem definition phase was then described with three main parameters: the Inputs, the Function and the outputs. The preliminary toolbox is composed of this list of Function Blocks. Although the preliminary toolbox development was based on addressing specifically the challenges of BIGG, the final product allows the use of the Function Blocks for different use cases. Some examples of the AI toolbox tools used by the pilots are explained in section IV.

III. BUSINESS CASES

The BIGG project aims at demonstrating the application of big data technologies and data analytic techniques for the complete buildings life-cycle of more than 4000 buildings in 6 large-scale pilot test beds. This section introduces the 6 Business Cases (BC) along with the 15 Use Cases (UC) in which they are divided.

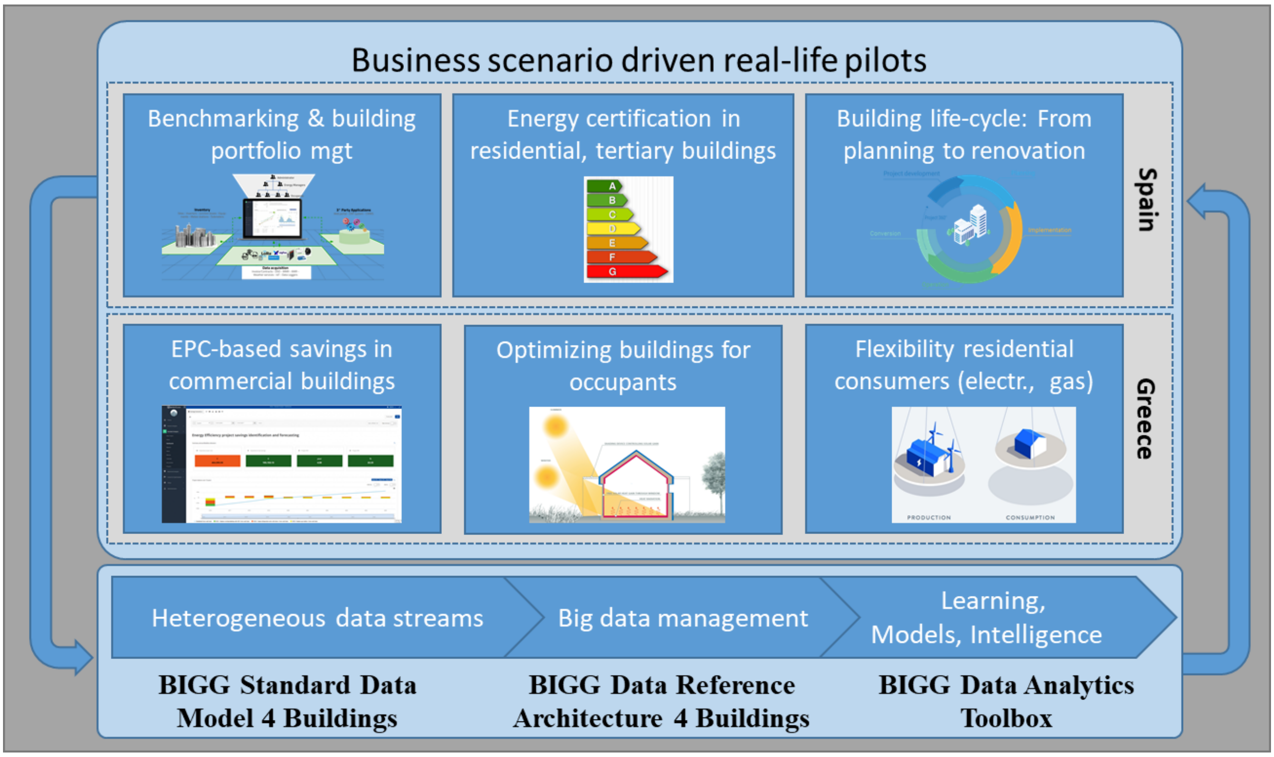


Figure 3 - BIGG business cases

In this section there is a summary for each Business Case including the objectives of both the business case and the use case specific ones, as well as, the expected improvements to obtain from the technical development of BIGG. The BIGG project is developing technical solutions (as explained above) based on the needs defined by the 6 Business cases described in this section.

III.1.1. Business Case 1: Benchmarking and Energy Efficiency tracking in Public Building - ICAEN

The BIGG project will offer considerable advances in building data gathering, management and services for energy efficiency in public buildings by providing:

- An **open** big **data** infrastructure for storing all building data in one place and monitoring the performance of the whole building stock of the organisation through an easily accessible web application.
- Advanced energy **benchmarking** by using the BIGG data analytics and storage capabilities, and tailored reports for different stakeholders in the organisations (policy decision makers, energy managers, maintenance staff, financial officers)
- **Continuous data gathering** from different sources (energy consumption, investments in energy efficiency measures, user provided information) for evaluation of applied energy efficiency measures (EEM) both in terms of energy and financial performance.

The following two use cases descriptions are focused on the improvement of the energy efficiency on a major part of Catalonia's public buildings, by monitoring their consumptions and energy efficiency actions. The first challenge for BC1 was the selection of the information to be gathered and the set-up of the information gathering processes.

III.1.1.a. Use Case 1: Benchmark and Monitoring of Energy Consumption

Use case 1 focuses on developing tools and systems that enable advanced building benchmarking and monitoring both of building's performance and energy efficiency trends.

The main objective of this use case is to give public authorities and energy managers the necessary tools to improve control and manage the energy performance of a large park of buildings with automated methods. This is made possible by processing together large amounts of data (which were disperse in different databases before the project) and giving qualified and usefull information to improve the decision making related to buildings energy management.

The specific objectives are:

- The improvement of the current comparison between similar buildings (benchmarking), introducing new clustering technics, considering all available data and, specifically, the data contained in the hourly consumption time series (profiles, base load, heating and cooling dependency).
- The improvement of the current evaluation of building energy performance trends for each building, to generate better baseline models to improve the presented results' confidence.
- The identification and quantification of the building energy performance and the impact in energy saved or wasted, and the time and duration of these changes (by performing analysis of the changes in consumption patterns).

The expected improvements with BIGG are linked to the combination of data sources and automation of both the data gathering and processing (avoiding human error and bias during the data gathering). The improvements need to include:

- Statistical data processing: Use of additional parameters within the building's characterization. For example, by extracting the building operational profile obtained from consumption time series (use schedules, base load, heating and cooling dependency, etc.) and collecting additional parameters extracted from cadastral information (compactness, number of floors, orientation, etc).
- Advanced Clustering techniques: The identification of building similarity is not trivial when the number of samples and the number of parameters of each one is high. For this reason, the use of advanced clustering techniques seems a good option for grouping similar buildings and for improving the benchmarking results. In addition, the identification of buildings that do not behave according to any model is required in order to not interfere with the cluster and its model.
- Evolution of benchmark indicators: Changes in benchmark indicators must identify the real impact of an energy conservation measures and detect that performance is going worse.

With the calculated baseline models it may be possible to estimate the saved or wasted energy of a set of buildings in order to verify compliance with established savings targets. The improvement on the trends analysis of building energy performance could be materialized in:

- The improvement of the reliability of baseline models
- The analysis of the daily, weekly, and monthly energy consumption profiles.
- The identification where variations in energy efficiency trends occur (base load periods, heating or cooling periods, etc.)
- The quantification of energy savings or loses (wasted energy).

- The identification of the exact moment in time in which energy performance variations occur, providing energy managers with information for further analysis.

III.1.1.b. Use Case 2: Energy Efficiency Measures, EEM: Registration and Evaluation

Besides the monitoring of energy consumptions in order to make benchmarking, it is very important the follow up of energy efficiency measures (EEM), as a key point to evaluate the savings progress according to the achievement to sustainable EU targets. Use case 2 is developing an EEM repository starting by the identification and classification of Energy Efficiency Measures (EEM) based on their typology, characteristics, difficulty of implementation, required investment, etc., and evaluation on impact assessment of measures on achieved energy savings.

The main objective of this use case is to make a structured data base to store EEM and evaluate their impact on achieved energy savings from energy consumption data.

The expected improvements with BIGG are first linked to the quality of the data and second the capability to act on the data. It is expected to get more detailed information of the EEMs involving energy managers by registering the information in a more structured way, including some front end that allows to register and consult this information. Additionally, it will facilitate to:

- Process together historical information from the already applied EEMs and also to new EEM during the project. This implies a reformulation of the list of EEM (in standard way) and facilitate the mapping of historical data over it.
- Improve statistical analysis over the registered EEMs to extract more valuable information, that helps to improve the decision-making process inside the organization.
- Improve the algorithms of EEM savings evaluation. Data driven approach based on the analysis of the applied measures and on the historical energy consumption time series, to be able to evaluate the impact of each measure and a combination of them, over the energy consumption.

In summary, use case 2 wants to collect all the EEM information and link it with use case 1 energy consumption monitoring capabilities to be able to track real savings obtained from EEM. The real savings data will be crucial to inform policy makers and private companies in the most ideal technologies and actions to improve their organisations energy efficiency.

III.1.2. Business Case 2: Energy Certification (EPC) in Residential and Tertiary Buildings – ICAEN

The contribution of the BIGG project to the advance of the energy performance certificates (EPCs) information utilization will provide an important improvement with respect to its current state:

- By providing an open big data infrastructure to store the EPC data, offering at the same time a clear mapping of data, in a harmonized way;
- The simple fact of having the data stored, mapped, harmonized, and verified will favor the possible use of these, not only a punctual moment of the life of the building as it is the current case, but they can be used and updated throughout the cycle-life of buildings.

III.1.2.a. Use Case 3: Integration of INSPIRE spatial data with Energy Performance Certification

This use case pretends to harmonize the building energy performance Certificates with the INSPIRE European standards (https://inspire.ec.europa.eu).[1]

The main objectives of this use case are to adapt the current certification database to INSPIRE and to facilitate the use of this informaiton for decision making and policy making. These goals have been structure along several specific objectives that are:

- To check certification information under ICAEN's database in order to validate, by comparison, which fields are compatible and could then be aligned with INSPIRE scheme's information.
- To be able to offer information about certificates under INSPIRES's format and under an open data format. This is fully justified by the fact that cadastral registry and energy information will be under the INSPIRE's format.
- To put in place a 3D Visor for energy certificates that will allow sharing useful and visual information to any citizen or any person/company interested.
- To have the correct and useful information in geo-located files with the capacity to visualize them in an easy and fast way. This would represent a key improvement for ICAEN's current registry.

The potential improvements expected with the interaction with BIGG is:

- First to be able to standardize the data of the BPC, at least the data available in open data, in the INSPIRE format.
- This standardization should help us to be able to verify the data entered in the certificates, for example, cadastral reference, constructed surface, surface by plant, elevations, etc. and on the other hand, this standardization of the public data will improve the reuse, exploration, exchange and processing of these data for the public.

The possible correlation of the data of the BPC with INSPIRE will improve the credibility of the results of the certifications and, on the other hand, it will facilitate the reuse of the data, either in future certificates on the same building or in the exploration of all together.

It is expected that the joint use of BPCs data and cadastral data will improve the quality and information of the BPCS viewer that currently the Catalan government makes available to the public.

III.1.2.b. Use Case 4: Adoption of sustainability indicators of EU framework Level(s) in building Certification

Use case 4 seeks to expand the current indicators that ICAEN has for its buildings certification, according to the European Level(s) framework - Level(s) (https://ec.europa.eu/environment/topics/circular-economy/levels_en).[2]

The main objective of this use case is to improve and expand the indicators that could be extracted from the Building Performance Certificate (BPC) registry. This will be achieved by aligning the current indicators extracted from the building certificates with the Level(s) standard. In order to achieve this goal, specific objectives are set, which are:

- Explore the indicators of current BPCs and align them with those marked by Level(s).
- Explore existing data to extract new indicators and align them with Level(s).

In this case, no final results with direct application are expected for all BPCs, but it is expected to better understand the existing and future possibilities that can be given to BPCs. It should be noted that any modification of BPC methodologies requires a lengthy legislative process.

The expected improvements with BIGG for the current BPC are:

- Mapping of the Level(s) indicators to the BPC and identification of the extra required information to qualify for them.

- Establish which indicators of Level(s) have already information within the current BPC registry and any other publicly available source of information, such as the Cadastre, meteorological data and air quality data.
- Inclusion of this information in the ICAEN's certification searcher to offer this information for each file.

With the information currently available in the Registry of BPCs, there are some registers with information available to get the following indicators (from Level(s)):

- 2.1 Life cycle tool: Building bill of material (kg): The main building elements and Reporting on the four main types of materials.
- 3.1 Use stage water consumption (m^3/occupants/year)
- 4.2 Time out of thermal comfort range (information in some simulation tools).
- 6.1 Life cycle costs (€/m^2/year)

For all those cases, the available information in the buildings energy efficiency certificates should be collected to perform calculations in order to have a value of all these indicators. It should be considered that all information received from each certification tool is different, so it might not be applicable to all registries but only to a few instead.

III.1.3. Business Case 3: Building Life-Cycle: From Planning to Renovation – ICAT

The main objective of this business case is to facilitate the **interoperability** between the different tools (and their datasets) that can be used during the whole building cycle life. This interoperability must ensure the data exchange between systems and application, facilitating the reusing of data between them, reducing the cost of setting of them and giving more value and new advanced services of data processing for the buildings.

The actors involved in the building construction phase, on-site and in the maintenance phase (during the exploitation of the building) are also developing and using different tools and generating a large amount of data. In the design phase the BIM model contains static information of a building element. However, combining with more dynamic information, in operation phase, such as data stemming from IoT sources, or exchanging the dynamic data with building maintenance tools will increase its usefulness over the whole building lifecycle.

BIGG will advance beyond the state of the art in:

- Combining static and dynamic data from building HVAC systems, comfort and occupancy information, BIM Models by harmonizing the data through transformations to the internal BIGG Standard Data Model 4 Buildings;
- Achieve interoperability of different types of data hosted in BIGG format with external tools that can be a reference in Europe.

III.1.3.a. Use Case 5: Interoperability between BIM, BMS, CMMS and building simulation engines

The main objective of this use case is to guarantee the interoperability between the different data acquisition / generation systems that we can find during the life cycle of the buildings. This interoperability will be achieved by the harmonization and mapping of them over the BIGG standard data model. This interoperability must enable the creation of an integrated value chain across building design, operation, maintenance, commissioning and refurbishment decision making.

During the life cycle of a building, there are many systems and / or applications that are used by different actors to design, manage or improve buildings.

In the design phase of the buildings, either for new construction or rehabilitation, different applications are currently used. These applications can be BIM models, energy simulation tools or energy efficiency certification tools. These tools require significant resources for the collection of necessary input data and also in the creation of the modelling itself. The reality of its final use is limited to obtaining static results of support in decision making at specific times in the life of the building.

On the other hand, in the phase of operation of the buildings, increasingly digital systems seem to favour the management, maintenance and operation of the buildings. These systems can be monitoring systems, computerized maintenance management systems (CMMS), facility control systems (BMS or HVAC remote controls) and IoT sensors or applications.

In general, the operation of these systems is always individually, making the effort in the initial configuration of these systems is always large and expensive. In fact, in most cases the results of these applications cannot be combined with each other or integrated anyhow, forcing even the replication of registers or sensors to combine information that really is already available.

The expected improvements with BIGG are the followings:

- To harmonize and map the different input data sets. Currently, buildings and systems generate a large amount of data that is stored in a different DBs, which makes joint data processing/analysis impossible.
- To allow the users to set, update, explore the data from different tools or systems together thought a unique access point.

For an organization like Infraestructuras.cat, in charge of the energy management and maintenance of a multitude of public buildings owned by other entities, the fact of being able to have all or most of the data generated in the useful life of the buildings in a single point, (in an orderly manner and linking the data between them) is a spectacular improvement in daily management.

III.1.3.b. Use Case 6: Interoperability of BIGG with EEFIG-DEEP

The objective of this use case is to ensure the interoperability between the BIGG platform and the De-risking Energy Efficiency Platform (DEEP).

De-risking energy platform (DEEP) is an open-source database for energy efficiency investments performance monitoring and benchmarking, created by the Energy Efficiency Financial Institutions Group (EFFIG) actively supported by the European Commission.

It provides an improved understanding of the real risks and benefits of energy efficiency investments by providing market evidence and investment track records. DEEP Includes 15,000+ energy efficiency projects in buildings and industry from 30 data providers.

In the BIGG project different use cases collect data from the implementation of energy performance improvement measures or projects (example, UC 2).

The first improvement that this use case brings is that the collected efficiency measures data are aligned to a standard taxonomy. This allows for the joint processing of energy efficiency measures.

On the other hand, working with standard taxonomies facilitates the exchange of information between platforms (e.g. DEEP -BIGG). This improves confidence in the results obtained in them.

To accomplish this main objective the following specific objectives should be achieved:

- To harmonize the energy efficiency measures and projects collected from BIGG pilots and the registers and models existing in DEEP platform.

- To establish the procedures for exchanging information between BIGG and DEEP Platforms.

III.1.3.c. Use Case 7: Interoperability between EU Building Stock Observatory (EUBSO) and national/regional Energy Performance Certification through BIGG

The objective of this use case is to ensure the interoperability between EU Building Stock Observatory (EUBSO) and national/regional Energy Performance Certification (EPC) hubs through the BIGG platform. To accomplish this main objective the following specific objectives should be achieved:

- Mapping and harmonization of EU Building Stock Observatory (EUBSO) and national/regional Energy Performance Certification (EPC)
- Definition and development of the procedure to exchange data between EUBSO and EPC Hubs

III.1.4. Business Case 4: Energy Performance Contract (EPC) based savings in commercial buildings – Cordia

The objective of BC4 is to create a solution able to manage EPC contracts from A to Z, from storing and organizing any EPC contract related assets, acquiring their related data (both static and dynamic), tracking the achieved savings, managing the contracts and milestones and building any required report. The solution will have to enable smooth communication between the ESCO managing the EPC contract and the end customer who must be notified in case of any major savings deviation or when corrective actions are required.

III.1.4.a. Use Case 8: Assets management to store, view, update all relevant assets such as buildings, contracts, invoices, meters, sub-meters, sensors, equipment.

Use case 8 tries to enable the user to store, access, view and manage all relevant data regarding the management of an EPCo (Energy Performance Contract). The data includes the relevant information to describe the building, the contract, the invoices and consumption data, the monitoring hardware (meters, sensors) and the equipment.

The main objective of this use case is to structure the data collection process to enable the storage of all relevant information for the management of both an on-going EPC contract and a new EPC in the kickoff phase. Specifically, it is important to manage all the assets and data that intervene in the lifetime of EPC contracts, in a single digital platform.

Eventually, this data will be accessible from a single access point to ease the EPC management process and decision making.

For every site with an EPC contract, the process will be as follows:

1. Necessary research into the key areas for HVAC systems or Building envelop integration, in accordance with the desired ambient conditions in order to achieve energy savings;
2. Collection and analysis of ambient data parameters, for selected areas;
3. Collect the meta-data of all the physical assets, for which data must be stored and organized according to a tree structure;
4. Collect the EPC contract data;
5. Collect all the required dynamic data for EPC follow up, savings tracking, etc.

6. Take into consideration and assess relations that help to understand the use profiles and implications.

The expected improvements with BIGG for this Use Case are:

- Usage and validation of the data model from the BIGG platform (WP4)
- Centralize data collection using the collection layer from BIGG Platform (WP3)
- Easy Export & Import of assets from and to the BIGG platform (WP4)
- Transform of time-series data to align them with standard time grids in order to exploit them with the AI toolbox (WP4&5)
- It is desired from the ESCo part (CORDIA) that the tools currently used will be improved for the optimization of the energy management services and Energy Performance Contracts delivered (by the ESCo).
- Establishment of new innovative services regarding facilities management, esp. related to technical maintenance of energy efficiency of HVAC systems is also an expectation from BIGG.

III.1.4.b. Use Case 9: Actual savings tracking realized by the Energy Conservation Measures (ECMs) undertaken by the ESCO and monitors on a daily/weekly/monthly basis

Use case 9 tries to ease the process of quantifying the impact of an Energy Conservation Measure on a given building through an accurate modelling of the building consumption. Additionally enables the user to track the implemented ECMs in time and their impact on the managed asset.

The main objective of this use case is to track the actual impact of ECMs and verify the associated savings.

The present use case –according to the pilot scenario is taken into consideration- focuses on pre-existing buildings so measures are rather linked to different consumptions adjustment (e.g., electricity) and optimization of internal conditions (e.g., CO_2 concentrations lighting levels) rather than design plans (orientation of windows/openings).

The process that is being followed focuses on the next three steps:

1. From the energy consumption data prior to the EPC project and the data about factors impacting consumption, a regression model of the consumption is being identified to be used as baseline. The baseline takes into consideration the crucial parameters that contribute to energy consumption (e.g. outside temperature);
2. The precision of the model will be assessed according to the IPMVP protocol and must reach a good accuracy level in order to be used;
3. During the whole EPC lifetime, continuously compare the actual energy consumption with the baseline. The difference provides the estimated savings.

In this process there are the following general comments:

1. When identifying the baseline models, particular care must be taken to avoid overfitting.
2. A high model accuracy is a key requirement. Without it, in case the expected savings are not realized as expected, it is often impossible to determine if the cause lies within the ECM impact estimation, within a misuse of the building post renovation or within the poor accuracy of the savings estimation by the baseline model. This can lead to endless discussions between the customer and the ESCO and sometimes even to trial.
3. In order to achieve the highest accuracy to the baseline model, it may be needed to consider more than one parameter as independent variable (e.g., outside temperature and building occupancy) in creation.

Baseline models can be identified for a whole building, building parts or even a single equipment (and its respective energy use).

The expected improvements with BIGG for this Use Case are:

- To improve the regression models for more accurate savings estimation (WP5)
- To standardize ECM formalization (WP4)
- To build accurate savings estimations procedures for independent ECMs (WP5)
- To integrate non-routine adjustments to the IPMVP follow up (WP5)
- To define and create valuable savings tracking dashboards (WP3)
- To define and create the baseline models for new EPC contracts
- To establish new innovative services around facility management of the building.

III.1.4.c. Use Case 10: Energy Performance Contract Management to manage the EPC life-cycle and perform actions (eg. Reporting) according to contractual milestones

Use case 10 tries to manage the EPCo life cycle and perform actions (e.g. reporting) according to contractual milestones. The process concerns the management of an EPCo which involves the management of the building equipment operation, the impact of occupant's behaviour and the conditions of the building maintenance contract's implementation. It is strictly focused on building operation on either new buildings or existing ones. It can be implemented for any building which is operational (built and commissioned) and when an Energy Performance Contract is signed.

The objective of this use case is to simplify the management of an EPC contract on a single platform leveraging the templated data collection process both static and dynamic, and the ECM tracking capabilities.

The goal is to centralize all relevant information that has an impact on the existing performance of the building (existing equipment but also existing operational conditions such as expected comfort level or light level) and to define what will be the technical perimeter of the project as well.

The existing factors of influence (such as HDD or CDD) are critical for an accurate measurement of the project real impact.

The projected savings are another static data input that is defined in an EPC contract. The actual savings will be monitored dynamically on site by means of either the existing monitoring infrastructure or, if such monitoring infrastructure does not exist, additional monitoring points.

In addition, the solutions provided by BIGG should also enable the management and the monitoring of the building operational parameters so that routine operations can be accounted for, measured and managed.

Finally, the BIGG solutions should enable a simplified reporting mechanism where the impactful events over the period are identified, their impact quantified and a status of the building performances is given with a confrontation with the expected results based on the initial models.

The process involves the building owner, the building occupants and the building manager or energy service company that has been missioned to operate the building in its behalf.

The expected improvements with BIGG for this Use Case are:

- To formalize EPC contract structure and data architecture (WP4).
- To build tools to follow up EPC timeline and evolutions (WP3&4): EPC contracts go through several phases (e.g., pre- & post-retrofit) and may require adjustments along the way (On-going building management, routine actions)

- To build an ECM actions management tool with actions follow-up (WP3&4)
- To transform savings into financial indictors (WP5)
- To build contract management dashboards (WP3)
- To improve the tools used for energy management of the buildings. Identification of energy consumption exceedance and alarming, comparison of energy KPIs between respective buildings, automation of optimum operating of HVAC systems in buildings.

III.1.5. Business Case 5: Buildings for occupants: Comfort Case – Cordia

Building Management Systems (hereafter BMS) are optimizing comfort based on the current outside weather, a programmed occupancy schedule and the expected comfort level in the different building parts. They use a single objective function which is quite simple and consumption, cost and green energy usage are not taken into consideration in this optimization.

In BIGG a multi-objective function will be applied in which consumption, cost and usage of green energy must be optimized. The optimization will not only use inputs about the current situation but also about the forecasted situation of the building (weather, occupancy, PV production, price). The output will be used to overrule BMS actions or send instructions via IoT actuators.

III.1.5.a. Use Case 11: Optimization using weather forecast

Use case 11 tries to consider weather forecasts like predicted outside temperature, predicted solar irradiation, etc., as part of the optimization logic.

The objective of this use case is to design and develop a control algorithm that takes into account weather forecasts to optimize energy usage of the site. Variables such as hourly outdoor temperature prediction and solar irradiance forecast will be part of the decision-making process to control other devices in a smart and autonomous way.

The process is that the facility management company will perform a site survey of the on-site equipment (HVAC, chiller, AHUs, …), collect information from occupants to identify comfort issues in the site, building or in zones of the building. When required, extra sensors will be installed on site.

The facility manager will design and implement the ruleset to optimize comfort and energy usage. Assets and metrics will be used in the AI ruleset. The BIGG platform will allow us to build the models which will be used to make predictions of consumption & comfort.

The facility manager will have a dashboard for comfort & energy monitoring of the different buildings and zones. The occupants of the building will have a local dashboard to see the decision logic of the optimisation algorithms provided by the BIGG platform and to follow the comfort related KPIs

The expected improvements with BIGG for this Use Case are:

- To collect weather forecast data in the BIGG platform (WP3)
- To exploit forecast data in rules to optimize buildings (WP5)
- To improve controllers of existing equipment (air handling units, boilers, chillers) to avoid energy destruction and wastes (WP5)
- To communicate optimization results to the occupants through public dashboards (WP3)

III.1.5.b. Use Case 12: Optimization using occupancy forecast

The objective of this use case is to design and develop a control algorithm that considers weather and occupancy forecasts to optimize energy usage of the site.

Variables such as expected occupancy in one hour will be part of the decision-making process to control other devices in a smart and autonomous way.

The same process described in UC 11 will be followed. The facility manager will be able to take current and future occupations into account in the ruleset. The occupants of the building will see the current and forecasted occupation in the local dashboard

The expected improvements with BIGG for this Use Case are:

- Collect reliable occupancy data (WP3):
- Exploit occupancy data to avoid energy usage during unoccupied hours (WP5)
- Communication of the optimization results with the occupants through public dashboards (WP3)

III.1.5.c. Use Case 13: Optimization using price forecast

The objective of this use case is to design and develop a control algorithm that takes into account weather, occupancy and price forecasts to optimize energy usage of the site.

The same process described in UC 11 and 12 will be followed. The facility manager will be able to take the current and future energy price into account in the ruleset. The user will be able to calibrate the rules on multiple objectives namely comfort, consumption and cost. The facility manager will have an extra dashboard to follow up the cost savings.

The expected improvements with BIGG for this Use Case are:

- Collect pricing data matching country regulations (WP3)
- Exploit pricing data to use energy in a cost-effective way (WP5)

III.1.6. Business Case 6: Flexibility potential of Residential consumers on electricity and natural gas - Heron-DomX

The main objective of this business case is to demonstrate and exploit the flexibility potential of residential and commercial buildings across the two main energy vectors of electricity and natural gas. The focus will be on characterizing the availability and the distribution of flexible loads within both residential and commercial setups, by analysing the plurality of data combined from various data sources, residing both at consumer premises (smart meters, controllers, sensors) and on the cloud (remote databases, services, etc.).

This approach will rely on the constant monitoring of user requirements and comfort limits, in order to characterize the amount of flexible energy consumption that can be either shifted or reduced towards meeting the supplier needs. End users will employ friendly smartphone applications to manage the operation of their connected heavy consuming appliances (electric water heaters, gas boilers, etc.). User preferences (e.g., target temperature, device activation schedules) will be constantly logged through the apps, while also providing the main communication interface for interacting with the demand-response (DR) management system and services.

III.1.6.a. Use Case 14: On demand-response for Electricity

This use case allows residential electricity end-users to monitor the total power/energy consumption of their household and the consumption of specific appliances with heavy loads such as washing machines or air conditioners. On top of that, users could perform manual actuation (ON/OFF) for controllable devices, while they receive real-time advice suggesting them to shift the operation of the monitored appliances during periods of heavy RES production in the system. Access to pilot participants' real-time smart metering data provides the required technical and software infrastructure to facilitate comparison of energy consumption and carbon footprint between similar consumers with similar consumption characteristics and the evaluation of changes in the energy consumption trends. Smart-metering data is critical in this respect as consumption analysis on monthly basis tends to overlook the daily/hourly patterns that differentiate electricity consumers.

In more detail, through this Use Case the following objectives are foreseen to be achieved:

1. Typical consumption patterns will be identified considering electricity consumption per flexible device (e.g., water heater) and for the aggregate portfolio on a daily and/or monthly basis to make customers aware of their energy wastages.
2. The current energy consumption of residential consumers and carbon footprint will be compared with similar trends of other households or their own consumption history.
3. Load profile (electricity use and PV production) at prosumer level will be identified through data monitoring and analysis for evaluating the available flexibility to be harnessed.
4. Identification of the flexibility potential by enabling users providing their flexibility preferences through a user interface (mobile app or web-based).
5. Facilitate continuous monitoring of user engagement through dashboards, while reporting the successful status change actuations.

The expected improvements with BIGG for this Use Case are:

- Collect real-time smart metering data in a secure and GDPR compliant environment (WP3)
- Develop innovative user-driven services based on existing infrastructure (WP3)
- Monitor smart-metering infrastructure (WP3)
- Provide load profiles for real-time consumption advice (WP5)
- Create clusters based on consumption patterns to compare residential consumers in terms of consumption and carbon footprint (WP5)

III.1.6.b. Use Case 15: On demand-response for Natural Gas

Use case 15 describes how users of legacy natural gas boilers can upgrade their heating systems through the cost-effective heating controller of domX, while enabling their participation in flexibility provision services to the natural gas supplier. Targeted devices include residential and commercial heating devices operating on natural gas, supporting several types of control modes (ON/OFF, power modulation, etc.). The edge controllers are interconnected with a cloud-based energy management system that constantly collects, stores and analyses the collected data. The end users can interact with the upgraded boiler, both through the existing thermostat and the smartphone application, providing climate comfort limits and collecting real-time feedback on the boiler operation. The proposed concept focuses on the Management of Natural Gas consumption in buildings, by actively controlling and optimizing the indoor environment, with the aim of (a) improving energy efficiency through load reduction and (b) contributing to energy system flexibility providing real-time gas balancing services.

In more detail, through this Use Case the following objectives are foreseen to be achieved:

a. To enable smart and remote control of legacy natural gas boilers

b. To collect detailed heating data from the natural gas boiler (water temperature, modulation, etc.), the thermostat (room temperature and target) and through sensors of the heating controller (outdoor temperature, etc.)
c. To collect consumer comfort limits and heating schedules through the smartphone application
d. To analyse the building and boiler performance based on: building characteristics (size, orientation, insulation, etc.), boiler specs, as captured by the building Energy Performance Certificate (EPC) data and indoor/outdoor temperature variations
e. To dynamically adapt the operation of gas boilers for heating to deliver improved energy efficiency, based on the prevailing:
    i. user comfort limits and heating schedules
    ii. building and boiler performance
    iii. outdoor weather variations
f. To analyse and forecast the natural gas demand in real-time at individual consumer level and aggregate portfolio level of the supplier
g. To identify the flexibility potential of connected buildings and gas boilers, based on the list of end users subscribed to flexibility services and their heating schedules
h. To dynamically adapt the demand of connected gas consumers to maintain a portfolio balance, to adjust the identified imbalances.

The expected improvements with BIGG for this Use Case are:

- To centralise data collection using the collection layer from BIGG Platform (WP3), by considering multiple different data sources:
    - Weather forecasts collected from meteorological data sources
    - Gas market data as collected from national and EU level sources
    - Building EPC data
- To standardize the transformation and representation of collected data types based on the common BIGG format (WP4)
- To exploit the transformed data, in order to apply the AI toolbox (WP4&5)
- To build accurate energy efficiency improvement estimations for end consumers (WP5)
- To improve the regression models for gas demand forecasting (WP5)
- To improve the regression models for gas demand flexibility evaluation (WP5)
- To communicate energy savings results to the occupants through the smartphone application (WP3)
- To visualize the real-time and forecasted portfolio demand through dashboards designed for the gas supplier (WP3)

IV. RESULTS OF THE BIGG TOOLS PROVIDED

The BIGG project is currently at the middle of the project (M18) and has focuses so far in the development of the technical aspects of the project. The technical development was designed to tackle the diversity of pilot cases of BIGG (also known as business cases) ensuring a wide applicability of the obtained results.

The technical development of the project has already produced a reference architecture framework (RAF) in WP2, some personalised ingestors for the data and the initial definition of security to take into account in WP3, a BIGG data model that will allow the data harmonisation for all the BC in WP4, and a wide array of analytical and data processing tools for the AI toolbox in WP5. Currently, the technical WP are expanding the already developed features of each one of them as well as working on the integration of all the components created along with the data, to smoothly be able to analyse and process all the pilots' data and provide the "final" results.

The pilots of BIGG have three distinct phases, starting with the data acquisition actions, followed by the data processing steps and closed up with the users' interaction with the platform and its systems. They start one after the other but can run in parallel until the end of the project, since the project will be uploading and analysing data continuously. In order to measure the progress of each BC key performance indicators (KPIs) were defined for each of them.

The KPIs can also be divided into three main categories based on what they analyse. First the data acquisition KPIs that analyse all the actions connected to gathering the data into the platform. The actions range from uploading building data, energy consumption data, and the set-up of any links between different data sets of information (associating building and energy consumption data). The second group are the data processing KPIs that measure all aspects of the data transformations, harmonisation and analysis using the developed AI tools. The actions include data quality checks (for example, outlier detection), data upload checks (to detect data losses for new data), analysis such as baseline calculation, savings calculation or benchmarking performed. The third group are the KPIs that measure user interaction with the platform, this group uses a wide range of analysis, such as total number of users registered or share of active users compared to the total users.

The summary section will also analyse for each BC the aspects of the project referring to i) Limits detected to each BC and ii) Reasons for including or excluding data (associated to the progress of each BC). The analysis will only cover the aspects that are relevant to each BC, if there are any worth mentioning at the current stage of the project.

IV.1. Business Case 1: Benchmarking and Energy Efficiency tracking in Public Building – ICAEN

The results of BC1 are divided among UC1: "Benchmark and Monitoring of Energy Consumption" and UC2: "Energy Efficiency Measures (EEM): Registration & Evaluation". The purpose of each use case as explained above is to develop tools and systems to enable advanced building benchmarking and monitoring both of building's performance and energy efficiency trends. UC1 and UC2 focus on the same buildings from different perspectives, meaning that to achieve the BC1 goals both of them have to progress. It also means that some KPIs will be shared since lots of data will be used for both UC1 and UC2, being the user interactions a great example of shared KPIs, which will only be displayed in the UC1 section.

IV.1.1. Use Case 1: Benchmark and Monitoring of Energy Consumption

The KPIs of UC1 analyse sequentially the data acquisition, data processing and user interaction. However, only the data acquisition KPIs have results assigned to them at the moment. The main reason for the lack of results at the data processing KPIs section is the current state of the technical WP, they are just finishing the integration of all the BIGG systems (the tools are currently independent and are being combined for each BC) which then will allow the analysis of the whole datasets. The first test for the different tools has been carried out successfully. The user interactions will be measured when the platform is up and running and the analytics are working. Currently, there is an ongoing effort to engage as many energy and building managers as possible to ensure a wide implementation of the platform from the early days by a large variety of organisations within the Catalan government.

Table 1 – Use Case 1: Data acquisition KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	Current Value (M18)	% of achievement M18
Number of Public Buildings (with data)-[UC1-NPB]	Public Buildings with their data associated to Platform: GPG data (building properties), building location (weather data), link to supply (link CUPS and buildings)	3000	981	33%
Number of electricity consumption with a building-[UC1-NEC]	Amount of consumption points linked to the buildings where they are used	6000	1169	19%
Number of gas consumption with a building-[UC1-NGC]	Amount of consumption points linked to the buildings where they are used	800	326	41%
Availability of monthly electricity energy data (electricity)-[UC1-MED]	Public Buildings with their monthly electricity data (recorded) associated to Platform	>80%	82%	102%
Av. of hourly consumption data (electricity)-[UC1-HED]	Public Buildings with their hourly electricity data associated to Platform	>80%	82%	102%
Av. of Monthly gas energy data (GN)-[UC1-MGD]	Public Buildings with their monthly gas data associated to Platform	>80%	88%	110%

The data acquisition of BC1-UC1 is an ongoing process of sorting out all the available information and ensuring the linking of the different sources and their respective data sets. The advancements on the data acquisition were linked to the associations between datasets, in part due to the work of WP4.

The first KPI focuses on the number of public buildings [UC1-NPB] with usable data for the project. It means that from the more than 3000 buildings of the Generalitat de Catalunya data is available but at the moment only 33% of them fulfil the criteria of having the building information (GPG database), the building location (link to weather stations) and the CUPS (energy consumption point) associated using internal identifiers. Meaning that the information is all available and that it has been possible to link each piece of information to a building.

Of the 6000 consumption points of indicator “Number of electricity consumption with a building-[UC1-NEC]” 1169 (the 19%) are associated to buildings (one building can have more than one CUPS). The gas consumption indicator (Number of gas consumption with a building-[UC1-NGC]) showed greater advances with 326 consumption points out of 800 (41%) already linked to their respective buildings. The three indicators require the association of information sources finding key values that allow to combine different datasets (from different sources) to a building. This line of work rests on the data harmonisation of WP4.

Indicators UC1-MED and UC1-HED analyse the share of buildings with information (first indicator) that have monthly and hourly electricity energy data available. Currently, both indicators are already performing great having reached the target of having more than 80% of building with data.

The final indicator measuring data acquisition is the Availability of monthly gas data-[UC1-MGD] that measures monthly gas data for the public buildings. It has already reached the target of having more than 80% of the building with the gas data by M18 (May 2022).

Table 2 – Use case 1: Data processing KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
Number of Monthly Electricity data with enough quality-[UC1-MEQ]	Dataset integrity check for monthly electricity data	>95%
Number of hourly Electricity data with enough quality-[UC1-HEQ]	Dataset integrity check for hourly electricity data	>95%
Number of Monthly gas data with enough quality-[UC1-MGQ]	Dataset integrity check for monthly gas data	>95%
Monthly electricity data with sufficient update time-[UC1-MEU]	Data logging has a delay of less than 6 months	>80%
hourly electricity data with sufficient update time-[UC1-HEU]	Data logging has a delay of less than 2 months	>80%
Monthly gas data with sufficient update time-[UC1-MGU]	Data logging has a delay of less than 6 months	>80%
Number of buildings with a baseline-[UC1-NBB]	Public Buildings with their baseline consumption calculated by the platform	3000
Number of Buildings with longitudinal benchmarking-[UC1-NBH]		3000

The data processing of BC1-UC1 includes all the different data transformation and analysis steps that use BIGG related tools, from the harmonisation to the AI toolbox. One example of a tools developed to check the data integrity are the ones designed to detect outliers, from impossible values (previously defined, in the case of energy consumption, it should be a positive value and not exceeding the total capacity permitted) to calendar outliers (based on local working days and holidays). Data integrity also analyses the presence of data within the datasets to ensure that the device relaying the information is properly working. The data integrity checks will be carried out for electricity data for both the hourly [UC1-HEQ] and monthly [UC1-MEQ] data, as well as, the monthly gas data [UC1-MGQ].

The data upload time for both electricity at hourly [UC1-HEU] and monthly [UC1-MEU] intervals and gas monthly data [UC1-MGU] are key to ensure the timely management of large building portfolios. One of the BC1 objectives is to provide energy mangers the necessary tools to improve control and manage the energy performance of a large park of buildings with automated methods, which needs the data readily available to perform analysis and control of the performance.

All the data quality steps, integrity (>95%) and upload time (>80%) have set high targets to ensure that all the data that is found within the system is reliable, and that the acquisition step does not add any extra uncertainty to the data, and the following analysis.

The main analysis section will focus on calculating baselines for all the buildings that will later be used to estimate energy savings or over-consumptions. Associated to the baseline calculation, the building can be compared (benchmarking) against its past-self (longitudinal benchmarking) or against peer buildings (cross-sectional benchmarking). The two indicators that will measure the progress in the analysis section focus on calculating the baseline for all buildings [UC1-NBB] and performing the longitudinal benchmarking of the buildings [UC1-NBH]. The tools used for performing the analysis are being developed and are presented in the AI toolbox (WP5, https://github.com/biggproject).

Table 3 – Use case 1: User interaction KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
Users registered-[UC1-UR]	Total number of users registered	130
Active users-[UC1-AU]	Share of active users (that at least log in once in 6 months)	20%

The user interactions with the BC1 will be measured using the same indicators for both UC1 and UC2. The first indicator measures the total number of users registered [UC1-UR] that have access to the platform and the BIGG tools, the users registered are expected to be mainly energy and building managers with a small share of policy makers.

The second indicator will measure the share of users that are active of the total users [UC1-AU], which will measure the platform interactions as a proxy of the platform usefulness to them.

IV.1.2. Use Case 2: Energy Efficiency Measures, EEM: Registration and Evaluation

The work of use case 2 focuses on the energy efficiency measures (EEM) registration and evaluation to build a repository of their essential information. The EEM must be associated to a building (UC1) to be able to associate them to energy savings obtained. The KPIs of UC2 analyse the data acquisition and data processing sides of the UC, the user interactions are presented along with UC1 since they use the same system. The project progress so far has centred into the data acquisition steps to provide the data processing tools with information, therefore the results presented are only for the data acquisition KPIs.

Table 4 - Use case 2: Data acquisition KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)
Nº of improvement actions collected-[UC2-IAC]	Amount of improvements in general in a given building or facility.	2200	471
Share of actions without finish date-[UC2-WFD]	When logging data the finish date of the action is missing, or it is not complete	<50%	0%
Share of actions without the value of EEM effect over whole building-[UC2-WSD]	When logging data the affected share over the total building is missing, or it is not complete	<50%	18%
Share of actions without typology of action-[UC2-WTD]	When logging data the typology of the action is missing, or lacking in specific details	<50%	0%
Share of actions without investment cost-[UC2-WID]	When logging data the investment cost is missing	<25%	6%

As explained in UC1, the data acquisition for BC1 is an ongoing process of both sorting the information and linking the different sources. The first KPI focuses on the number of improvement actions collected [UC2-IAC] which are recorded for a building or facility. Currently, there are 471 EEM registered that were obtained using the pre-platform excel file that will be improved by the implementation of the BIGG platform. The implementation of the BIGG platform will ease the uploading of new EEM into the system which will facilitate reaching the set target, for example, it will allow to record the EEM directly associating them to existing buildings and it will show the essential information to record.

There is an expectation that a wide range of users will interact with the platform differently, leading to data voids, missed information and EEM registered without key information for the later analysis such as the finish date.

The finish date [UC2-WFD] provides an indication of when to start measuring the expected “savings” associated to the EEM implemented due to it being completed, assuming that the impact can be analysed from the same moment. For example, improving heating over summer will not be detected as savings until the next heating season.

The affectation of the EEM over the whole building [UC2-WSD] provides knowledge of the share of the old installation affected by the improvement action, and therefore an idea of the effect it will have regarding savings, as well as, a measuring of the savings potential.

The typology of action [UC2-WTD] allows to categorise the EEM based on their typology which is essential to understand the effect each action will have.

The investment cost of an EEM [UC2-WID] is essential information needed to perform any economic calculation in combination with the savings obtained from the EEM and the energy cost at the time. The knowledge of the investment cost and the economic value of the savings can be used to calculate the return of investment (ROI), the net present value (NPV) and a wider array of economic indicators.

Table 5 - Use case 2: Data processing KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
Share of savings evaluated-[UC2-NSE]	Share of savings evaluated = Savings evaluated/Savings registered	15%
Share of EEM which ROI, Pay-back time and IRR can be calculated based on investment-[UC2-NFC]	Share of financial indicators = Financial indicators can be evaluated/Savings registered	15%

The data processing of UC2 evaluates the two essential items for the energy efficiency measures, being the savings evaluation [UC2-NSE] and the economic indicators calculations [UC2-NFC]. The main aim of the UC2 is to try to evaluate the savings obtained from the registered EEM, therefore the KPI share of savings evaluated [UC2-NSE] was stablished with the goal to reach 15% savings estimation. The challenge to calculate the savings does not come from the analytics developed in the AI toolbox (WP5), but from the data itself since the BC1 uses only one sing smart meter data per building that includes all the energy consumption of the location. The single point of energy data means that any EEM that achieves small savings compared to the whole building consumption will not be statically significant enough to be beyond the error/confidence margins established, and therefore the savings will not be measurable for that particular EEM.

The calculation of the financial indicators follows the same logic as the savings evaluation, since the calculation of the economic returns of investment depends on having the savings obtained in financial terms (saved €/m^2 instead of kWh/m^2). The financial indicators can be estimated based on the investment cost of the EEM and the predicted savings for a certain EEM (based on technical estimations or previous similar actions).

IV.1.2.a. Summary of BC1

The BC1 aims to give public authorities and energy managers the necessary tools to improve control and manage the energy performance of a large park of buildings with automated methods. This objective requires to gather all the relevant building and energy data in a system to perform AI based analysis on it, with the aim to establish baselines, detect savings, and building degradation.

Towards these goals UC1 is progressing as expected in all three categories of indicators, data acquisition, data processing and user interaction. The data acquisition indicators show that the current situation of the UC1 regarding data still has work to do in order to reach all the set targets. Even though some indicators are below 50% the overall progress of the project is not impeded, because there is plenty of data to start the deployment of the analytical tools developed in WP5. It is also worth mentioning that the users are being recruited for each department of the Catalan government and they will be in charge of speeding the association of the different data sources, by providing BIGG with the key elements in common for each database and by using the platform to improve their building energy governance.

UC2 is progressing as expected in all two categories of indicators, data acquisition and data processing. The data acquisition indicators show the current situation of the UC2 regarding data has achieved almost all its targets, however, the challenge will be to keep the data gaps low with the upcoming data uploads in which the platform users will be part of the data gathering process directly. The analytical tools of UC2 have already been developed and are awaiting the progress of UC1 to couple energy consumption, savings and EEM.

IV.1.2.a.1. Limits detected to BC1

Baseline calculation will be affected by the working patterns induced by the Covid pandemic, the most relevant of them the generalisation of working from home for all the workforce of at least two days a week. This change implies new patterns of building occupation, with more people in a single building but with a concurrent lower occupation than before Covid, therefore, there should be a lower need for support systems such as HVAC. The challenge will reside in having enough pre-covid data for most of the buildings to understand if the “work from home” schemes do have a statistical impact on the energy consumption of the buildings. Savings estimation/calculation will also be impacted by the “effected” baselines since the reduction in energy consumption could be associated only to a reduction in work force within the office.

Another aspect of working from home is the fact that the same space can host way more people since they are not all there at the same time, meaning that the organisations do require less overall space (meaning less buildings for large organisations), which in turn reduced the overall energy consumption of an organisation. This effect can be englobed within the normal dynamics of any organisation with large building portfolios that change to adapt to needs of space and economic needs overtime. For the Catalan government there has been a trend to move from several small buildings to fewer larger buildings, coupled with the building renovation moving from old to new buildings.

The work of preparing BC1 and analysing the different scenarios that were coming up in lead us to some pending discussions. The first topic is part of BC1, what do we do with the buildings that do not fit the models? That cannot be assigned to a group of buildings due to their anormal behaviour? How often will the buildings be checked for this criteria to decide if they have to be included or excluded? How will the removal of buildings from the analysis be handled and communicated?

The European aims to drastically reduce its $CO_{2eq.}$ emissions by 2030 and achieve climate neutrality by 2050 (European Green Deal) [3,4], in line with these targets all public institutions are bound to reduce their impacts and emissions. To reach these targets the emissions have to be accounted for, which is one of the strengths of BIGG, however, the externalisation of services may impede the accounting. This is an old debate renewed for a service such as BIGG, if data centres are externalised to the “cloud” our buildings will not have that as energy demand, only as an economic flow, therefore energy saved. However, the energy is consumed, probably more efficiently that in the buildings itself (which is positive overall), but it should be accounted in some way (at least for the side of CO_2 eq. emissions).

IV.2. Business Case 2: Energy Certification (EPC) in Residential and Tertiary Buildings – ICAEN

The results of BC2 focus towards taking advantage of the energy certifications and laying the ground work for future applications and modifications of the certificates. Towards these goals the BC2 aims to first (UC3) integrate the data with INSPIRE format to standardise it (easier communication with other systems) and second (UC4) start exploring future avenues for the certificates such as the Level(s) indicators. Due to the nature of BC2 most of the work carried out focused on the data processing steps, including data harmonisation and proposal of data mapping for Level(s).

Table 6 - BC2: Data acquisition KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	Value (M18)	% of achievement M18
Number of energy performance certificates-[BC2-NC]	Amount of certificates which data has been uploaded	1,000,000	1,235,268	124%

The data uploaded for BC2 are the energy performance certificates (EPC) obtained from the open access data managed by ICAEN. The KPI number of certificates [BC2-NC] aim to include 1,000,000 certificates has already been achieved by M18 with a current total number of certificates of 1,235,268, representing the 124% of the target (open data Catalonia). The data obtained from the building certificates includes information regarding the key parameters of an energy certification (Non-renewable energy consumption, associated CO_2 eq. Emissions, etc), without disclosing any personal information. The acquisition of this data will be a continuous process since with time new fields of information will be released, such as information about the thermal bridges.

IV.2.1. Use Case 3: Integration of INSPIRE spatial data with Energy Performance Certification

The main target of UC3 is to adapt the current certificates to the INSPIRE standard, adapting all the certificates fields and defining the harmonisation where possible.[1] The main task for UC3 will be defining the harmonisation of the BPC and ensuring that the end product complies with the INSPIRE standard.

Table 7 - Use case 3: Data processing KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
Share of BPC files with cadastral information-[UC3-CAD]	Share of BPC = BPC files with cadastral information/All BPC files	>95%
Share of BPC data Standardised in INSPIRE format-[UC3-STD]	Share of BPC in INSPIRE = BPC standardised in INSPIRE/all BPC data	>85%

The KPIs Share of BPC files with cadastral information [UC3-CAD] measures the number of certificates that have the cadastral reference associated to the BPC file. The cadastral database (already in INSPIRE standard) provides several items of information for each building such as coordinates of the buildings (UTM format) and building surfaces. The information provided may be used to cross check with other sources of information or as a common reference between different databases, since the cadastral number is widely used as a reference for buildings. Therefore, ensuring that most BPC have the cadastral reference [UC3-CAD] will facilitate future applications of the certificates towards private citizens, policy makers and the European Commission itself.

The progression towards the standardisation of the BPC certificates towards INSPIRE is measured by the KPI Share of BPC data standardised in INPIRE format [UC3-STD]. The aim is to maximise the use of the BPC as a source of information for other projects, therefore, they must be aligned to the INSPIRE spatial data standard, and this can be achieved by the harmonisation of the current BPC data into the above-mentioned standard [UC3-STD].

IV.2.2. Use Case 4: Adoption of sustainability indicators of EU framework Level(s) in building Certification

The work of UC4 aims to set a path towards Level(s) based on the current energy performance certificates information. In order to reach this target, there are several steps of mapping the current information within the energy performance certificates to the requirements of Level(s). [2] The goal of the mapping is to establish the necessary information to breach the gap between EPC and Level(s), therefore, most of the KPIs aim to understand the 6 different indicators of Level(s) and their requirements. The work for UC4 has been carried out to understand the data requirements to map the above-mentioned indicators with the BPC, the work is still going on, and there are no definitive results so far.

Table 8 - Use case 4: Data processing KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
Share of indicators that have a proposal of future mapping-[UC4-PFM]	Share of indicators that a mapping route has been described for the BPC	20%
Share of indicators mapped for: Greenhouse gas emissions along a buildings' life cycle-[UC4-EL1]	Greenhouse gas emissions along a buildings' life cycle	50%
Share of indicators mapped for: Resource efficient and circular material life cycles-[UC4-EL2]	Resource efficient and circular material life cycles	25%
Share of indicators mapped for: Efficient use of water resources-[UC4-EL3]	Efficient use of water resources	100%
Share of indicators mapped for: Optimised life cycle cost and value-[UC4-EL6]	Optimised life cycle cost and value	50%
BPCs indicators aligned with European Levels framework - Level(s)-[UC4-ELF]	BPC indicators aligned to Level(s)	1

The process of associating the current information within the BPC certificates to the different indicators of Level(s) is the mapping step, which will prove to be of varying success rate. The main reason for the variable success rates will be the current information within the BPC, which focuses on energy, emissions and building properties associated to energy loses and solar gains. The mapping will be divided among the 6 macro-objectives of level(s)[UC4-EL1-6].[2]

The first macro-objective covered by a KPI is the Greenhouse gas emissions along a building life cycle [UC4-EL1], is divided among two indicators, one for the energy use during the building occupation (kWh/m^2/year) and another analysing the whole life cycle building global warming potential (kg CO_2 eq./m^2/year). Both indicators have relevant information already present in the BPC, which has the global non-primary energy consumption and renewable production values for the energy indicator, and the emissions during the use phase (not the whole life cycle values) by source such as electricity consumption, HVAC, illumination, etc.

The second macro-objective covered by a KPI is the Resource efficient and circular material life cycle [UC4-EL2] analyses 4 different indicators, being the Bill of quantities, materials and lifespans the only one that has a slight connection to the current BPC information.

The third macro-objective covered by a KPI is the Efficient use of water resources [UC4-EL3] analyses the use stage water consumption, information that the BPC just holds in the form of the daily hot water consumption.

The sixth macro-objective covered by a KPI is the Optimised life cycle cost and value [UC4-EL6] analyses 2 different indicators being the Life cycle costs the only one that has a slight connection to the cost of the BPC in the form of the energy cost during the use phase.

There are two macro-objectives of Level(s) that are not currently analysed, which are the fourth and fifth macro-objectives, Healthy and comfortable spaces and Adaptation and resilience to climate change, respectively. They are not covered at the moment due to a lack of development of both indicators by Level(s) and because there have been no matches found among the current EPC towards these indicators, which made them redundant to study at the moment.

The overall aim is to map as many Level(s) indicators as possible to the energy performance certificates (BPC), however, it is also an objective to align the BPC information to one indicator of Level(s) [UC4-ELF]. Aligning the BPC to Level(s) will require to obtain any information source not present into the BPC, extract it and harmonise it to the point that all calculations required within the Level(s) indicator can be performed.

IV.2.2.a. Summary of BC2

The main objective of BC2 is to advance the utilisation of the energy performance certificates information. The BC2 work focused on harmonising the information of the EPC and start exploring new indicators such as Level(s).

The uploading of EPC certificates has already reached the target set for M36, providing large amounts of data for testing the harmonisations tools being developed in WP4. The progress of the work in BC2 is closely linked to the harmonisation tools developed in WP4 for UC3, as well as, the work in UC4.

The work in UC4 is currently analysing all the indicators of Level(s), to match as many indicators of Level(s) to pieces of information found in the current EPC with the aim to define the missing information for the full calculation of one of the Level(s) indicator.

IV.2.2.a.1. Limits detected to BC2

The main limit detected in BC2 is the diminished definitions of the Level(s) indicators of macro-objectives 4 and 5 and mainly the lack of a link between the current EPC and these two macro-objectives.

IV.3. Business Case 3: Building Life-Cycle: From Planning to Renovation – ICAT

As mentioned above, the objective of BC3 is to demonstrate the improved interoperability of data between systems thanks to BIGG project. The results of this BC presented in this section allow to demonstrate in UC5 the data interoperability between systems within the building (BIM, CMMS, BMS, etc..), in UC6 the interoperability of data of Energy Efficiency Measures stored in BIGG format with EFFIG-DEEP platform, and finally in UC7 the interoperability of BPC (Building performance Certificates) with euBSO (European Building Stock Observatory).

IV.3.1. Use Case 5: Interoperability between BIM, BMS, CMMS and building simulation engines

The UC5 KPIs sequentially analyse data acquisition, data processing and final results (linked data). However, at the current stage of the project, only values/results on the data acquisition KPIs can be provided. The main reason for not having values for the data processing KPIs and the results KPIs is that the technical Work packages is still working on the integration of the components to provide data processing and final results.

Table 9 - Use case 5: Data acquisition KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	Current Value (M18)	% of achievement M18
Basic building data -[UC5-NBD]	Number of buildings with basic data (id, name, area, location) imported into the system (raw data).	272	390	143%

CMMS Building data -[UC5-MM]	Number of CMMS data from different buildings imported into the system (raw data)	272	2	1%
Remote control (BMS) Buildings data -[UC5-BMS]	Number of BMS data from different buildings imported into the system (raw data)	40	25	63%
BIM models data-[UC5-BIM]	Number of BIM models data from different buildings imported into the system (raw data)	25	1	4%

BC3-UC5 data acquisition is an ongoing process of sorting through all available information and linking the different sources and their respective datasets. (Part of the work done in WP4-Harmonization).

The first KPI focuses on the number of public buildings [UC5-NPB] with usable data for the project. It means that out of the 272 that were initially planned to be available in the project, thanks to the work done on data acquisition from Infraestructures.cat, the project has recorded 390 buildings, 143%, more than planned.

The second indicator "CMMS Building Data -[UC5-MM]", gives information on the amount of data from the computerized maintenance management system (CMMS) of the different buildings. The target value of this KPI is 272, at this moment the system has registered CMMS data from only 2 buildings, but it is expected that the target will be reached quickly. Infraestructuras.cat has been working with the CMMS systems providers in the development of communication API for its systems, these developments are ready for the first massive data imports.

The third KPI "Number of BMS data from different buildings imported into the system (raw data)" provides information on the amount of data from Building management systems (BMS) for different buildings. Out of the 40 buildings targeted by this KPI, currently, 25 buildings data from BMS systems have been registered. Infraestructures.cat and CIMNE has been working on the process of data collection form data from different BMS providers. Infrastructures.cat and CIMNE have been working intensively on the process of collecting data from the different BMS providers. This implies the installation of a communication gateway in each building (IXON) and the adaptation of the output data of the BMS systems in a homogeneous protocol, in this case BACnet has been chosen.

The last acquisition KPI is the "Number of BIM model data of different buildings imported into the system (raw data)", this KPIs gives information of the number of BIM models of different buildings registered in the BIGG system. The project target for this KPI is 25 and the actual value is 1, which is 4% of the expected. It is expected that at the end of the project the target will be reached.

Table 10 - Use case 5: Data processing KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
BMS data sufficient update time -[UC5-UPD]	BMS data registered in the system with update delay of less than 1 week	>80%
CMMS data quality check -[UC5-QC-MM]	Percentage of CMMS data that successfully passed the quality check	>80%
BMS data quality check -[UC5-QC-BMS]	Percentage of BMS data that successfully passed the quality check	>80%

BIM models quality check -[UC5-QC_BIM]	Percentage of BIM data that successfully passed the quality check	>80%

BC3-UC5 data processing includes different data transformation and analysis steps using BIGG-related tools, from harmonization to the AI toolbox. As discussed above, these tools are not developed and values cannot be provided. In this UC the processing gives information of data update time and data quality from different data sets. The update is only recorded for BMS data, because it is the only flow data that the use case has [UC5-UPD]. The data quality process is applied to all data sources (CMMS, BMS, BIM...) and evaluated with the other KPIs [UC5_QC_MM, UC5_QC_BMS, UC5_QC_BIM].

Table 11 - Use case 5: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
CMMS data linked to Buildings -[UC5-MML]	Percentage of CMMS data recorded in the system that has been linked to the building entity.	>90%
BMS data linked to Buildings-[UC5-MSL]	Percentage of BMS data recorded in the system that has been linked to the building entity.	>90%
BIM data linked to Buildings-[UC5-IML]	Percentage of BIM model data recorded in the system that has been linked to the building entity.	>90%

As mentioned above, the main objective of this Use Case is to demonstrate the interoperability between the systems of a building, so the KPIs that verify this interoperability will reflect that the data of the different systems have been able to link with the building entity, and thus with each other. So, the KPIs results are percentage of CMMS data linked to building, BMS linked to building and BIM models data linked to building. The expected target for these KPIs is above 90%.

IV.3.2. Use Case 6: Interoperability of BIGG with EEFIG-DEEP

As mentioned above, the main objective of this Use Case is to demonstrate the interoperability of the data related to the Energy Efficiency Measures registered in BIGG and the DEEP platform.

The EEM data used in this Use Case are the same as in Use Case 2, so the KPIs related to data acquisition and processing are the same for both UCs. So, these are not going to be repeated in this section.

Only the result KPIs are unique for this use case. Specifically, this Use Case has only 1 result KPIs, [UC6-EXP] which indicates the percentage of the EEMs recorded in the system that are ready, i.e. in the right format, to be exchanged with DEEP.

Table 12 - Use case 6: Results KPI

Name of KPI and acronym [ID]	Description or Formula	Target
EEM/ projects ready to shear with DEEP -[UC6-EXP]	Percentage of EEMs registered ii the BIGG platform ready to be exported to DEEP platform	>50%

As in other use cases, the results of this KPs are not yet available, as the technical work packages are still assembling the components for data processing. No problems are foreseen in exceeding the target set by this KPI before the end of the project.

IV.3.3. Use Case 7: Interoperability between EU Building Stock Observatory (EUBSO) and national/regional Energy Performance Certification through BIGG

Use case 7 is intended to demonstrate the ease of CPB data exchange with widely deployed external systems, in this case the euBSO. As in use case 6, this use case uses data acquired and processed by other use cases. Specifically, the building energy certification data used in UC3 and UC4, from use case 2.

In this case, the only outcome KPI available is [UC7-EXP], which expresses the percentage of registered GCPs that are ready to be sent to EUBSO or other national GCP centres. The target for this KPI is more than 80%. The results are not yet available, but it is not expected that there will be problems in reaching it.

Table 13 - Use case 7: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target
EEM/ projects ready to shear with DEEP - [UC6-EXP]	Percentage of EEMs registered ii the BIGG platform ready to be exported to DEEP platform	>50%

IV.3.3.a. Summary of BC3

The main objective of BC3 is to advance in the interoperability of building energy data, on the one hand, between systems within a building (UC5) and, on the other hand, between BIGG and external standard repositories (UC6 and UC7).

The work performed in BC3 has focused on data acquisition (especially in UC5), where heterogeneous data have been collected from different systems. The collected data have been harmonized to be stored in a single system and linked together.

In some cases, the data load has already reached or is close to reaching the targets, e.g. basic building data, certificates, measurements and control systems; in other cases, BC3 is still working on data acquisition, as is the case for CMMS data or BIM models.

The progress of the work in BC3 is closely related to the harmonization tools developed in WP3 and WP4.

IV.3.3.a.1. Limits detected in BC3

The main limit detected in BC3 is acquiring and communicating data from existing private systems. This often requires some work, even if it is minimal, on the provider side (enabling some API or communication process, changing/adapting communication protocols, etc...).

IV.4. Business Case 4: Energy Performance Contract (EPC) based savings in commercial buildings – Cordia

IV.4.1. Use Case 8: Assets management to store, view, update all relevant assets such as buildings, contracts, invoices, meters, sub-meters, sensors, equipment.

Use Case 8 is focused on data collection and digitization. The main goal of the use case is to collect existing information that describe the actors, contractual terms and details of an Energy Performance contract. As such the KPIs were defined quantitatively by the information that was gathered, digitized, stored and made accessible for use in the other use cases related to BC4.

The KPIs cover most of the aspects of an Energy Performance Contract to be digitized. It includes the contract details, building details, description of the building assets that are impacted by the EEM project, the nature of the EEM, the nature of the data streams that will be collected and the actuators details.

Table 14 - Use case 8: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Portion of EPC contracts related information digitized on BIGG data format-[UC8-KPIs001]	Portion of the information describing an Energy performance contract digitized and harmonized through eh BIGG platform	100%	100%	100%
Number of EEM digitized on BIGG data format-[UC8-KPIs002]	Number of EEM for which the critical information has been collected, analysed and digitized	5	5	100%
Number of buildings digitized on BIGG data format-[UC8-KPIs003]	Number of buildings for which the critical information has been collected, analysed and digitized	2	1	50%
Number of buildings entities digitized on BIGG data model-[UC8-KPIs004]	Number of buildings entities for which the critical information has been collected, analysed and digitized	91	44	48%
Number of energy bills digitized-[UC8-KPIs005]	Number of Energy Bills for which the critical information has been collected, analysed and digitized	(not enough data)	(not enough data)	(not enough data)
Number of Time series data collected-[UC8-KPIs006]	Number of time series for which the critical parameters	409	300	73%

	have been collected, analysed and digitized			
Number of Actuators data collected-[UC8-KPIs007)	Number of actuators for which the critical parameters have been collected, analysed and digitized	30	12	40%
Average Time series Data completeness [UC8-KPIs009]	Measurement of the data completeness (% of data available). Is being measured in % of the last 12 consecutive months	90	75	83%
Data completeness pre-ECM implementation (for at least 12 months) [UC8-KPIs010]	Measurement of the data completeness (% of data available). Is being measured in % of the total baseline period which must be minimum 12 months long	95	100	100%

Use cases 8, 9 and 10 aim at providing a simplified and easier way to deploy an EPCo with a customer by standardizing the setup and the inputs associated with an EPCo. The main impact of Use Case 8 from a user perspective is to be able to quickly access details about a given contract and enable to extract relevant information about the location, the systems and or the energy performances. Eventually, these three use cases combined should enable a front-end application to display all details about the contract, create reports on the EPC on-going results (amount of savings achieved, comparison with contract terms) and set up periodic reports generated automatically.

As such this use case is very linked to the progress of the harmonization work package (WP4). The harmonization is an on-going process and will leverage the data collection that was done in the early phase of the project to update the BIGG data model. Two energy performances contracts were provided in the context of this use case and the information related to these contracts was gathered and listed in a dataset. The main goal was then to list all the aspects of an EPCo that needed to be harmonized to enable a standardization of the EPCo setup on an EMS platform.

The KPIs above are showing the results of this data collection phase and harmonization back and forth process. They track the completion of harmonization of the main assets related to EPCos and thereby enable to validate the ability of BIGG to comply with the management of these contracts. The graphical interface that will be associated with this has not been implemented as of yet.

At the moment the two energy performance contracts have been digitized entirely. Information regarding the buildings, the contracts, the equipment impacted, the expected savings, the baseline definition are mapped over the BIGG data model.

IV.4.2. Use Case 9: Actual savings tracking realized by the Energy Conservation Measures (ECMs) undertaken by the ESCO and monitors on a daily/weekly/monthly basis

Use Case 9, is defined as the logical extension of use case 8. While Use case 8 focuses on collecting and analysing existing data about EPC contract, use case 9 is designed around the creation of data model to predict a given building baseline to be used in the context of an EPC contract.

As a result the KPIs created have been identified to measure the pace at which models could be created and monitor the accuracy of the created models.

The KPIs are defined in the table below.

Table 15 - Use case 9: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Number of building consumption model created-[UC9-KPIs001]	Data streams for which historical data was collected and for which a data model pipeline was created and ran to get a consumption data model. This KPIs will be monitored through the ML Flow platform which is the platform used to monitor the execution of AI pipelines.	1	1	100%
EPC management dashboard created to follow an EPC results-[UC9-KPIs002]	Dashboards created on an existing platform or a BIGG specific User Interface to monitor the progress of the EPC performances	1	1	100%
Average Mean biais error (Normalized) of building consumption model across models-[UC9-KPIs003]	NMBE = 1/AVG(m_i) * SUM(m_i - s_i) / n with m_i and s_i being the model and actual values of timestep i and n being the total number of timesteps on which the SUM and AVG operations are performed[1]	[-5 : 5]	0	100%
Average CVRMSE of building consumption model across models -[UC9-KPIs004]	CVRMSE = 1/AVG(m_i) * sqrt(SUM((m_i - s_i)^2) / n) with m_i and s_i being the model and actual values of timestep i and n being the total number of timesteps on which the SUM and AVG operations are performed [1]	[0 : 5]	2	100%
Average R^2 of building consumption models across models-[UC9-KPIs005]	R^2 = ((n * SUM(m_i * s_i) - SUM(m_i) * SUM(s_i)) / sqrt((n * SUM(m_i^2) - SUM(m_i)^2) * (n * SUM(s_i^2) - SUM(s_i)^2)))^2 with m_i and s_i being the model and actual values of timestep i and n being the total number of timesteps on which the SUM and AVG operations are performed 1	[0.9 : 1]	1	100%

[1] Model evaluation criterion described by the IPMVP protocol which specifies the conditions to enable the usage of a model for Measurement & Verification purpose. See [Ruiz, Germán Ramos, and Carlos Fernández Bandera. "Validation of calibrated energy models: Common errors." *Energies* 10.10 (2017): 1587] for a proper definition of these criteria in the context of UC9.

Qty of model under the IPMVP Threshold for Mean bias error (normalized)-[UC9-KPIs006]	NMBE = 1/AVG(m_i) * SUM(m_i - s_i) / n with m_i and s_i being the model and actual values of timestep i and n being the total number of timesteps on which the SUM and AVG operations are performed [1] Percentage of the models which show data quality indicators above the IPMVP threshold, Should be [-5 : 5]	95%	100%	100%
Qty of model under the IPMVP Threshold for Average CVRMSE -[UC9-KPIs007]	CVRMSE = 1/AVG(m_i) * sqrt(SUM((m_i - s_i)^2) / n) with m_i and s_i being the model and actual values of timestep i and n being the total number of timesteps on which the SUM and AVG operations are performed [1] Percentage of the models which show data quality indicators above the IPMVP threshold, Should be <20	95%	100%	100%
Qty of model under the IPMVP Threshold for Average R^2-[UC9-KPIs008]	R^2 = ((n * SUM(m_i * s_i) - SUM(m_i) * SUM(s_i)) / sqrt((n * SUM(m_i^2) - SUM(m_i)^2) * (n * SUM(s_i^2) - SUM(s_i)^2)))^2 with m_i and s_i being the model and actual values of timestep i and n being the total number of timesteps on which the SUM and AVG operations are performed [1] Percentage of the models which show data quality indicators above the IPMVP threshold, Should be >.75	95%	100%	100%
Basic Operations needed on the platform to generate 100 models (measured in click per 100 model for 100 model)-[UC9-KPIs009]	Given that there is enough data to generate 100 models. Number of basic operations to identify 100 models.	30	(unknown)	NA

Just as the use case 8 is designed to allow an energy management company to quickly implement an EPCo by standardizing the necessary inputs, use case 9 focuses on standardizing the necessary calculations needed to define the baseline (the asset consumption model) and the savings associated with the project (computation of the model, assessment of the impact of the influence factors and comparison with the actual consumption of the building

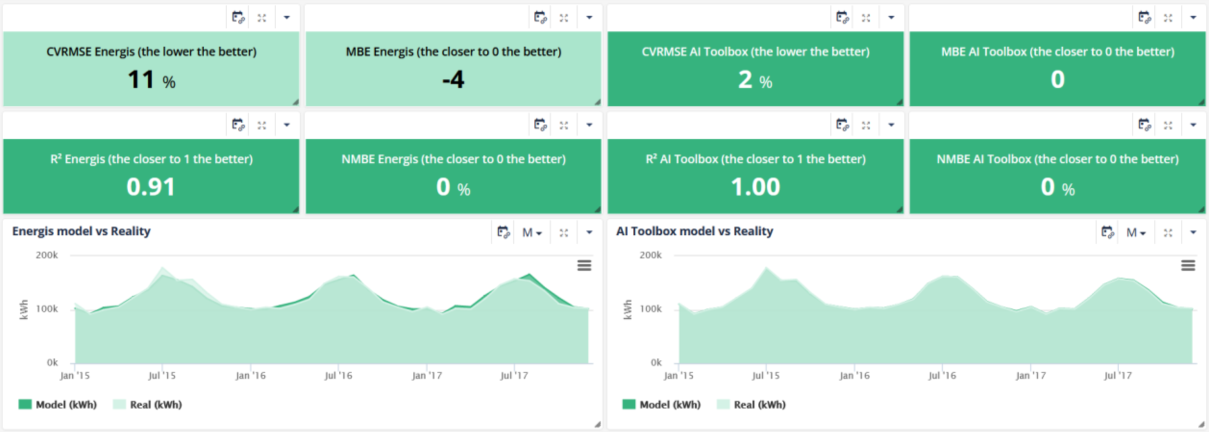
For this specific use case, Cordia and Helexia made use of the two available platforms in use in their respective environment: Cordia Connect and Energis Cloud.

After the different data timeseries had been standardized through the WP4 data model, a building consumption model would be created by means of the analytic toolbox provided by the WP5 activity. After being harmonized, Consumption data, Temperature data, Occupancy data would then flow from the Cordia Connect platform through the Energis platform where the data would be used to assess the results of the EPCo.

Using the Energis platform had two main advantages in this instance. The first was that the Energis platform already has a modelling capability built in and it allowed to measure the accuracy of the model created by the WP5 AI toolbox by comparing it to the model created via the Energis platform.

A second advantage was that it allowed to test the readiness of the harmonization and standardization process. Data being pulled from one platform and used on another, the workflow involved allowed to test the completeness of the BIGG data model and also its suitability to real data streams.

At this point, all data streams were harmonized for one building and one contract, a baseline model was created using historical data and the computation of savings was implemented using the baseline. The model was then compared to an existing model created via the Energis platform. The results were as follows:



IV.4.3. Use Case 10: Energy Performance Contract Management to manage the EPC life-cycle and perform actions (eg. Reporting) according to contractual milestones

Use case 10 focuses on the EPCo management itself providing a set of supporting tools to facilitate the management process through automatization of several aspects of EPCos such as savings calculations. The use case anchors in the observation that managing an EPCo is generally done in an ad hoc way, redoing the work entirely for every new contract, even though the essence of EPCo contract management is similar from one contract to the next. The KPIs were chosen to describe how the BIGG platform helped to generate EPC indicators and periodic reports, and how these indicators were used in the context of existing Energy performance contracts.

Today the time allocated with managing an EPCo comes as a limiting factor. Reporting is still being handled manually or with a strong involvement of the manager where standardization and harmonization could be a real game changer, allowing the EPCo manager to only verify the results of the EPCo last period.

The goal of this use case is to leverage the two previous use cases and allow Energy Service Companies to optimize the time associated with an EPCo management and increase the profitability of the contract. This would eventually lead to more profits made, an increase of the number of EPCo being contacted and eventually to a cost of EPCo decreasing allowing more customers to implement them.

As members of the consortium and EPCo managers, both Cordia and Helexia see a strong interest in this use case that could be implemented and generate value very quickly in their own activities.

Table 16 - Use case 10: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Ability to recreate results from existing reporting-[UC10-KPIs001]	Ability to create a report through the BIGG platform that outputs the same indicators that the existing EPCo report. KPIs measured in percentage of variation compared to the existing report.	100%	100%	100%
EPC periodic reports created by BIGG Platform-[UC10-KPIs001]	% of quarterly reports over last 12 months	100%	25%	25%

IV.4.3.a. Summary of BC4

The main objective of BC4 is to provide the ability to easily implement, monitor and control an EPCo of commercial buildings, to give the necessary feedback for any deviations from the savings goals and lastly to assess and recommend any corrective actions that should be made. In order to do so, the relevant data (energy & environmental) has to be gathered and be available to the corresponding partners.

IV.4.3.a.1. Achievements of BC4 implementation

In the early phase of the project, effort was put on the modelling aspects of the Business Case (Use Case 9), the other two use cases being closely related to the progress of WP4 harmonization and WP3 ingestion.

A custom ingestor was built to connect the Cordia platform and Energis platform and allow analytics on data streams from a platform to another (essentially by-passing the harmonization phase that would be integrated later on).

Historical data was collected for building consumption, building occupancy, temperature (outdoors and indoors) and a model was created using this data to generate the baseline. A model was also generated using the formula defined in the Energy Performance Contract to assess by comparison the accuracy of the model created via the AI toolbox and apprehend the likeliness of using the data models in Energy Performance Contracts.

Savings were then calculated according to each model allowing to measure the impact of the model accuracy over the EPCo results by understanding when the ESCO is overcharging or undercharging because savings are not quantified properly.

The model generated by BIGG, compared to the one defined in the EPC contract, featured a significant improvement with all the criteria[2] on which it has been evaluated, meaning that it is more reliable to use to estimate savings, as well as savings deviations.

IV.4.3.a.2. Limits detected to BC4

The data gathered during the time period since the beginning of BIGG project development and still being retrieved, will seem to be altered in comparison to the historical data of the relevant buildings. The reason to that is the COVID19 pandemic, as it caused very significant

[2] Prescribed from the IPMVP protocol, https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp

changes to the working environment and hour profiles and in turn, important differentiations occurred to the equipment operation, the energy consumption and the indoor environmental conditions of those buildings.

Specifically, in most cases due to pandemic, the facility operators had to mandatorily operate the Air Handling Units (AHU) constantly, in order for the air to always be freshened. This resulted in the creation of new, revised baseline consumptions, both for the total and the HVAC consumption, due to the constant operation of the AHU fans. In addition to that, the “work from home” instructions resulted in a different and more unique profile in the indoor environmental conditions.

All of the above, result in more difficulties concerning the creation of the models and make it even more challenging.

Furthermore, the project’s needs included the installation of new metering equipment, which of course, had to be on site. The pandemic restrictions that were relevant to transportation and also to the site visiting permissions along with all the bureaucracy that comes with it, resulted in huge delays and difficulties for the completion of the necessary works.

The progress made on the data modelling aspect raised the question of contractualization of a model. EPCo models used nowadays are usually linear or polynomial and these are not necessarily the models that show the best results in terms of data analysis. But one of the key conclusions of this work was that, a data model to be contractualized would need not only to be accurate but also to be understood and computable by the final customer. This point raised the issue of potential disqualification of data models due to their complexity and the impossibility to clearly describe them in a written contract. Alternatively, ad hoc solutions will have to be developed to enable the transparent and trustworthy usage of models, in agreement with the requirements of an EPCo.

IV.4.3.a.3. Reasons for including or excluding data

The conditions due to COVID 19 resulted in revisions of baselines of energy consumptions calculation

As a whole, the BC4 was severely impacted by the COVID situation with a building occupancy that was significantly lowered for a long period of time. Not only occupancy was impacted but HVAC operating conditions were also adapted to reflect the extraordinary air treatment needed to ensure a better air quality.

From a data management perspective, this was a very interesting to be considered as a non-routine event. Non routine events are a common theme in the management of EPCo. Usually non routine events are related to extraordinary events that have an impact that to be considered singularly. Obviously COVID magnitude was beyond anything that is commonly encountered in an EPCo but from a data management perspective, it could be considered as a non-routine adjustment and delt with accordingly.

IV.4.3.a.4. Recommendations and requirement for improved tools and analytics

The above-mentioned diversifications that lead us to constant reviews and optimization of the existing models.

Include a criterion of simplicity and contractualization in the modelling tool to allow to filter potential models according to their applicability in an EPCo application.

IV.5. Business Case 5: Buildings for occupants: Comfort Case – Cordia

The comfort case as described earlier in the document organized in 3 use cases. All use cases are aiming at the optimization of building performances using data models.

IV.5.1. Use Case 11: Optimization using weather forecast

Use case 11 is leveraging weather forecast service to insert predicted outside conditions in the building control logic.

The KPIs associated with this use case are evaluating sequentially the collection of weather data forecasts, the actions triggered on the building control system and the results that these actions had on the building performances and the comfort of building occupants.

Table 17 - Use case 11: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Weather forecasts data time series collected on the BIGG platform-[UC11-KPIs001]	Based on three potential data time series (temperature, RH, Irradiance)	6	1	17%
Number of Actuators enabled in control capabilities-[UC11-KPIs002]	Number of actuators for which control rules are applied	19	5	26%
Average temperature comfort ratio witnessed on the building zones where actions are taken-[UC11-KPIs003]	% of time during which the internal room temperature is within the comfort interval (between minimum and maximum threshold) during occupancy hours, averaged over all controlled areas	90%	(not enough data)	NA
Average relative humidity comfort ratio witnessed on the building zones where actions are taken-[UC11-KPIs004]	% of time during which the internal room relative humidity is within the comfort interval (between minimum and maximum threshold) during occupancy hours, averaged over all controlled areas	90%	(not enough data)	NA
Average CO2 comfort ratio witnessed on the building zones where actions are taken-[UC11-KPIs005]	% of time during which the internal room CO2 level is within the comfort interval (below maximum threshold) during occupancy hours, averaged over all controlled areas	90%	(not enough data)	NA
Average overall comfort ratio witnessed on the building zones where actions are taken-[UC11-KPIs006]	Average of [UC11-KPIs003], [UC11-KPIs004] and [UC11-KPIs005]	90%	(not enough data)	NA
Energy efficiency gain (energy consumption reduction during controlled hours) - [UC11-KPIs007]	% difference between the actual consumption during controlled hours and the baseline consumption during the same hours. The baseline is determined as a regression model based on UC9 methodology.	-5%	(not enough data)	NA

Measuring the quantity of data collected is important because it helps to understand how available this data actually is and hence how replicable the process is.

The following KPIs UC11-KPIs002 really describes the capacity to implement a control sequence on the concerned asset. This constitutes by far the most challenging aspect of the business case. Use cases 11, 12 and 13 rely, on one hand, to the capacity to leverage data models but more importantly to the possibility of defining rules and taking actions upon the on-site operation.

KPIs 003 to 007 were define to follow the trends of comfort and energy during the phases when rules are triggered and make sure the rules effect is eventually an increase of comfort and a decrease of energy consumption.

IV.5.2. Use Case 12: Optimization using occupancy forecast

Use case 12 is very similar to use case 11, the most significant difference being that the building occupancy is used instead of the weather forecast as a variable of adjustment.

From a workflow perspective, the two use cases are very similar. From a data perspective, the two use cases are showing a major difference in the sense that weather forecasting service exists as a public service and the associated data is available. Building occupancy on the other hand does not exist and needs to be analysed through sensors data and a building occupancy model needs to be created to make predictions.

A significant challenge associated with using occupancy models is to push the capacity to use occupancy forecasts down to the building zone level. As this stage, the implementation has been focused on using an occupancy model at building level and take action on the central cooling/heating system. The next step is to assign each occupancy sensor and each heating or cooling emitter to a specific building zone and implement a rule-based engine for each zone specifically.

Table 18 - Use case 12: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Occupancy history data time series collected via the BIGG service-[UC12-KPIs001]	Number of occupancy timeseries data collected	2	1	50%
Occupancy model created based on historical data-[UC12-KPIs002]	Number of occupancy models identified	2	1	50%
Number of Actuators enabled in control capabilities using occupancy-[UC12-KPIs003]	Number of actuators for which control rules are applied using occupancy data and model	19	5	26%
Average temperature comfort ratio witnessed on the building zones where actions are taken-[UC12-KPIs004]	% of time during which the internal room temperature is within the comfort interval (between minimum and maximum threshold) during occupancy hours, averaged over all controlled areas	94%	(not enough data)	NA

Average relative humidity comfort ratio witnessed on the building zones where actions are taken-[UC12-KPIs005]	% of time during which the internal room relative humidity is within the comfort interval (between minimum and maximum threshold) during occupancy hours, averaged over all controlled areas	94%	(not enough data)	NA
Average CO2 comfort ratio witnessed on the building zones where actions are taken-[UC12-KPIs006]	% of time during which the internal room CO2 level is within the comfort interval (below maximum threshold) during occupancy hours, averaged over all controlled areas	94%	(not enough data)	NA
Average overall comfort ratio witnessed on the building zones where actions are taken-[UC12-KPIs007]	Average of [UC12-KPIs004], [UC12-KPIs005] and [UC12-KPIs006]	94%	(not enough data)	NA
Energy efficiency gain (energy consumption reduction during controlled hours) - [UC12-KPIs008]	% difference between the actual consumption during controlled hours and the baseline consumption during the same hours. The baseline is determined as a regression model based on UC9 methodology.	-10%	(not enough data)	NA

KPIs 1 and 2 are measuring the quantity of data collected and is important for the same reason explained for use case 11. Occupancy data streams are usually more difficult to collect because they imply the installation of sensors. BMS only include occupancy sensors in recent installations but are not so common on older systems. The second KPIs is important to describe the BIGG capability to use occupancy data streams to generate models. Unlike other data streams, occupancy data is very prone to irregularity and occupancy sensors are often reporting on a non-regular basis but rather on an event-based sequence which presents a specific challenge in terms of data management and data analysis.

The same comment about the importance of being able to take control on the on-site equipment also applies to this use case.

At this stage in the project, occupancy data is being collected for one building. The data collection started rather early in the project and, as a result, was sufficient to enable the creation of occupancy model.

Two main rules have been implemented in the context of use case 12:

- Thermal inertia ruleset

To use thermal inertia of the building, the building occupancy once known is used as an input to know at what exact time the building will turned unoccupied. A control sequence is implemented to command the HVAC system to turn in night mode as soon as possible without affecting the occupant comfort.

- Pre-cooling ruleset

Pre cooling is used with two different inputs. One is the building occupancy to detect at what time in the morning the first people are entering the building. Second are the weather conditions: expected irradiance and expected outdoor temperature. This

During the first half of the project, a significant effort was put on setting the control system up on the Interamerican building. Beside the technical challenge associated with the implementation of the equipment allowing to take control, a significant effort was needed on the communication process needed between the ESCO and the on-site O&M team. As anticipated taking control over the HVAC equipment and managing the communication with the O&M team to ensure that remote control would not jeopardize the on-going operation was a major hurdle and turned out to be the major limit to overcome.

IV.5.3. Use Case 13: Optimization using price forecast

Use case 13 was designed as a logical continuation of the two previous use cases. Use case 11 to optimize comfort based on outside conditions, use case 12 adding the possibility to account for the unoccupancy of the building. The use case 13 will focus on adding the energy cost as an additional factor of optimization.

The KPIs were defined following the same logic as the use cases 11 and 12. First KPIs describe how available the pricing information is and how difficult is the creation of an energy pricing model. The one KPIs to reflect the success rate of control optimization over the existing control sequences on site.

The following KPIs are defined to reflect the impact of the pricing optimization on the comfort ratio and the final cost to the customer.

Table 19 - Use case 13: Results KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Pricing forecasts data time series collected on the BIGG platform-[UC13-KPIs001]	Number of pricing forecast timeseries data collected	1	0	Based on three potential data time series (temperature, RH, Irradiance)
Number of Actuators enabled in control capabilities-[UC13-KPIs002]	Number of actuators for which control rules are applied using pricing data	19	0	0%
Average temperature comfort ratio witnessed on the building zones where actions are taken-[UC13-KPIs003]	% of time during which the internal room temperature is within the comfort interval (between minimum and maximum threshold) during occupancy hours, averaged over all controlled areas	92%	(not enough data)	NA
Average relative humidity comfort ratio witnessed on the building zones where	% of time during which the internal room relative humidity is within the comfort interval (between	92%	(not enough data)	NA

actions are taken-[UC13-KPIs004]	minimum and maximum threshold) during occupancy hours, averaged over all controlled areas			
Average CO2 comfort ratio witnessed on the building zones where actions are taken-[UC13-KPIs005]	% of time during which the internal room CO2 level is within the comfort interval (below maximum threshold) during occupancy hours, averaged over all controlled areas	92%	(not enough data)	NA
Average overall comfort ratio witnessed on the building zones where actions are taken-[UC13-KPIs006]	Average of [UC13-KPIs003], [UC13-KPIs004] and [UC13-KPIs005]	92%	(not enough data)	NA
Energy efficiency gain (energy consumption reduction during controlled hours) -[UC13-KPIs007]	% difference between the actual consumption during controlled hours and the baseline consumption during the same hours. The baseline is determined as a regression model based on UC9 methodology.	-10%	(not enough data)	NA
Cost reduction from baseline -[UC13-KPIs008]	% Cost savings = (SUM_i energy_consumption_with_control_i * energy price_i) / (SUM_i energy_consumption_baseline_i * energy price_i), where i measures a timestamp at the granularity of the pricing data. The baseline is determined as a regression model based on UC9 methodology.	-15%	(not enough data)	NA

IV.5.3.a. Summary of BC5

Business case 5 goal, is to optimize the occupant comfort. To achieve this, a multi-objective function that takes into consideration the consumption, costs, occupancy and weather data, will be applied. Except from the current data that will be gathered, weather, occupancy and price forecasts will also be considered, for a more dynamic and efficient operation of the equipment. This would be achieved in some cases, by providing relevant recommendations for the optimum equipment operation and in some case by overruling the current control system.

IV.5.3.a.1. Achievements of BC5

For the implementation of BC5, none of the two existing platforms used in BC4 could be leveraged for control sequence implementation. The Cordia Connect platform and the Energis platform both present strong capabilities in terms of data management and data analysis but were not designed to manage BMS capabilities and control sequence of operations.

As a result, a dedicated framework was used leveraging the two platforms for data collection, data aggregation and data transfer but a separate dashboard was created on the open-source tool Grafana to manage the display of actuators and rule implementations.

The control aspect being one of the most challenging of this business case, it was chosen to use a very versatile tool provided by Energis: the Raspicy. This data logging device is used by Energis and Helexia on other projects and allows both to collect, store and manage data but also to be used as a relay to the BMS and the implementation of control rulesets.

IV.5.3.a.2. Limits detected to BC5

Similarly to the BC4, significant constraints were identified during the development of the business case 5. As a result of COVID-19 pandemic, according to the instructions of the ministry of health, the AHU system in office buildings should always keep operating to constantly freshen the air. So, this resulted in difficulties accessing and controlling the relevant systems and additionally was giving a hard time to focus in the comfort and the energy consumption optimization. Up until now, controversial discussions are taking place on the AHU operation, aiming at the optimization of the occupant comfort and the energy efficiency of the system, alongside the health measures that keep being applied.

Beside the COVID-19 impact, the second significant challenge of this Business case was the consortium capacity to take control over the equipment on site. This is a common limit to the use of on-line platforms and more generally of the use of data models on control logic optimization. In this case, it has been strengthened by the fact that the Cordia team is no longer in charge of the O&M contract on site. Cordia remains committed on the energy efficiency of the building but is dependent on a third party to take action upon the on-site equipment. This specific organization led to difficulties in the communication process and constituted a significant hurdle in the efficiency of the rule's implementation. Choice was made to investigate the use of another building and we chose to implement the business case on Cordia's Headquarter building.

This point explains the lack of data for some of the KPIs defined above. Most KPIs were defined to reflect the impact of rule implementation but the instances where control could be implemented for a long period of time.

IV.5.3.a.3. Reasons for including or excluding data

Some changes on the plans of the local technical management team and the new property managers of one of our clients, affected several of our pilot sites and our ability to control their equipment. So, it created the need to add another building in our agenda of the pilot sites and more specifically, the CORDIA's HQ building. This meant that all the necessary data that are described in the relevant D6.1 document had to be gathered for this additional building together with the metering and control equipment data and control inputs.

IV.5.3.a.4. Recommendations and requirement for improved tools and analytics

It was agreed by members of the consortium to work on getting additional buildings added to this business case focusing on buildings where the ESCo is also responsible for O&M services.

As such Cordia is now working on the implementation of the business case on their Head Quarter building.

IV.6. Business Case 6: Flexibility potential of Residential consumers on electricity and natural gas - Heron-DomX

As mentioned above, the objective of BC6 is to demonstrate and exploit the flexibility potential of residential buildings across the two main energy vectors of electricity and natural gas. The following analysis details the two considered use cases. UC14 focuses on electricity consumers that participate explicitly in demand response schemes. UC15 focuses on the participation of natural gas consumers to: (a) improve the energy efficiency of legacy boilers through load reduction and (b) contribute to real-time gas balancing services.

IV.6.1. Use Case 14: On demand-response for Electricity

UC14 KPIs aim at quantifying the performance of the data acquisition, data analysis and user interaction procedures. Considering that the integration of the BIGG systems and services has not yet been completed, only data acquisition KPIs have been evaluated at the moment. The group of Data processing and acquisition KPIs [UC14 001-005] aim to evaluate the technical infrastructure of the pilot, most notably the installation of smart meters and flexibility assets.

Data analysis KPIs [UC14 006-014] and user interaction KPIs [UC14 015-016] have been setup to quantify the performance of the under development BIGG platform, however quantification of actual data analysis and user interaction procedures will be carried out as soon as the full set of pilot participants are engaged and able to participate and when the BIGG platform is up and running and the data analysis pipeline is operational.

Table 20 - Use case 14: Data processing and acquisition KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Number of potential pilot participants accepting terms and conditions and GDPR [UC14-KPIs001]	Count (invited participants)	100	20	20%
Number of monitored households [UC14-KPIs002]	Count (households with installed smart meter)	100	20	20%
Number of installed flexible assets: relay for electric boiler [UC14-KPIs003]	Count (households with installed electric relay)	10	1	10%
Number of installed monitored assets: smart plugs on washing machines	Count (households with installed smart plugs on washing machines)	20	1	5%

[UC14-KPIs004]				
Number of monitored households with smart meter being online over 80% of time [UC14-KPIs005]	Count (households that satisfy requirement) /Count (households with installed smart meter)	80%	60%	75%

Table 21 - Use case 14 : Data analysis KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Baseline electricity consumption (kWh - within a specific time period, e.g. daily, monthly) [UC14-KPIs006]	Calculate electricity consumption (kWh) for a given interval (t) under the baseline mode of operation	(not enough data)	(not enough data)	NA
Total capacity of DR potential: the amount of energy consumption the end user could potentially reduce/shift within a specific time period, e.g. daily, monthly [UC14-KPIs007]	Calculate energy consumption of all flexible/ monitored assets for a given interval (t): Power (KW) * historical data of hours used per interval (normalise for h) kWh	(not enough data)	(not enough data)	NA
Total actual DR impact: the amount of energy consumption that has been reduced/shifted within a specific time period, e.g. daily, monthly [UC14-KPIs008]	SUM [Set (parameter=1 if DR advice has been follower) * Power of asset (W) * (minimum time interval set)] kWh	(not enough data)	(not enough data)	NA
Total energy consumption over a specific time period, e.g. daily, monthly [UC14-KPIs009]	SUM (electricity consumption for given interval) kWh	(not enough data)	(not enough data)	NA
Aggregated peak demand calculation over a specific period [UC14-KPIs0010]	Count (peaks in aggregated consumption based on a target set using historical data ~ 5% interval)	(not enough data)	(not enough data)	NA

Number of scheduled DR requests within a specific time period, e.g. daily, monthly [UC14-KPIs011]	Count (scheduled DR requests)	(not enough data)	(not enough data)	NA
Number of activated DR requests within a specific time period, e.g. daily, monthly [UC14-KPIs012]	Count (activated DR requests)	(not enough data)	(not enough data)	NA
Define clusters based on total consumption [UC14-KPIs013]	Count consumption patterns based on historical data	(not enough data)	(not enough data)	NA
CO_2 emissions reduction: Reduction in direct CO_2 emissions reflecting the energy consumption reduction achieved in given intervals [UC14-KPIs014]	SUM [Set (parameter=1 if DR advice has been follower) * Power of asset (W) * (minimum time interval set)] * CO_2 in the system	(not enough data)	(not enough data)	NA

Table 22 - Use case 14: User interaction KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
No. of registered users with a unique account created [UC14-KPIs015]	Count (Number of registered users)	100	10	10%
No. of registered users with a unique account created that are actively using the system [UC14-KPIs016]	Count (Number of active users)	60	(not enough data)	NA

IV.6.2. Use Case 15: On demand-response for Natural Gas

The UC15 KPIs aim at quantifying the performance of the data acquisition, data analysis and user interaction procedures. Considering that the integration of the BIGG systems and services has not yet been completed, only data acquisition KPIs have been evaluated at the moment. Initial tests for testing the Energy efficiency and Demand flexibility mechanisms on top of pilot uses have been carried our successfully. However, the performance quantification of the data analysis and user interaction procedures will be carried out as soon as the full set of pilot participants are engaged and able to participate and when the BIGG platform is up and running and the data analysis pipeline if operational.

Table 23 - Use case 15: Data acquisition KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Number of monitored households [UC15-KPIs001]	Count (households with installed heating controller)	100	60	60%
Number of monitored households with heating controller being online over 90% of time [UC15-KPIs002]	Count (households that satisfy requirement) /Count (households with installed heating controller)	80	50	62.5%
Number of buildings with available EPCs [UC15-KPIs003]	Count (Number of buildings with available EPCs)	50	0	0
Households with AVG Monthly gas consumption data (legacy DSO meter) [UC15-KPIs004]	Count (Households with AVG Monthly gas consumption data)	>50	10	20%
Households with AVG Daily gas consumption data (smart DSO meter) [UC15-KPIs005]	Count (Households with AVG Daily gas consumption data)	>10	1	10%

Table 24 - Use case 15: Data analysis

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
Baseline Gas consumption for space heating (kWh - within a specific time period, e.g. daily, monthly) [UC15-KPIs006]	Calculate gas consumption for space heating (kWh) for a given interval (t) under the baseline mode of operation	100	50	50%
Adaptive Gas consumption for space heating (kWh - within a	Calculate gas consumption for space heating (kWh) for a given interval (t) under the	100	50	50%

specific time period, e.g. daily, monthly) [UC15-KPIs007]	weather adaptive mode of operation			
Gas consumption reduction %" [UC15-KPIs008]	Calculate gas consumption reduction for the same household under days with similar heating requirements between the baseline and weather adaptive modes of operation	>20%	(not enough data)	NA
Average temperature comfort ratio witnessed on the buildings where measures are employed [UC15-KPIs009]	% of time during which the internal room temperature is within the user specified target temperature and comfort band (between minimum and maximum threshold)	>80%	(not enough data)	NA
Total energy consumption savings evaluated within a specific time period, e.g. daily, monthly [UC15-KPIs010]	Amount of energy consumption savings (in kWh) over a given period of time	(not enough data)	(not enough data)	NA
Number of DR participating households [UC15-KPIs011]	Count (households participating in the given DR request)	(not enough data)	(not enough data)	NA
Number of scheduled DR requests within a specific time period, e.g. daily, monthly [UC15-KPIs012]	Count (scheduled DR requests)	(not enough data)	(not enough data)	NA
Number of activated DR requests within a specific time period, e.g. daily, monthly [UC15-KPIs013]	Count (activated DR requests)	(not enough data)	(not enough data)	NA
Demand Flexibility Potential: The total amount of energy consumption that end users could potentially accept to reduce/shift within a specific time period, e.g. daily, monthly [UC15-KPIs014]	Calculate the difference between the baseline gas consumption for space heating (kWh) for a given interval (t) and the consumption under the DR mode	(not enough data)	(not enough data)	NA

Table 25 - Use case 15: User interaction KPIs

Name of KPI and acronym [ID]	Description or Formula	Target	current Value (M18)	% of achievement M18
No. of registered users with a unique account created [UC15-KPIs015]	Count (Number of registered users)	100	(not enough data)	NA
No. of registered users with a unique account created that are actively using the system [UC15-KPIs016]	Count (Number of active users)	60	(not enough data)	NA

The user interactions of UC15 will be consider the total number of registered end users [UC15-KPIs015] that have installed the domX heating controller at their natural gas boilers, enabling them to access the BIGG tools and services. The second KPIs [UC15-KPIs016] measures the share of users that are actively using the system, evaluated on top of their interactions through the smartphone application, as a proxy of the platform usefulness to them.

IV.6.2.a. Summary of BC6

BC6 promotes Demand Response solutions in the electricity and natural gas domains. Although a unified Business Case with several common characteristics (as shown in in the respective KPIs lists) they do have different objectives. Given the current and mid-term regulatory framework in Greece and the lack of DSO deployed smart-metering infrastructure, the focus of the electricity Use Case (UC14) is to make electricity consumption "greener" by shifting it towards time interval dominated by RES generation. On the contrary, although for Natural Gas DSO smart-metering is equally limited, Natural Gas Use Case (UC15) can achieve monetary savings by reducing overall consumption under given comfort levels.

IV.6.2.a.1. Limits detected in BC6

Several constraints were identified during the development of BC6. Below, we briefly mention the various detected issues group under three main categories:

Device installation issues as a result of the COVID-19 pandemic. There was a lack of interest of engaged users to have an installer visiting their home for the installation of both electricity smart meters and domX heating controllers. This posed significant delays in fixing an installation appointment. In addition, unexpected disconnection issues were also faced for users with installed monitoring equipment, mainly arising due to users changing their router's WiFi credentials. Similar issues were faced also with users moving to a new household and not timely informing DOMX and HERON, in order to properly manage the device uninstallation and reinstallation process. Finally, in the context of UC15, compatibility issues were detected, as several engaged users had older boiler types that support only ON/OFF based control. The adaptation by HERON and DOMX: both are implementing a continuous recruitment and user support process, constantly expanding the pool of pilot participants. In order to extend the device support to more boiler types, DOMX developed a new heating controller version that can provide the basic functionalities of remote management for ON/OFF based natural gas boilers, thus being able to extend the range of eligible pilot households.

Encountered legal constraints in a complex GDPR process. The handling of real-time electricity consumption data is a complex process which involved significant effort and coordination between HERON's DPO and legal and R&D teams. Despite the effort, there have been several loopholes identified once the user registration process was open to even a controlled group of potential pilot participants. The most important one was a common characteristic among Greek families, whereby the bill payer / owner of the supply and the household dweller are not the same person. Consent forms had to be re-written and users that had accepted former versions had to be contacted so that they can sign new documents

Limitation of assets for direct electricity Demand Response. Initial surveying of the pool of prospective pilot participants for UC14 showed that a significant percentage either did not own a water boiler to be heated by electricity, or that they were not willing to let the asset be controlled remotely. This could limit the scope of the project as flexibility potential of 5 water boilers could be negligible. UC14 was modified accordingly to expand the technical infrastructure by including smart plugs to monitor heavy loads. Specifically, washing machines have been selected given that their use could be shifted within the day, and due to access for physical intervention. Furthermore, direct control has been replaced by an under development real-time advice/ suggestion interface.

The collection of EPCs from the Hellenic Ministry of the Environment and Energy changed from the proposal to the implementation of BIGG. During the proposal preparation phase, the Hellenic Ministry of the Environment and Energy committed to facilitate offline access to the EPC data of the buildings participating in the Greek pilot activities. However, as soon as the project started, the contact person at the Ministry informed us that EPC data can only be shared with public bodies for statistical and research purposes, and the building owners, but not with research project partners. As in the BC6 use cases, most of the end consumers are renting their apartments, the BC6 partners (DOMX, HERON) are not in the position to reach the building owners directly. In order to overcome the identified issue, a survey was developed for end users to collect the core characteristics of pilot households (size, location, year of construction, # of occupants, etc.).

The impact of the energy efficiency mechanism may be superimposed by other factors, especially the extreme rise in energy prices. Based on preliminary analysis carried our by DOMX, several pilot users of UC15 actively changed their energy behaviour (target temperature, reduced heating duration) over this last winter. This fact further complexes the impact analysis of the energy efficiency and DR mechanisms. In order to tackle this limitation, DOMX decided to consider the target temperature and heating duration, as two additional factors to be considered by the clustering algorithm that is employed for identifying heating days with similar characteristics, between the baseline and intervention periods.

V. CONCLUSIONS

The report covers the project progress during its first half (until May 2022) using each of the 6 pilots as proxies of the progress. During this period the pilots have worked on several tasks. The first three months of the project were used to define each of the Business case, with their respective use cases, and the datasets that they would provide and require to achieve their objectives. The technical WP then used the definitions provided by the pilots to develop the required solutions, their results can be found in the public deliverables D2.1, D2.2, D3.1, D4.1 and D5.1. These deliverables cover the system arquitecture, the need of creating modular solutions, the data ingestion and security, harmonisation and data model and the AI toolbox developed to tackle each of the business cases.

The next task addressed by the pilots was the definition of a tracking system to measure the project progress. Each pilot defined key performance indicators (KPIs) to track the progress of the use cases over all the aspects of the pilot, which in general terms include data acquisition, data processing and user interactions. The indicators measure the capability to reach the pilot goals, which range from uploading the data, to being able to measure economic indicators (ensuring all the necessary information is uploaded and recorded) or perform building comparisons (benchmarking) based on certain conditions. The KPIs developed are the cornerstone of the pilots' progress monitoring, since they provided a method to keep track of each pilot and allow to detect deviations from the main plan.

The pilots also deployed all the necessary monitoring, measuring and IoT devices required to ensure the gathering of data and the capability to control the required systems of the buildings, based on the needs of each Business case. The deployment of devices led to the continuous monitoring of the pilots that will run until the end of the project and that provides all the data about the behaviour of the target equipment and buildings. The preparation work carried out by the pilots from the definition of the business cases to the measuring devices installation has led to the current continuous monitoring, which provides the project with the data needed to test the technical solutions developed and will return feedback on them as the project evolves.

The work of **Business case 1: "Benchmarking and Energy Efficiency tracking in Public Building"** has managed to set up all the necessary infrastructure to gather the data from the targeted buildings. The data gathering required to link diverse data sources (building, weather and consumption information) to provide the upcoming data analytics tools with the necessary information to operate. Currently already 33% of the buildings, out of 3,000, have the necessary data linked and are ready to start testing the AI toolbox tools developed. Of these, at least 80% have both hourly and monthly electricity information, as well as, the natural gas information.

The first half of the project has provided valuable lessons towards its own implementation. The main one is that buildings are dynamic, due to the Covid pandemic and the changes it brought building occupation and behaviour will never be the same as before the pandemic. The pandemic has promoted a shift in the way buildings are used, mainly by "encouraging" the "work from home", which reduced first the building occupation, and then allowed to host the same number of people with a lower number of buildings, since most of them are working remotely and not concurrently. Another example is the internal dynamics of organisations in which the management of certain buildings will shift from one person to another or partially shift, and therefore the system developed must be able to cope with this type of changes.

BC1 focus until the end of the project will evolve from the current data gathering and quality checks and move towards the implementation of the AI toolbox functions for baseline calculation and building benchmarking. These tools will allow the comparison of buildings within the Catalan government highlighting the ones with potential for intervention and focusing the use of the resources where they can have a higher impact, as well as, the monitoring of the building's behaviour over time and the estimation of the energy savings obtained from the implementation of energy efficiency measures. The benchmarking tools will also allow to compare EEM actions based on their potential savings and estimated cost, both based on the stored database of similar actions. These services will provide another tool for decision making of EEM implementation in large building portfolios.

The aim of the **Business case 2 "Energy Certification (EPC) in Residential and Tertiary Buildings"** is to expand the utilisation of the energy certificates information. The two paths analysed are the standardisation of the certificates information into the INSPIRE format, and the exploration of the Level(s) indicators towards defining the path between the current energy performance certificates and Level(s). Towards those aims, the first step has been uploading energy certificates exciding the 1,000,000 targeted, which then will be used to test the harmonisation tools of WP4. The remaining work for BC2 revolves around using the harmonisation tools (WP4) to adapt the current energy performance certificates into the INSPIRE format and to expand the range of indicators by exploring common data source for indicators with Level(s).

The work of **Business case 3 "Building Life-Cycle: From Planning to Renovation"** has managed to collect and harmonise data from different systems from the building ID, name, location to more specific data coming from BMS. The association of all the different data sources several coming from different existing private systems required some work to contact the providers, in order to be able to set up API or communication process. The future work of BC3 towards the end of the project will be the collection of more complex data such as building BIM models and the interoperability with the EEFIG-DEEP to become data providers about the state and type of energy efficiency measures being implemented to date.

Business case 4 "Energy Performance Contract (EPC) based savings in commercial buildings" started the project by modelling aspects of the Business Case (Use Case 9) about energy conservation measures savings tracking. The other two use cases being closely related to the progress of WP4 harmonization and WP3 ingestion. Cordia platform and Energis platform were connected and enable analytics on data streams from one to the other. Historical data was collected for building consumption, occupancy, temperature (outdoors and indoors) and a model was created using this data to generate the baseline. Then, a model was also generated using the formula defined in the Energy Performance Contract to assess by comparison the accuracy of the model created via the AI toolbox and apprehend the likeliness of using the data models in Energy Performance Contracts. Finally, savings were calculated according to each model allowing to measure the impact of the model accuracy over the EPCo results by understanding when the ESCO is overcharging or undercharging because savings are not quantified properly

The project's needs included the installation of new metering equipment, which of course, had to be on site, and that presented a challenge to overcome during a pandemic. The pandemic restrictions along with the bureaucracy that comes with it, resulted in huge delays and difficulties for the completion of the necessary works.

EPCo models used nowadays are usually linear or polynomial and these are not necessarily the models that show the best results in terms of data analysis. A data model that should be contractualized would need not only needs be accurate but also to be understood and computable by the final customer. This point raised the issue of potential disqualification of data models due to their complexity and the impossibility to clearly describe them in a written contract. Alternatively, ad hoc solutions will have to be developed to enable the transparent and trustworthy usage of models, in agreement with the requirements of an EPCo. The above-mentioned diversifications lead to constant reviews and optimization of the existing models. Additionally include a criterion of simplicity and contractualization in the modelling tool to allow to filter potential models according to their applicability in an EPCo application.

Business case 5 "Buildings for occupants: Comfort Case" could not take advantage of either Cordia platform and Energis platform because they could not be leveraged for control sequence implementation. A dedicated framework was used leveraging the two platforms for data collection, data aggregation and data transfer, but a separate dashboard was created on the open-source tool Grafana to manage the display of actuators and rule implementations. The control aspect used the Raspicy, which is a data logging device used by Energis and

Helexia on other projects and allows both to collect, store and manage data but also to be used as a relay to the BMS and the implementation of control rulesets.

Similarly to BC4, significant constraints were identified during the development of the business case 5. As a result of COVID-19 pandemic, according to the instructions of the ministry of health, the AHU system in office buildings should always keep operating to constantly freshen the air. This resulted in difficulties accessing and controlling the relevant systems and additionally was giving a hard time to focus in the comfort and the energy consumption optimization. Beside the COVID-19 impact, the second significant challenge of this Business case was the consortium capacity to take control over the equipment on site. The organization led to difficulties in the communication process and constituted a significant hurdle in the efficiency of the rule's implementation. A choice was made to investigate the use of another building and it was decided to implement the business case on Cordia's Headquarter building.

Towards the second half of the project, BC5 will try to get additional buildings added to this business case, focusing on buildings where the ESCo is also responsible for O&M services. As explained above, Cordia is now working on the implementation of the business case on their own Head Quarter building.

The initial work of **Business case 6 "Flexibility potential of Residential consumers on electricity and natural gas"** started with both Use Cases setting up the pilot infrastructure, which will be further expanded in terms of recruiting additional pilot participants (users). HERON has managed to initiate the UC14 pilot with 10 engaged electricity consumption points with installed metering equipment (with a target of 100 households). DOMX progressed in UC15 by engaging and installing their heating controller at the gas boiler of 60 households (with a target of 100 households). In the context of UC15, baseline data have been collected between October 2021 and April 2022, while initial tests and evaluation of the Energy efficiency mechanism have also been carried out. The detailed analysis of collected data will be executed, as soon as the BIGG platform is up and running and the data analysis pipeline is operational.

One of the key lessons learned is that significant effort is required for maintaining the pilot users constantly engaged and to make sure that pilot equipment (meters, controllers, etc.) are constantly connected with the platform and services. Furthermore, GDPR challenges have been addressed by amending the user consent forms for handling all the related data and introducing terms and conditions that safeguard the integrity of the deployed pilot assets by not allowing unauthorized intervention. In addition, the access to datasets offered by third parties was identified as hard to be guaranteed (EPCs collected from a public body in Greece), thus requiring the deployment of alternative data collection processes for accessing the key data. Compatibility of legacy assets identified at end user premises with smart equipment is another crucial factor for extending the pilot deployments, which necessitates the adaptation of applied tools to a wider range of available assets (gas boilers, white goods, electric heaters, etc.).

Finally, specifically for UC14, a survey of the prospective participants revealed limited interest in the deployment of relays for the remote control of water boilers, hence called for an overhaul of the Use Case and the transition from a strictly reactive DR solution towards an advice based DR solution that relies less on technical infrastructure. This can increase the impact of BIGG toolbox, after the project concludes by introducing a scalable service that relies on appliances that can be found on every household.

VI. REFERENCES AND INTERNET LINKS

[1]. European Comission, 'INSPIRE', *Infrastructure for spatial information in Europe*. https://inspire.ec.europa.eu (accessed May 31, 2022).

[2]. European Comission, 'Level(s)', *Level(s) European framework for sustainable buildings*. https://ec.europa.eu/environment/topics/circular-economy/levels_en (accessed May 31, 2022).

[3]. 'European Green Deal', *A European Green Deal Striving to be the first climate-neutral continent*. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en (accessed May 31, 2022).

[4]. European Parliament and The Council, 'European Climate Law'. Jun. 30, 2021.