D^2EPC Pilots Demonstration v1

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DELIVERABLE 5.4
D^2EPC Pilots Demonstration v1

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Executive Summary

The Task 5.3 implements in real-life building environments the concepts and solutions developed in previous WPs to assess, validate, and evaluate their actual performance. The necessary IoT devices that were installed - if not already available - serve multiple monitoring operation needs of the buildings. Buildings are monitored on a regular basis for their dynamic assessment of energy performance, updated through the delivery of the dEPCs. This deliverable D5.4 is a technical report of the development work made by all partners on the implementation and demonstration activities in the pilot buildings. The operational steps for defining D^2EPC validation methodology are hereby described. Starting from the nZEB Smart House at CERTH premises in Greece as the point zero for testing and validating the D^2EPC prototype, a total of six study cases including (Germany (CLEO and SEC) and Cyprus (FRC) will be put under test towards further elaborating on the application of D^EPC technologies on the residential and tertiary sector.

The scope of the validation and demonstration is to test the achievement of behavioural and multiple environmental benefits deriving from the application of dEPC as a tool for monitoring performances of buildings related to financial, human comfort and smart readiness indicators. The possibility of monitoring the triple set of indicators could be beneficial also for experimenting with new actions for renovation purposes.

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List of Acronyms and Abbreviations

Term	Description
AEC	Architecture Engineering Construction
AECO	Architecture Engineering Construction and Owner - operated
BACS	Building automation and control system
BIM	Building Information Model
BMS	Building Management System
BREEAM	Building Research Establishment Environmental Assessment Method
CAD	Computer Aided Design
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardisation
D	Deliverable
DHW	Domestic Hot Water
DT	Digital Twin
dEPC	dynamic Energy Performance Certificate
EBC	Energy in Buildings and Communities
EED	Energy Efficiency Directive
EPB	Energy Performance of Buildings
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ETSI	European Telecommunications Standards Institute
EU	European Union
FM	Facilities Management
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
IAQ	Indoor Air Quality
IEQ	Indoor Environment Quality
IEA	International Energy Agency
IFC	Industry Foundation Classes

IFD	**International Framework for Dictionaries**
ISO	**International Organization for Standardization**
IoT	**Internet of things**
LEED	**Leadership in Energy and Environmental Design**
LCA	**Life Cycle Assessment**
LiDAR	**Light Detection and Ranging**
M/480	**Mandate M/480, standardization requests issued as the recast of the EPBD**
MEP	**Mechanical, Electrical and Plumbing Systems**
MS	**Member State**
NDT	**National Digital Twin**
PIR	**Passive infrared sensor**
RED	**Renewable Energy Directive**
SRI	**Smart Readiness Indicators**
T	**Task**
TBS	**Technical Building Services**
TCs	**Technical Committees**
TVOC	**Total volatile organic compounds**
WP	**Work Package**

1. Introduction

1.1 Scope and objectives of the deliverable

The main scope of this report is to describe the methodology validation and implementation in real-life building environments of the concepts and solutions developed in previous WPs in order to assess, validate, and evaluate their actual performance. The deliverable describes the operational steps that were taken in the study cases to monitor the buildings regularly for their dynamic assessment of energy performance, which was updated through the delivery of the dEPCs.

It should be noted here as well that this deliverable acts as a planning tool for organising the next steps in tasks 5.3 and 5.4: validation methodology, test stage deployment and evaluation. It will be updated for confidential usage and completed by M36.

1.2 Structure of the deliverable

The deliverable is divided into three main parts:

1. The **business scenario mapping upon pilots** (chapter 2).
2. The **general deployment timeline** (chapter 3)
3. The **validation methodology** (chapter 4).

Finally, the **demonstration based on study** cases will provide empirical evidence on the performance of different typologies of buildings**.** Each study case has its own deployment timeline, barriers, and opportunities to be analysed and its own stakeholders to be engaged. The stakeholder engagement process is tailor-made for each specific context accordingly to the needs of the end users, followed rigid GDPR protocols to obtain the consent of the users in first place. The report acts as a planning tool for the coordination of the different pilots defining common testing stages. The evaluation of buildings' performance informs, in a recurrent cycle, the validation process and the business scenario.

1.3 Relation to other Tasks and Deliverables

This deliverable is part of the T5.3 and is especially interconnected with the previous analysis and preparation of the D^2EPC pilot sites within T5.2; it addresses the core activity of deployment of the D^2EPC solutions at the pilot sites and validation of the integrated framework. It is preparatory to the evaluation of the impacts achieved by the D^2EPC framework implementation at pilot buildings that will lead to learn consolidated lessons from real-life demonstrations. The business scenarios and use cases requirements are related to the previous deliverable D1.7 (technical software foundation) and other WP1 activities especially T1.2 and T1.3 since they represent the market and user needs, and the envisioned high-level scheme of the D^2EPC system, respectively. The D^2EPC business scenarios have been identified to be able to address the market needs and challenges that have been identified through D1.1. In this report, the Business Cases are connected to empirical use cases of the study cases. Throughout the T1.4 activities, four business groups were identified, including in a total of five (5) business scenarios, further divided into 19 Technical Use Cases, which almost correspond to the Test Cases (TC).

The theoretical background defined in T1.3 and the specified use scenarios in T1.4 and the overall D^2EPC's solution are hereby validated using the methodology depicted in Chapter 4 of this report. The validation procedure refers to D1.4 System Architecture and iteratively provides feedback towards the complete system architecture to be delivered on M36. The IoT framework (T3.1) functions in conjunction with the pilot's various IoT infrastructures deployed in T5.3. The results of demonstrations and validation of the test cases will give baseline information for the evaluation T5.4 and comparative assessment.

2. D^2EPC Business Scenarios Mapping upon Pilots

This section will provide an overview of the investigated business scenarios and use cases for each one of the D^2EPC demonstration sites.

A business case or scenario (BS) captures the need or problem that enables understanding of the business value. It may also capture the reasoning that facilitates a decision to start a project. The D^2EPC Business scenarios are the following:

- BS1 Definition of buildings energy class and whether minimum requirements are met for Asset Rating
- BS2 Definition of buildings energy class and whether minimum requirements are met for Operational Rating
- BS3 Provision of (near) real-time building information, deviations, and recommendations
- BS4 Provision of district/area level of EPC statistics for third party stakeholders
- BS5 Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns

Table 1: Business Scenarios / Use Cases / Test Cases

Business Group A: Issuance of Energy Performance Certificates			
BS1	**Definition of buildings energy class and whether minimum requirements are met for Asset Rating**	**CORRELATED TEST CASES**	**Cases study**
UC1.1	Extract and Verify Data from BIM	TC-10	CS1, C2, CS3, CS4, CS5, CS6
UC1.2	Issue a D^2EPC asset EPC	TC-01; TC-04; TC-06; TC-13; TC-14	CS1, C2, CS3, CS4, CS5, CS6
UC1.3	Issue an SRI report	TC-01; TC-02; TC-06; TC-13; TC-14; TC-15	CS1, C2, CS3, CS4, CS5, CS6
UC1.4	Asset Rating Indicator Assessment Report	TC-01; TC-02; TC-06;	CS1, C2, CS3, CS4, CS5, CS6
UC1.5	Provide Design recommendations for performance improvements	TC-01; TC-02; TC-03; TC-04; TC-06; TC-15	CS1, C2, CS3, CS4, CS5, CS6
UC1.6	Asset Rating as a service	TC-01; TC-02; TC-03; TC-04; TC-06; TC-15	
BS2	**Definition of buildings energy class and whether minimum requirements are met for Operational Rating**	**CORRELATED TEST CASES**	**Cases study and testing stage**
UC2.1	Extract and Verify Data from Measurements for the Digital Twin		CS1, C2, CS3, CS4, CS5, CS6
UC2.2	Issue a D^2EPC operational EPC	TC-07; TC-09; TC-10; TC-11; TC-12;	CS1, C2, CS3, CS4, CS5, CS6

UC2.3	Operational Rating Indicator Assessment Report	TC-08; TC-11; TC-13; TC-14; TC-16; TC-17	CS1, C2, CS3, CS4, CS5, CS6
UC2.4	Provide Operational recommendations for performance improvements	TC-07; TC-08; TC-11; TC-13; TC-14	CS1, C2, CS3, CS4, CS5, CS6
UC2.5	Operational Rating as a service	TC-07; TC-08; TC-09; TC-12; TC-13; TC-14; TC-16;	
Business Group B: EPC Monitoring, Evaluation & Recommendation			
BS3	**Provision of (near) real-time building information, deviations, and recommendations**	**CORRELATED TEST CASES**	**Cases study (CS) testing stage**
UC3.1	Provide real-time building information	TC-01; TC-07; TC-13; TC-16	CS1, C2, CS3, CS4, CS5, CS6
UC3.2	Provide information on as-designed/in-operation deviations	TC-01; TC-07; TC-08; TC-09; TC-16; TC-04	
UC3.3	Provide regular recommendations for improving operational energy performance & conditions in terms of health and comfort.	TC-05; TC-13;	CS1, C2, CS3, CS4, CS5, CS6
Business Group C: Evaluation and Benchmarking of more certificates for policy making / marketing / business purposes			
BS4	**Provision of district/area level of EPC statistics for third party stakeholders**	**CORRELATED TEST CASES**	**Cases study (CS) and testing stage**
UC4.1	Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset rating	TC-17; TC-18	
UC4.2	Regional Level Visualisation of (near) real-time energy performance information for operational rating	TC-07; TC-18	
UC4.3	Building performance benchmarking statistics for operational standardization	TC-01; TC-07; TC-16; TC-18	
BS5	**Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns**	**CORRELATED TEST CASES**	**Study case and testing stage**

UC5.1	Provision and Visualization of correlation of building materials and energy performance	TC-01; TC-15; TC-16; TC-17	
UC5.2	Provision and Visualisation of correlation of building assets/systems and energy performance	TC-01; TC-15; TC-16; TC-17	

2.1 Business Group A: Issuance of Energy Performance Certificates

This business group is the main set of scenarios that aims to deliver the core functionalities of the D^2EPC framework. Focusing on two important aspects (asset and operational rating), these scenarios will deliver an EU-based platform for issuing energy performance certificates.

2.1.1 BS1: Definition of buildings energy class and whether minimum requirements are met for Asset Rating

This Business Scenario (described in D1.7) aims to deliver one of the core functionalities of the D^2EPC platform, which is the Asset Rating, or otherwise known Calculated or 'As Designed'. Expanding current methodologies while adopting most recent standards, this scenario will showcase the importance of BIM-based assessment, including certain dynamic aspects and the new indicators which were introduced through WP2 activities. As already highlighted, the main differences with current practices lie mainly on the use of BIM for providing all the necessary information from the infrastructure assessed, while also introducing new KPIs and practices for holistically addressing the building performance. On top of that, more sophisticated recommendations are expected to be provided to the issuer of dEPC (namely the EPC designer).

To fully cover this scenario the following technical use cases have been identified. These, along with the main actor and other related stakeholders are depicted in Figure 1.

- UC1.1 – Extract and Verify Data from BIM
- UC1.2 – Issue a D^2EPC asset EPC
- UC1.3 – Issue a SRI report
- UC1.4 – Asset Rating Indicator Assessment Report (LCC, LCA)
- UC1.5 – Provide Design recommendations for performance improvements
- UC1.6 – Asset Rating as a service

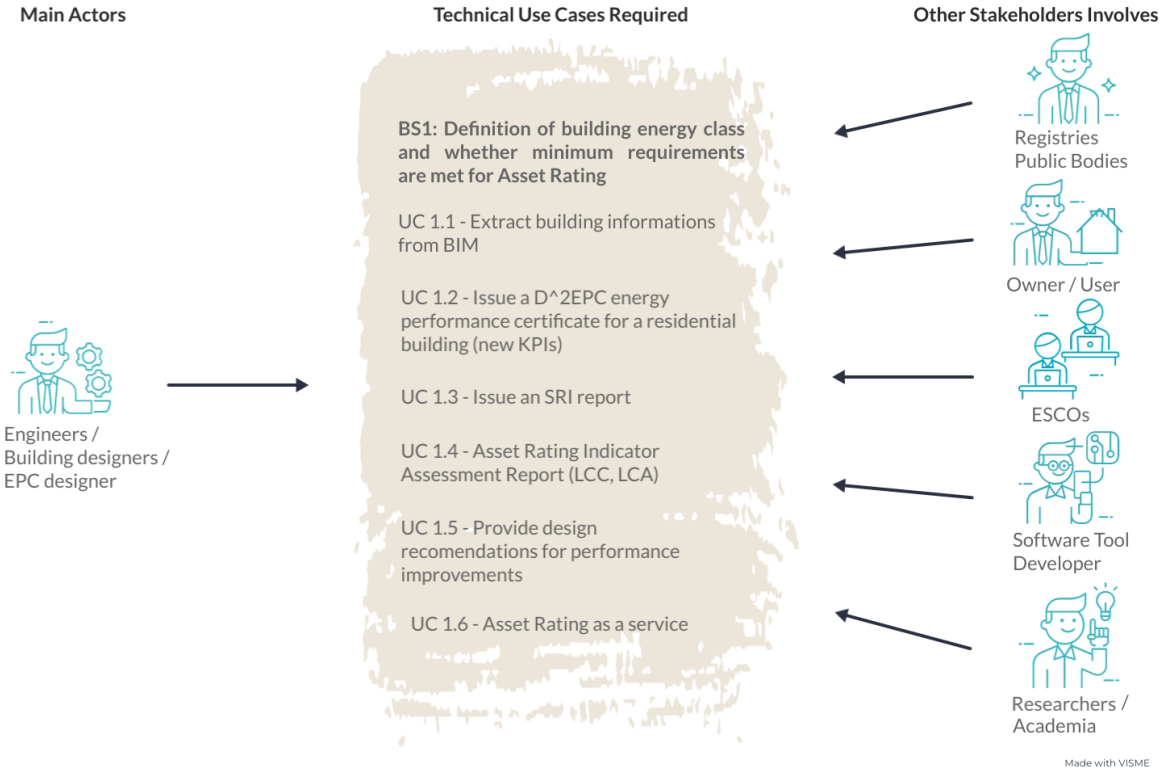


Figure 1: BS1 - Definition of buildings energy class and whether minimum requirements are met for Asset Rating

2.1.2 BS2: Definition of buildings energy class and whether minimum requirements are met for Operational Rating

This second business scenario aims to deliver for the operational rating, or otherwise 'Measured or In-Operation'. In contrast to the asset rating, here (near) real information flow from the building is crucial for the assessment of the operational building's performance. In addition, the indicators that are exploited towards delivering this scenario are not the same with the ones expected to be used in BS1, although certain overlapping may arise. In this scenario, recommendations will be provided to the main actor towards improving the overall experience and transferring the required knowledge. As a more dynamic procedure than the Asset Rating, the data required will be extracted from the complete building Digital Twin.

This Business Scenario, in alignment and as an extension of BS1, consists of the following technical Use Cases:

- UC2.1 - Extract and Verify Data from Measurements for the Digital Twin
- UC2.2 – Issue a D^2EPC operational EPC
- UC2.3 – Operational Rating Indicator Assessment Report (LCC, HC&W)
- UC2.4 – Provide Operational recommendations for performance improvements
- UC2.5 – Operational Rating as a service

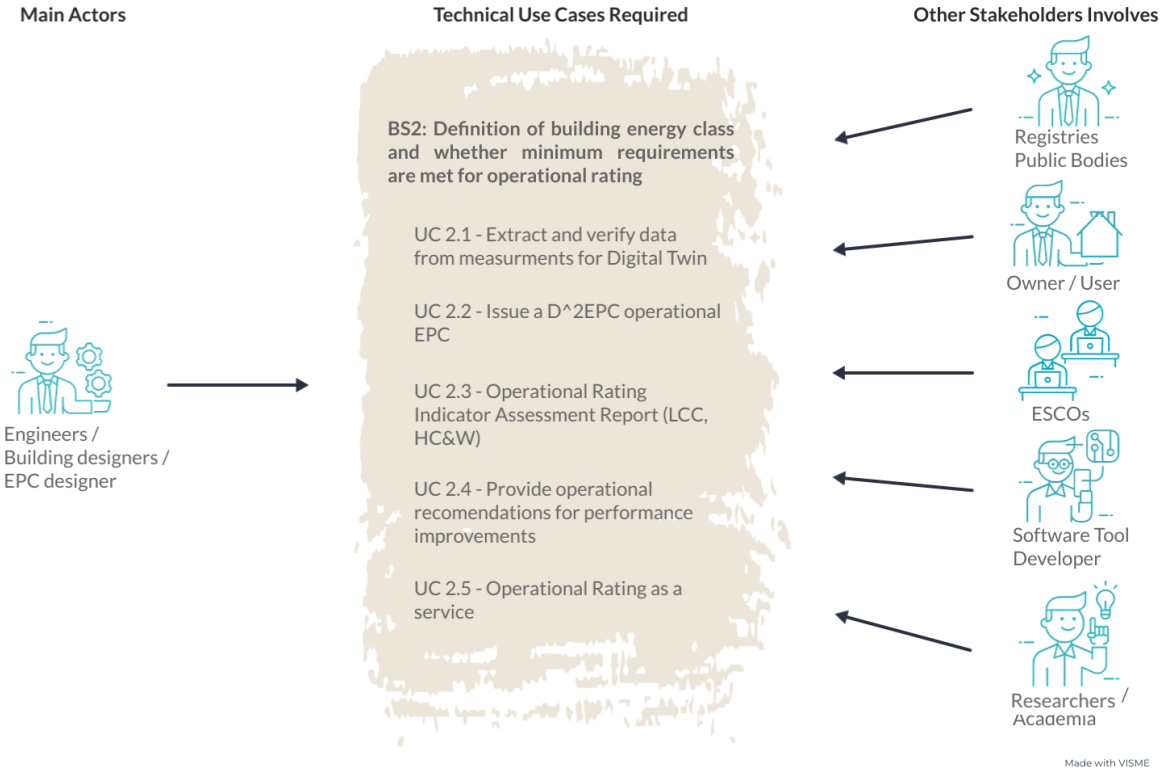


Figure 2: BS2 - Definition of buildings energy class and whether minimum requirements are met for Operational Rating

2.2 Business Group B: EPC Monitoring, Evaluation & Recommendation

This group covers another critical business requirement, and therefore the D^2EPC platform's business value, which is the capability to be able to monitor and evaluate real-time information from the building. Hence, the performance of the infrastructure after the EPC has been issued can be dynamically re-evaluated and provide the necessary notifications and recommendations in terms of deviations, improvements, or general preventive and corrective actions. At this point, only one business scenario is documented. However, further exploration of the market potential may deliver additional aspects, that will be documented (if identified) in the next versions of this report.

2.2.1 BS3: Provision of (near) real-time building information, deviations, and recommendations

This business scenario deals with the provision of real-time information to the end-users. Starting from simple monitoring of either raw data or performance indicators/metrics, to more thorough visual analytics that properly introduce identified deviations and recommendation, a 'user-centred' approach is followed for regularly supporting the building's operation, iterative focusing on the users and their needs in each phase of the design process. Through this business scenario, it is also possible for authorities or public bodies to effectively and automatically monitor both asset (indirectly) and operational (directly) ratings.

This Business Scenario (Figure 3), consists of the following technical Use Cases:

- UC3.1 – Provide (near) real-time building's energy performance information
- UC3.2 – Provide information on as-designed/in-operation deviations
- UC3.3 – Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort.

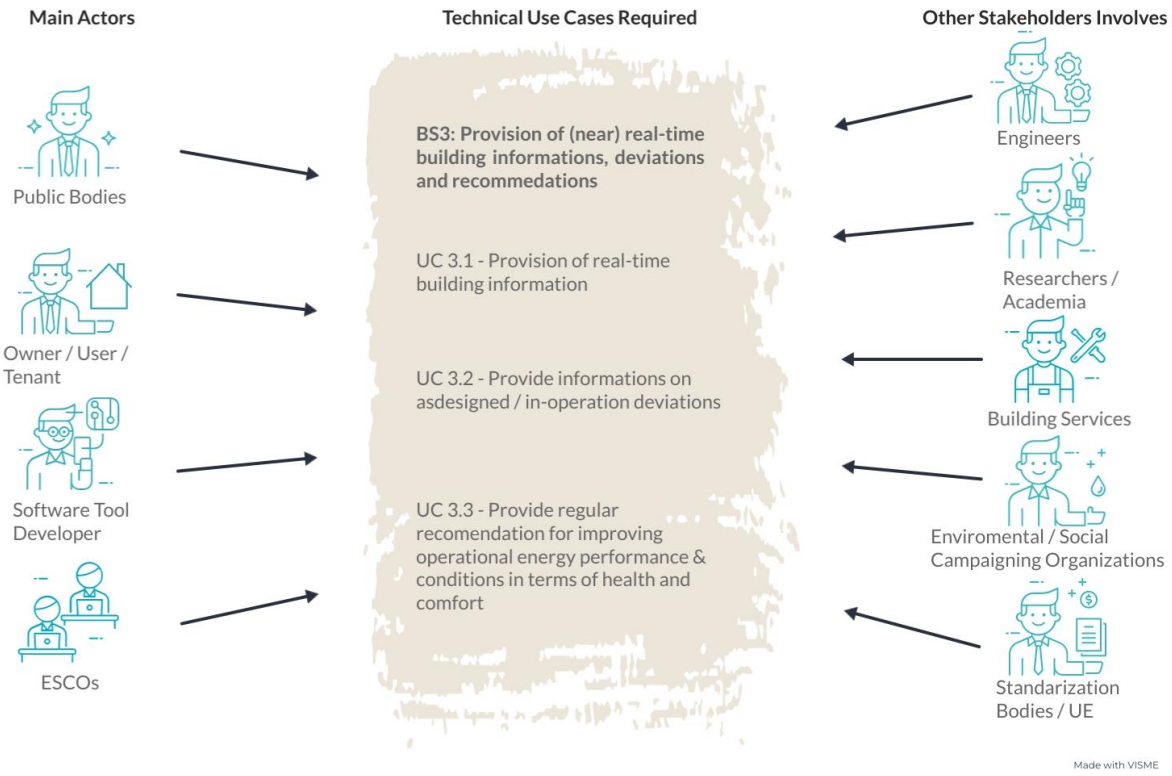


Figure 3: BS3 - Provision of (near) real-time building information, deviations, and recommendations.

2.3 Business Group C: Evaluation and Benchmarking of more certificates for policy making / marketing / business purposes

Following the dynamic aspects introduced by D^2EPC, additional added value services are introduced. These are covered within this group of business scenarios, where energy performance is anonymized and is provided as a service in quantity. Others, by employing GIS-based representation or statistics that are presented through enriched visual analytics. The two business scenarios introduced, cover added-value services that have been identified and can introduce quite a few potential business models and revenue streams.

2.3.1 BS4: Provision of regional level of EPC statistics for third party stakeholders

The D^2EPC platform will be able to deliver data sets through the envisioned Web GIS tool. The results can be used as a baseline for regional policy-making for example targeting energy poverty, energy transition and renovations plans, enhancing the information offered with additional dimensions (3D) and level of details (5D).

Another aspect covered by this scenario is the utilization of such provided information for benchmarking and standardisation purposes.

This Business Scenario (Figure 4) consists of the following technical Use Cases:

- UC4.1 – Regional Level Visualization of dynamic (aspect of time) energy performance information for asset-based EPCs
- UC4.2 – Regional Level benchmarking and statistics comparison between regions
- UC4.3 – Building performance statistics for operational rating of pilot buildings and 3d visualization

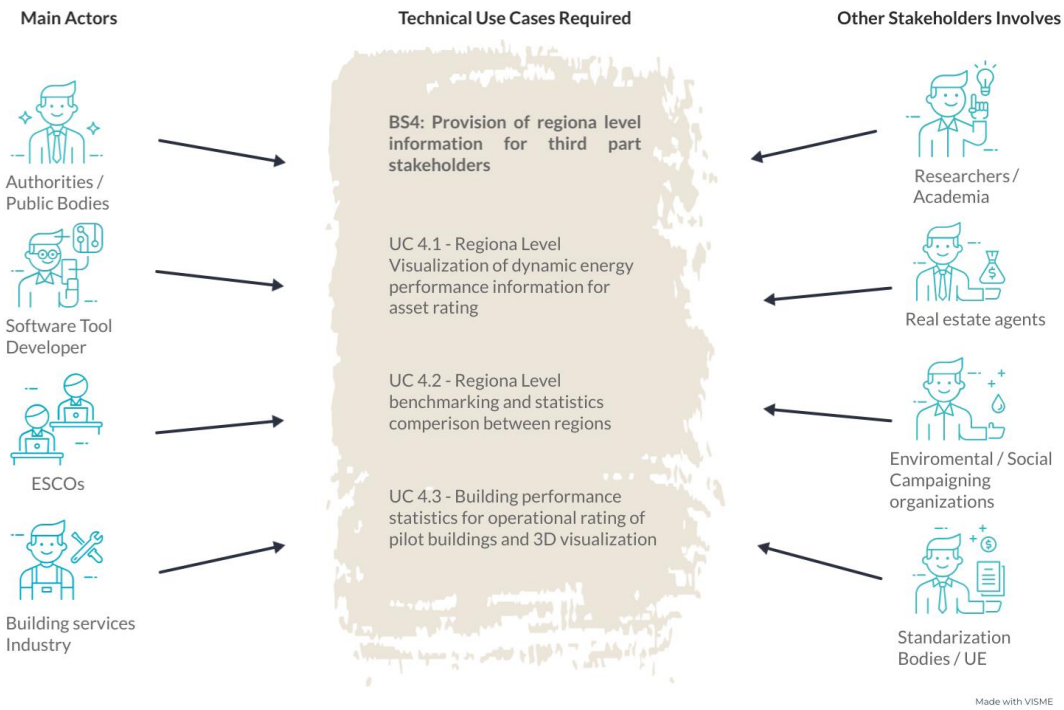


Figure 4: BS4 - Provision of regional level of EPC statistics for third party stakeholders

2.3.2 BS5: Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns

As time passes, information deriving from dynamic EPCs, and building performance in general, both in terms of asset or operational ratings, is expected to gain significant business value. In fact, various stakeholders closely related to building performance but not actively engaged with EPCs, might require services that will introduce new revenue streams. As such, within D^2EPC, one additional business scenario has been identified and is documented below towards presenting this potential. This scenario and its actors are graphically presented in Figure 5. Two main technical use cases have been also included:

- UC5.1 – Provision and Visualisation of correlation of building materials and energy performance
- UC5.2 – Provision and Visualisation of correlation of building assets/systems and energy performance

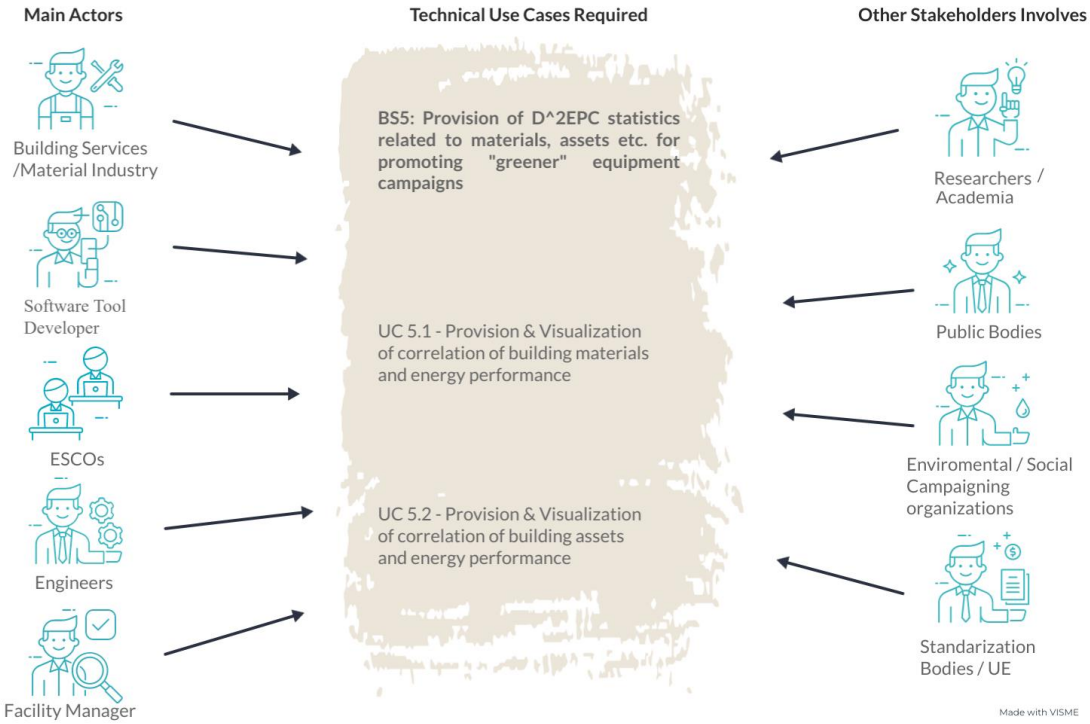
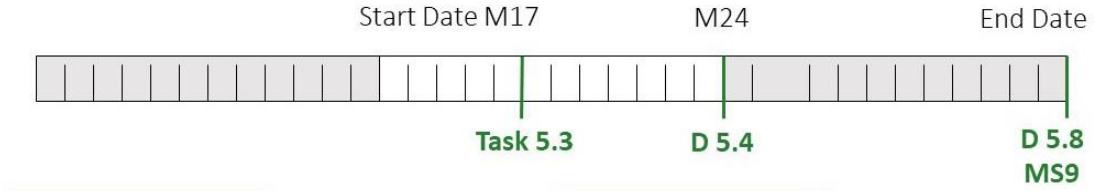


Figure 5: BS5 - Provision of dEPC statistics related to materials, assets, etc. for promoting "greener" equipment campaigns

3. General deployment timeline

This section includes an overall time schedule for the D^2EPC deployment at the demonstration sites, including a timeline figure.



Start date	**M17**	**Task Leader**	**CLEO**
End date	**M36**	**Task Contributors**	**CERTH(4), KTU(2), SEC(4), HYP(4), FRC(5)]**
Deliverables:	**D5.4 D^2EPC Pilots Demonstration v1 (M24)** Initial version on pilot demonstrations (public version). Linked with T5.3 and T5.4 outcomes (Public) **D5.8 : D^2EPC Pilots Demonstration v2 (M36)** Final version of the Pilots (deployment, execution, lessons learned) (Confidential)		
Milestones:	**MS9 Successful completion of the D^2EPC Pilots and evaluation (M36)**		

Figure 6: General deployment timeline

PRELIMINARY Stage (M17-M27): Close pilot testing: the testing and evaluation plan (predefined testing criteria) to ensure data retrieval and the creation of an initial baseline (starting with Nzeb Smart House)

- A testing phase of IoT equipment along with interfaces for data exchange between the onsite assets and D^2EPC platform.
- Ensure that the IoT framework (T3.1) functions in conjunction with the pilots' various IoT infrastructures.
- Selection of pilot use case scenarios to be investigated for the close pilot testing phase.
- Different tools tested during the development.

INTERMEDIATE Stage (M27-M34): Open pilot deployment: Including demonstration activities to all the D^EPC pilots

- Definition of timeline of data collection events accordingly to the requirements of the calculation methodology (WG2) and dynamic D^2EPC indicators (WP2).
- Detailed evaluation framework for the pilots.

FINAL Stage (M34-M36): D^2EPC prototype testing and validation of the specified use scenarios (according to T1.4) and the overall D^2EPC solution

- Develop the "Performance Measurement and Verification Methodology" for the evaluation of the project's Key Performance Indicators (KPIs) (T1.4, T5.4).
- The KPIs set the values that the project needs to achieve its completion, and they are related to the **project objectives.**
- Prototype validation of the specified scenarios from T1.4.

4. D^2EPC validation methodology

The definition of holistic test cases in terms of flow diagrams and process descriptions are derived from a scenario and corresponding system configuration as well as use cases within a setup. Thus, the test case aims to identify specific test criteria, relating to a test system configuration, relevant use cases and a specific test objective. The test case sets up benchmarking criteria to guide the evaluation and the learning process.

4.1 TC-01 – Extract and Verify Data from BIM

Test case 1	**Extract and Verify Data from BIM**
Intent	To build a BIM file, extract all required information for asset rating and relevant set of indicators available in that BIM file and ensure that it's in the correct data format and complete.
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC Designer (user) requests from the building owner the BIM file and imports it through the D^2EPC platform. In case the BIM is incomplete or wrong, the user should be informed. It should also be possible to input (additional) data through a simplified UI. The BIM file is then used to create the building's Digital Twin, with data stored in the D^2EPC Repository.
Assumptions	The building owner has a BIM file
Pre-conditions	None
Trigger	A request for a new EPC
Goal (Successful End Condition)	All data needed for asset rating, which can be extracted from the BIM file, available after.
Post-conditions	Building Data are available for other processes and operations.
Related Use Cases	UC1.2, UC1.3, UC1.4, UC1.5, UC1.6, UC3.1, UC3.2, UC4.3, UC5.1, UC5.2
Execution	Technical steps for the execution of the test case: 1. The EPC assessor requests the BIM File from the building owner. 2. The EPC assessor uploads the BIM file to D^2EPC Web platform. 3. The BIM-based Digital Twin checks if the BIM file contains all the necessary information through a validation procedure. 4. A failed validation procedure returns invalid input to the EPC assessor, which is stored in the repository. The EPC assessor requests additional data from the user and must upload the BIM file to the Web platform again. 5. A successful validation procedure continues with storage of BIM file to Digital Twin repository and extraction of available information from the BIM Parser subcomponent of the BI-Based Digital Twin. 6. The D^2EPC Web platform presents the BIM information to the EPC assessor.
Expected results	Successful validation procedure and BIM information presentation of BIM file to the Web platform.
Successful criteria	Presentation of BIM file information to the Web platform.

Fail criteria	Lack of information in BIM-file.

4.2 TC-02 - Issue an D^2EPC asset EPC

Test Case 2	**Issue an D^2EPC asset EPC**
Intent	To issue an D^2EPC EPC based on asset rating
Actors Involved	Main Act or: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an asset EPC from the D^2EPC Web platform that sends the request to the Calculation Engine. The Calculation Engine requests the necessary data through the BIM-based digital twin and the Asset Rating module of the Calculation Engine performs the asset-based EPC calculation. The Calculation Engine stores the issued EPC in the Repository and sends the results to the Web platform that delivers the EPC.
Assumptions	Data from a BIM file and from user inputs, (as per UC1.1) are available in the Repository
Pre-conditions	UC1.1
Trigger	A request for a new asset EPC
Goal (Successful End Condition)	D^2EPC asset EPC issued
Post-conditions	Asset EPC data (energy class, asset rating-related indicators) are available for other processes and operations. The amount of EPC data available depend on the accessing user's role.
Related Use Cases	UC1.3, UC1.4, UC1.5, UC1.6,
Execution	Technical steps for the execution of the test case: 1. The building owner requests the issuance of the asset EPC from the EPC assessor. 2. The EPC assessor makes an issuance request to D^2EPC Web platform. 3. The Web Platform requests the asset-based EPC calculation from Asset Rating module of the Calculation Engine 4. The Asset Rating module requests the building's infrastructure data from BIM-based Digital Twin. 5. The BIM-based Digital twin extracts the infrastructure data from the D^2EPC Repository. 6. Data are inserted into the Asset rating module for the required calculations. 7. The Asset rating returns the results to the Web platform for visualization and stores them into the Repository.
Expected results	Asset Rating EPC
Successful criteria	Realistic and precise EPC calculations and successful issuance

Fail criteria	Non-issuance of an EPC

4.3 TC-03 - Issue a SRI report

Test Case 3	Issue an SRI report
Intent	To perform an SRI assessment of the building and issue an SRI report
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an SRI report from the D^2EPC Web platform that sends the request to the Calculation Engine. The Calculation Engine requests SRI related data that are imported through the BIM-based digital twin. The Building Performance module of the Calculation Engine performs the SRI calculation and the report is sent to the Web platform and stored in the Repository.
Assumptions	The building owner has a BIM file. Calculation parameters available in the Repository and a new calculation of the SRI parameters is needed. D^2EPC EPCs are issued on a regular basis and available historical data can be retrieved from the Repository. If there is no need for an update of the SRI data, the SRI report can be automatically generated with the precondition of UC1.2.
Pre-conditions	UC1.1
Trigger	A request for a new SRI report
Goal (Successful End Condition)	SRI Report issued
Post-conditions	SRIs are available for other processes and operations
Related Use Cases	UC1.2, UC1.5, UC1.6
Execution	Technical steps for the execution of the test case: 1. The EPC assessor provides the required information through the D^2EPC Web Platform and requests the issuance of an SRI report. 2. The Web platform requests the SRI Report issuance from the Building Performance Module. 3. The Building Performance Module sends the input data to the BIM-based Digital Twin. 4. Digital Twin extracts data from the D^2EPC Repository and sends them to the Building Performance module 5. The Building Performance Module of the calculation engine calculates the SRI indicator and generates an SRI report 6. After calculation, the Building Performance module stores the calculated report to the Repository and returns the report to the Web Platform.
Expected results	SRI report
Successful criteria	Precise calculation of SRI indicator and creation of SRI report

Fail criteria	Inability to calculate and report the SRI indicator

4.4 TC-04 - Asset Rating Indicator Assessment Report (LCC, LCA)

Test Case 4	**Asset Rating Indicator Assessment Report (LCC, LCA)**
Intent	To extract all required data for the asset rating-related indicators assessment of the building
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an Asset Rating Indicator Assessment report, including the LCC and LCA set of indicators, from the D^2EPC Web platform that sends the request to the Calculation Engine. The Calculation Engine requests buildings information that are imported through the BIM-based digital twin. The Building Performance Module of the Calculation Engine performs the calculation of the indicators and the report is sent to the Web platform and stored in the Repository.
Assumptions	The building owner has a BIM file. Calculation parameters available in the Repository and a new calculation of the asset rating indicators is needed. D^2EPC EPCs are issued on a regular basis and available historical data can be retrieved from the Repository. If there is no need for an update of asset rating indicators, the Asset Rating Indicator Assessment report can be automatically generated with the precondition of UC1.2.
Pre-conditions	UC1.1
Trigger	A request for a new Asset Rating Indicator Assessment report
Goal (Successful End Condition)	Asset Rating Indicator Assessment Report (including selected LCC, LCA indicators) issued
Post-conditions	Asset Rating-related indicators are available for other processes and operations
Related Use Cases	UC1.2, UC1.5, UC1.6, UC3.2
Execution	Technical steps for the execution of the test case: 1. The EPC assessor performs a request for an Asset Rating Indicator Assessment report to the D^2EPC Web platform 2. The Web platform requests the Asset Rating Indicator Assessment from the Building Performance Module. 3. The Building Performance Module requests related data regarding the Financial and LCA indicators from the BIM-based Digital Twin. 4. The BIM-based Digital Twin extracts data from the Repository and sends them to the Building Performance Module.

	5. The Building Performance Module of the Calculation Engine calculates the LCC and LCA indicators and generates an Asset Rating Indicator Assessment report 6. After calculation, the Building Performance module stores the calculated report to the repository and returns the Asset Rating Indicator Assessment report to the Web platform
Expected results	Asset Rating Indicator Assessment report
Successful criteria	Precise calculation of LCC and LCA indicators and creation of Asset Rating Indicator Assessment report
Fail criteria	Non creation of an Asset Rating Indicator Assessment report

4.5 TC-05 - Provide Design recommendations for performance improvements

Test Case 5	**Provide Design recommendations for performance improvements**
Intent	To identify optimal asset-based design recommendation scenario and send recommendations for performance improvements
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer (user) requests optimal asset-based design recommendations from the D^2EPC Web platform that sends the request to the Roadmapping Tool. The Roadmapping Tool requests building infrastructure information that are imported through the BIM-based digital twin and then performs internal processes to identify the optimal scenarios. Based on those scenarios, the Roadmapping Tool requests new EPC results that are calculated as in UC1.2 by the Asset Rating module of the Calculation Engine and stored in the Repository. Based on the asset-based results and the new EPC Indicators, the Roadmapping Tool identifies the optimal scenario and sends information to the Notification and Alerts Tool that sends an alert for the availability of new optimal design recommendation to the Web platform. The user is informed about the new recommendation and data are stored in the Repository.
Assumptions	The building owner has a BIM file. Calculation parameters available in the Repository.
Pre-conditions	UC1.1, UC1.2
Trigger	A request for performance improvements
Goal (Successful End Condition)	Deliver optimal design recommendations for performance improvements
Post-conditions	EPCs based on optimal design recommendations are available for other processes and operations

Related Use Cases	UC3.3
Prerequisite	Asset rating EPC (UC1.2)
Execution	Technical steps for the execution of the test case: 1. The EPC designer requests optimal recommendations for energy performance upgrades from the D^2EPC Web platform 2. The D^2EPC Web platform creates a request that activates the Roadmapping Tool. 3. The Roadmapping tool requests current building infrastructure elements from the Repository 4. The Roadmapping tool retrieves infrastructure data from the repository. 5. The Roadmapping tool examines the necessity of a renovation action and generates scenarios. 6. For every renovation scenario, the Roadmapping tool makes requests to the Asset Rating of the Calculation Engine for calculating renovated building's EPC. 7. The Asset Rating module of the Calculation Engine returns the new results of the renovated building and makes a comparison with the current EPC. 8. The Roadmapping tool, concentrates all generated scenarios results for the optimization process 9. The Roadmapping tool stores a list of all feasible recommendations to the D^2EPC repository and informs Alerts and Notifications about the most optimal recommendations. 10. The Alerts and Notifications tool returns the available optimal recommendations to the D^2EPC Web platform and to the EPC designer.
Expected results	Optimal recommendations for energy performance upgrade
Successful criteria	Feasible and economical high rate optimal renovation recommendations
Fail criteria	Unfeasible, economical low rate, and not attainable recommendations

4.6 TC-06 - Asset Rating as a service

Test Case 6	Asset Rating as a service
Intent	To access the services of the D^2EPC Web platform based on asset rating through third party tools
Actors Involved	Main Actor: Engineers, Building designers (BIM/EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The BIM/ EPC designer using a third-party platform requests authorization from the D^2EPC Web platform in order to log in. If authorized access, the BIM/ EPC designer sends specific request to the Web platform which

	executes the request as in UC1.1-UC.1.5 after the user imports the required input (BIM file) and sends results to the third-party platform.
Assumptions	BIM file available
Pre-conditions	UC1.1
Trigger	Request from a third-party platform to use the services provided by the D^2EPC Web platform
Goal (Successful End Condition)	Deliver results according to the performed request
Post-conditions	-
Related Use Cases	UC1.2, UC1.3, UC1.4, UC1.5
Execution	Technical steps for the execution of the test case: 1. An EPC assessor requests authorization from the D^2EPC Web platform via a third-party platform 2. For authorized access, the EPC assessor uploads the BIM file to the Web platform and starts making requests for asset-based EPC, optimal recommendations, SRI report, and Asset Rating Indicator Assessment report. 3. Web platform returns the requested results to the third-party platform or tool of the EPC assessor
Expected results	Authorized access and execution of a variety of requests
Successful criteria	Approval of authorized access and successful creation of requests
Fail criteria	Unauthorized access and failure to make requests

4.7 TC-07 - Extract and Verify Data from Measurements for the Digital Twin

Test Case 7	**Extract and Verify Data from Measurements for the Digital Twin**
Intent	To collect, process and verify the validity of raw data collected from the IoT devices installed locally to be used in the Digital Twin
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	Building's data streams are transmitted from the D^2EPC Gateway to the Information Management Layer and then sent to the Verification and Credibility tool for check and to the D^2EPC Repository, through the Building Digital Twin, to be stored. If data quality is acceptable, then it can be retrieved by the BIM-based Digital Twin. If data quality not acceptable, then the user receives an alert generated by the Notifications and Alerts tools and

	visualised in the Web platform and the Mobile App. More details on the data not being accepted are provided by the Credibility UI.
Assumptions	IoT devices are installed locally and/or interfaces between the locally available BMS and the IML have been established.
Pre-conditions	None
Trigger	Continuous process – no trigger required
Goal (Successful End Condition)	Verified, cleansed, near real-time data
Post-conditions	Available data to be further used by other data-driven components of D^2EPC.
Related Use Cases	UC2.2, UC2.4, UC2.5, UC3.1, UC3.2, UC4.2, UC4.3
Execution	Technical steps for the execution of the test case: 1. Data from the building's sensors are transmitted to the Information Management Layer 2. The Information Management Layer provides the acquired data to the Verification and Credibility tool 3. The Verification and Credibility tool collects the building's data and starts a validation procedure to check the quality of the data. 4. if data quality is unacceptable the Credibility tool informs the Alerts and Notifications, which alerts the end user. 5. The End user can request credibility information from Credibility UI and the validation procedure starts again until data quality is acceptable 6. For acceptable data quality, data are stored into the D^2EPC Repository through the BIM-based Digital Twin.
Expected results	Real-time data storage in BIM-based Digital Twin
Successful criteria	Data stored in the D^2EPC Repository/User notified of unacceptable quality/insufficient data on time
Fail criteria	Fail to store data in the D^2EPC Repository/User not notified of unacceptable quality/insufficient data on time

4.8 TC-08 - Issue a D^2EPC operational EPC

Test Case 8	**Issue a D^2EPC operational EPC**
Intent	To issue a D^2EPC EPC based on operational rating
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs

Brief Description	The EPC designer requests the issuance of an operational EPC from the D^2EPC Web platform that sends the request to the Calculation Engine. The Operational Rating module of Calculation Engine requests the building's data retrieved from a BIM file and operational data which are imported through the BIM-based digital twin. Then, the Operational Rating module of the Calculation Engine performs the EPC calculation with additional parameters requested from the Repository. The Calculation Engine stores the issued EPC in the Repository and sends the results to the Web platform that delivers the EPC.
Assumptions	The building owner has a BIM file/Calculation parameter available in the Repository and building's data streams have been established Smart meters are installed in the building unit for measurement of individual energy carriers (electricity, natural gas, heating oil), of individual energy uses (heating, cooling, lighting, appliances), as well as occupancy sensors. Information on climatic data of the time of the operational rating assessment, as well as a typical meteorological year (TMY) of the building location are available.
Pre-conditions	UC1.1
Trigger	A request for a new operational EPC
Goal (Successful End Condition)	D^2EPC operational EPC issued
Post-conditions	KPIs and operational EPC are available for other processes and operations
Related Use Cases	UC2.3, UC2.4, UC2.5, UC3.2
Execution	Technical steps for the execution of the test case: 1. The building owner requests the issuance of the operational EPC from the EPC assessor. 2. The EPC assessor makes an issuance request to D^2EPC Web platform. 3. The Web Platform requests the operational-based EPC calculation from Operational Rating module of the Calculation Engine 4. The Operational Rating module requests the required building's infrastructure and operational data from BIM-based Digital Twin. 5. The BIM-based Digital twin extracts the infrastructure data from the D^2EPC Repository. 6. Data are inserted into the Operational rating module for the required calculations. 7. The Operational rating returns the results to the Web platform for visualization and stores them into the Repository.
Expected results	Operational Rating EPC
Successful criteria	Realistic and precise operational EPC calculations and successful issuance
Fail criteria	Non-issuance of an operational EPC

4.9 TC-09 - Operational Rating Indicator Assessment Report (LCC, HC&W)

Test Case 9	**Operational Rating Indicator Assessment Report (LCC, HC&W)**
Intent	To extract all required data for the operational rating-related indicators assessment of the building
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer requests the issuance of an Operational Rating Indicator Assessment report from the D^2EPC Web platform that sends the request to the Calculation Engine. The Calculation Engine requests buildings information, measurements and operational data that are imported through the BIM-based digital twin and additional calculation parameters that are imported through the Repository. The Building Performance module of the Calculation Engine performs the calculation of the indicators and the report is sent to the Web platform and stored in the Repository.
Assumptions	The building owner has a BIM file. Calculation parameters available in the Repository and a new calculation of the operational rating-related indicators is needed. D^2EPC EPCs are issued on a regular basis and available historical data can be retrieved from the Repository. If there is no need for an update of operational rating indicators, the Operational Rating Indicator Assessment report can be automatically generated with the precondition of UC2.2.
Pre-conditions	UC2.1
Trigger	A request for a new a new Operational Rating Indicator Assessment report
Goal (Successful End Condition)	Operational Rating Indicator Assessment Report (including selected LCC, HC&W indicators) issued
Post-conditions	Operational Rating-related indicators are available for other processes and operations
Related Use Cases	UC2.2, UC2.5, UC2.6, UC3.2
Execution	Technical steps for the execution of the test case: 1. The building owner requests the issuance of the operational EPC from the EPC assessor. 2. The EPC assessor makes an issuance request to D^2EPC Web platform. 3. The Web Platform requests the operational-based EPC calculation from Operational Rating module of the Calculation Engine 4. The Operational Rating module requests the required building's infrastructure and operational data from BIM-based Digital Twin.

	5. The BIM-based Digital twin extracts the infrastructure data from the D^2EPC Repository. 6. Data are inserted into the Operational rating module for the required calculations. 7. The Operational rating returns the results to the Web platform for visualization and stores them into the Repository.
Expected results	Operational Rating Indicator Assessment report
Successful criteria	Precise calculation of LCC and indoor comfort indicators and creation of Operational Rating Indicator Assessment report
Fail criteria	Non creation of an Operational Rating Indicator Assessment report

4.10 TC-10 - Provide Operational recommendations for performance improvements

Test Case 10	**Provide operational recommendations for performance improvements**
Intent	To identify any possible performance-degrading operational behaviours and send recommendations for performance improvements
Actors Involved	Main Actor: Engineers, Building designers (EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The EPC designer (user) requests operational-based recommendations from the D^2EPC Web platform (or it can be automatically generated as a request by the web platform) that sends the request to the AI-driven Performance Forecasts. The AI-driven Performance Forecasts requests building infrastructure information and measurements that are imported through the BIM-based digital twin and then performs internal processes to predict the months-ahead building operational behavior. Based on the predictions, the AI-driven Performance Forecasts requests new EPC results that are calculated as in UC2.2 by the Operational Rating module of the Calculation Engine and stored in the Repository. Based on the operational based results and the new EPC Indicators, the AI-driven Performance Forecasts identifies any possible operational patterns that might affect the building's performance and sends information to the Notification and Alerts Tool that sends an alert for the availability of new performance recommendations to the Web platform. The user is informed and data are stored in the Repository.
Assumptions	The building owner has a BIM file. Calculation parameters available in the Repository.
Pre-conditions	UC1.1, UC2.2
Trigger	A request for performance recommendations or self-triggered process

Goal (Successful End Condition)	Deliver recommendations for performance improvements
Post-conditions	-
Related Use Cases	UC3.3
Execution	Technical steps for the execution of the test case: 1. The building user requests optimal recommendations for energy savings from the D^2EPC Web platform 2. The D^2EPC Web platform creates a request that activates the AI Performance Forecasts tool. 3. The AI Performance Forecasts tool requests building infrastructure information, energy measurements and added information from external services (e.g. weather data, financial information etc.) 4. The AI Performance Forecasts tool calculates the predicted, month-ahead, building energy consumption. 5. The AI Performance Forecasts tool makes requests to the Operational Rating of the Calculation Engine for calculating the building's expected operational-based EPC and LCC indicators for the month-ahead horizon. 6. The Operational Rating module of the Calculation Engine returns the calculated results 7. The AI Performance Forecasts tool identifies any expected downgrade of the operational-based EPC and informs the Alerts and Notifications tool about suggested actions. 9. The Alerts and Notifications tool returns the outcome to the D^2EPC Web platform and to the building user.
Expected results	Optimal recommendations for energy performance upgrade
Successful criteria	Feasible and economical high rate optimal renovation recommendations and behavioral changes recommendations
Fail criteria	Unfeasible, economical low rate, and not attainable recommendations

4.11 TC-11 – Operational Rating as a service

Test Case 11	**Operational Rating as a service**
Intent	To access the services of the D^2EPC Web platform based on operational rating through third party tools
Actors Involved	Main Actor: Engineers, Building designers (BIM/EPC designers) Other: Registries, Public Bodies, Researchers/ Academics, Tenants/Owners, Software tool Developers, ESCOs
Brief Description	The BIM/ EPC designer using a third-party platform requests authorization from the D^2EPC Web platform in order to log in. If authorized access, the

	BIM/ EPC designer sends specific request to the Web platform which executes the request as in UC2.2-UC.2.4 after the user imports the required input (BIM file, measurements) and then sends results to the third-party platform.
Assumptions	BIM file and real time measurements are available. Measurements provided by the user are valid
Pre-conditions	UC1.1, UC2.1
Trigger	Request from a third-party platform to use the services provided by the D^2EPC Web platform
Goal (Successful End Condition)	Deliver results according to the performed request
Post-conditions	-
Related Use Cases	UC2.2, UC2.3, UC2.4
Execution	Technical steps for the execution of the test case: 1. An EPC assessor requests authorization from the D^2EPC Web platform via a third-party platform 2. For authorized access, the EPC assessor starts making requests for the operational-based EPC, optimal recommendations and the Operational Rating Indicator Assessment report. 3. The Web platform returns the requested results to the third-party platform or tool of the EPC assessor
Expected results	Authorized access and execution of a variety of requests
Successful criteria	Approval of authorized access and successful creation of requests
Fail criteria	Unauthorized access and failure to make requests

4.12 TC-12 - Provide (near) real-time building's energy performance information

Test Case 12	**Provide (near) real-time building's energy performance information**
Intent	To visualize real-time building energy performance information
Actors Involved	Main Actors: Public Bodies, Registries, Tenants/Owners, Software Tool Developers, ESCOs, Building services Industry Other: Standardization Bodies, Engineers, Researchers/Academia, Building services Industry, Professional Consultants, Environmental/ social campaigning organizations
Brief Description	The user/ owner requests (near) real-time building information from the Web platform which request is transmitted to the BIM based Digital Twin. Data available are retrieved from the Repository by the digital twin and then visualised to the user through the Web platform.

Assumptions	IoT devices are installed locally and/or interfaces between the locally available BMS and the IML have been established.
Pre-conditions	UC1.1, UC2.1
Trigger	Request for representation of (near) real-time building information
Goal (Successful End Condition)	(Near) real-time Building Information Representation
Post-conditions	-
Related Use Cases	UC2.2-UC2.5
Execution	Regarding this test case the following step must be implemented: 1. The end-user makes real-time requests for building information to the Web platform 2. The Web platform forwards the request to the BIM-based Digital Twin 3. The Digital Twin extracts the requested data from the repository The Digital Twin sends data to the Web platform and to the end-user
Expected results	The provision of near real time energy monitoring capabilities to the end users.
Successful criteria	Accurate and qualitative data and efficient data exchange
Fail criteria	Highly deviated data and faulty communication between the end-user and the data repository

4.13 TC-13 – Provide information on as-designed/in-operation deviations

Test Case 13	**Provide information on as-designed/in-operation deviations**
Intent	To check the deviations between as designed and in operation performance
Actors Involved	Main Actors: Public Bodies, Registries, Tenants/Owners, Software Tool Developers, ESCOs, Building services Industry Other: Standardization Bodies, Engineers, Researchers/Academia, Building services Industry, Professional Consultants, Environmental/ social campaigning organizations
Brief Description	The request is sent from the web platform (either triggered by the user or as a scheduled automated event) to the Calculation Engine that requires operational and asset rating data from the BIM-based Digital Twin, retrieved by the Repository. Based on these data and calculation parameters from the Repository, the Calculation Engine calculates as designed and in operation deviations, stores results in the Repository and informs the notification and Alerts Tool that notifies the user through the web platform.
Assumptions	-

Pre-conditions	UC 1.2, UC2.2
Trigger	Request by the user or as a scheduled automated process
Goal (Successful End Condition)	To enhance situational awareness on the buildings performance and indicate deviations between as designed and in operation
Post-conditions	-
Related Use Cases	UC1.3, UC1.4, UC2.3, UC2.4, UC2.5, UC3.1, UC3.3
Execution	The technical steps in test case 13 are the following: 1. A request for As-Designed and In-Operation deviation is being made through the Web Platform 2. The Web platform forwards to the requests to the Calculation Engine 3. To perform the necessary calculations the Calculation Engine requests operational and asset rating data from BIM-based Digital Twin 4. The Digital Twin acquires the data by making requests to the Repository 5. Data are retrieved from the Calculation Engine. 6. The Calculation Engines stores the results into the Repository and informs Alerts and Notifications module 7. The Alerts and Notifications tool send the deviations to the Web platform The Web platform sends the requested data to the end-user
Expected results	The provision of the asset's energy consumption "In-Operation" in contrast with the "As-Designed" values.
Successful criteria	The deviation of the above-mentioned deviations will indicate whether the occupants operate in the proper manner their property, which can also lead to further actions to reduce their energy consumption.
Fail criteria	Possible errors in the deviations between As-Designed and In-Operation energy values might lead end-users to mistrust the platform and discourage occupants energy reduction actions.

4.14 TC-14 - Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort

Test Case 14	**Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort**
Intent	To improve operational energy performance and indoor conditions (health, comfort)

Actors Involved	Main Actors: Public Bodies, Registries, Tenants/Owners, Software Tool Developers, ESCOs, Building services Industry Other: Standardization Bodies, Engineers, Researchers/Academia, Building services Industry, Professional Consultants, Environmental/ social campaigning organizations
Brief Description	The D^2EPC web platform sends request for improvement recommendations to the AI-driven Performance Forecasts and the Building Performance Module. The AI-driven Performance Forecasts requests building infrastructure information and measurements that are imported through the BIM-based digital twin and then performs internal processes to predict the months-ahead building operational behavior. The BPM requests building infrastructure information and HC&W measurements that are imported through the BIM-based digital twin. Based on the predictions, the AI-driven Performance Forecasts requests new EPC results that are calculated as in UC2.2 by the Operational Rating module of the Calculation Engine and stored in the Repository, while the BPM calculates the new HC&W KPIs. Based on the operational based results and the new indicators, the AI-driven Performance Forecasts identifies any possible operational patterns that might affect the building's performance or human comfort and sends information to the Notification and Alerts Tool that sends an alert for the availability of new performance/human comfort recommendations to the Web platform. The user is informed and data are stored in the Repository.
Assumptions	-
Pre-conditions	UC1.2, UC2.2
Trigger	Request for improving operational energy performance & conditions in terms of health and comfort
Goal (Successful End Condition)	Recommendations for improving operational energy performance & conditions in terms of health and comfort
Post-conditions	-
Related Use Cases	UC1.2, UC1.3, UC2.3, UC2.4, UC2.5
Execution	Technical steps for the execution of the test case: 1. The D^2EPC Web platform periodically creates a request for recommendations towards improving the energy performance and health & comfort that activates the AI Performance Forecasts tool. 2. The AI Performance Forecasts tool requests building infrastructure information, energy measurements and added information from external services (e.g. weather data, financial information etc.) 3. The AI Performance Forecasts tool calculates the predicted, month-ahead, building energy consumption. 4. The AI Performance Forecasts tool makes requests to the Operational Rating of the Calculation Engine for calculating the building's expected operational-based EPC for the month-ahead horizon.

	5. The Operational Rating module of the Calculation Engine returns the calculated results. 6. The AI Performance Forecasts tool identifies any actions that may improve the energy performance in terms of the operational-based EPC as well as of the HC&W indicators and informs the Alerts and Notifications tool. 7. The Alerts and Notifications tool returns the outcome to the D^2EPC Web platform and to the building user.
Expected results	The provision of personalized instruction for the building users to reduce their energy consumption and improve the indoor quality of their assets.
Successful criteria	Provision of recommendations for improvements in terms of energy performance and indoor health & comfort conditions
Fail criteria	Failure to provide recommendations or recommendations not applicable.

4.15 TC-15 - Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs

Test Case 15	**Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs**
Intent	Provision of regional (NUTS or administrative) visualisation tools for asset-based EPC ratings
Actors Involved	Main Actor: Authorities/ Registries/ Public Bodies, Software Tool Developers, ESCOs, Building services Industry Other: Researchers/ Academia, Real Estate Agents, Standardization Bodies, EU Commission, Environmental/ social campaigning organizations
Brief Description	Authorities/ Registries/ Public Bodies request from the WebGIS platform Regional Level Asset Ratings via selections on the map or via querying tools. The request is transmitted to the D^2EPC WebGIS backend which retrieves the data from the D^2EPC Geospatial Database, created explicitly for the D^2EPC WebGIS. The data in the DB are updated by the Calculation Engine upon EPC issuing requests. Results are sent to the WebGIS platform for visualisation through the Web platform.
Assumptions	The building owner agrees to share the building's asset rating. The building's approximate location should be provided without any major distortions
Pre-conditions	UC1.2
Trigger	The request of visualisation of asset ratings performance of buildings in an area/region
Goal (Successful End Condition)	Visualisation of Regional Level of dynamic (aspect of time) energy performance information for asset-based EPC ratings

Post-conditions	Building, region/area data are available for examination and evaluation from the stakeholders
Related Use Cases	UC1.3, UC1.5, UC1.6, , UC5.1, UC5.2
Execution	Technical steps for the execution of the test case: 1. Open the D^2EPC WebGIS platform 2. Select on a Specific Region / NUTS level upon Europe Or 2. Search the Name of a Specific Region / NUTS level upon Europe 3. Visualize the Results through the dedicated pop-up window / pie chart
Expected results	The tool provides the information / status of issued EPCs in different regional levels (NUTS) via figure pie charts and diagrams.
Successful criteria	An established connection with a respective geospatial database in order to feed the webGIS with the necessary information about issued EPC data
Fail criteria	Failure to establish connection with the respective geospatial database and the back-end of the module / Problematic or false EPC data

4.16 TC-16 - Regional Level benchmarking and statistics comparison between regions

Test case 16	**Regional Level benchmarking and statistics comparison between regions**
Intent	Provision of comparison & visualisation tools for regional (NUTS or administrative) statistics of EPCs. Provision of querying tools based on spatial attributes or EPC statistics
Actors Involved	Main Actor: Authorities/ Registries/ Public Bodies, Software Tool Developers, ESCOs, Building services Industry Other: Researchers/ Academia, Real Estate Agents, Standardization Bodies, EU Commission, Environmental/ social campaigning organizations
Brief Description	Authorities/ Registries/ Public Bodies have the ability to view the statistics for asset-based EPC ratings for a selected region on a map and compare them against a different region by also selecting it on the map. The comparison mode is activated by selecting it via dedicated button on the D^2EPC WebGIS front-end Authorities/ Registries/ Public Bodies have the ability to view EPC statistics based on attribute or spatial queries
Assumptions	The building owner agrees to share the building's real time measurements from the installed sensors. The building's exact location should be provided without any major distortions

Pre-conditions	UC2.2
Trigger	The request of comparison of EPC statistics for asset-based EPC ratings between different regions on the map
Goal (Successful End Condition)	Comparison of EPCs based on asset rating methodology between regions
Post-conditions	Building, region/area data are available for examination and evaluate from the stakeholders
Related Use Cases	UC2.3, UC2.5, UC3.1, UC3.2, , UC4.3, UC5.1, UC5.2
Execution	Technical steps for the execution of the test case: 1. Open the D^2EPC WebGIS platform 2. Select the Comparison Mode function 3. Select any two Regions / NUTS levels upon Europe 3. Visualize and compare the Results through the dedicated pop-up window / plot
Expected results	The tool provides the capability of comparing statistics from issued EPCs in different regional levels (NUTS) via figure plot charts and diagrams.
Successful criteria	An established connection with a respective geospatial database in order to feed the webGIS with the necessary information about issued EPC data
Fail criteria	Failure to establish connection with the respective geospatial database and the back end of the module / Problematic or false EPC data

4.17 TC-17 - Building performance benchmarking statistics for operational rating of pilot buildings and 3D visualization

Test Case 17	**Building performance statistics for operational rating of pilot buildings and 3D visualisation**
Intent	Provision of enhanced visualisation of BIM models in the WebGIS environment coupled with (near) real time energy performance data
Actors Involved	Main Actor: Building Owners
Brief Description	Building Owners can visualise the (near) real time energy performance of the building as well as the 3D modelling of the BIM
Assumptions	Only authorized users can select this mode
Pre-conditions	UC1.1, UC2.1,
Trigger	3D Visualisation of pilot case buildings
Goal (Successful End Condition)	Provide an enhanced visualisation of current building state in the WebGIS platform
Post-conditions	-

Related Use Cases	UC2.2, UC4.1, UC4.2, UC5.1, UC5.2
Execution	Technical steps for the execution of the test case: 1. Open the D^2EPC WebGIS platform 2. Select the Pilot Cases function 3. Select a pilot case from the respective drop-down list and then click-select on the respective point on the map 3. Visualize the 3D BIM model of a building in the 3d space. Visualize attribute data by selecting specific objects or surfaces of the building
Expected results	The tool provides the capability of 3D BIM visualization of a Building while also showcasing its specific objects or surfaces via attributes
Successful criteria	An established connection with a respective geospatial database to feed the webGIS with the necessary information about BIM .ifc file of a building
Fail criteria	Failure to establish connection with the respective geospatial database and the back end of the module / Problematic or false BIM data

4.18 TC-18 - Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance

Test Case 18	**Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance**
Intent	To provide insights to the various stakeholders on how the used building's materials/technical systems affect their energy performance
Actors Involved	Main Actor: Building Services/Material Industry, Suppliers, Engineers, Building designers, Facility Managers, ESCOs Other: Researchers/ Academia, Public Bodies, Environmental/social campaigning organizations, Standardization bodies, EU Commission
Brief Description	Building Services/Material Industry, Suppliers, Engineers, Building Designers, Facility Managers, ESCOs request from the Web platform Asset Rating Data benchmarked visualization and the request is transmitted to the Building Energy Performance Benchmarking Tool. Then the Asset Rating module of the Calculation Engine requests relevant data from the BIM-based Digital Twin, retrieved through the Repository and performs the calculation. Results are stored in the Repository and sent to Building Energy Performance Benchmarking Tool to perform the correlation between the building materials/technical systems and the energy performance. The correlation result is sent for visualisation through the Web platform.
Assumptions	The building owner agrees to share the building's real time measurements from the installed sensors. The building's exact location should be provided without any major distortions

Pre-conditions	UC1.2, UC2.2, UC 2.3, UC 3.2
Trigger	The request of visualisation of the correlation of building materials/technical systems and energy performance
Goal (Successful End Condition)	Find the more appropriate materials/technical systems for each case (location, use etc.) and establish best practices for the building construction industry.
Post-conditions	Building, region/area data are available for examination and evaluate from the stakeholders
Related Use Cases	UC4.1, UC 4.2, UC4.3
Execution	Technical steps for the execution of the test case: 1. The D^2EPC Web platform periodically creates a request for benchmarking different registered buildings according to their construction materials/technical systems and their energy performance. 2. The Benchmarking tool retrieves the necessary buildings' data from the Repository and performs the classification based on the provided criteria. 3. The benchmarked data are available through the Web Platform for visualization.
Expected results	The creation of a mapping between the energy behavior of a building and its construction materials/technical systems. The correlation refers to the whole building's life cycle.
Successful criteria	Successful mapping of the building materials/technical systems and the building's energy performance.
Fail criteria	Weak correlation between the materials/technical systems and energy behavior.

5. Overview of D^2EPC Case Studies

The development of an assessment framework for the European building stock requires a wide range of pilot buildings with different operational, architectural, and technical characteristics. The D^2EPC project has at its disposal six pilot buildings, namely, the nZEB Smart House DIH in Thessaloniki, Greece; a residential multi-family building in Velten, Germany; a tertiary building in Berlin, Germany; the new wing building of Frederic's University in Nicosia, Cyprus; and two multi-family buildings located in Berlin. The plethora of characteristics in this set of pilot buildings set a challenging environment for the applicability and validity of the under-development EPC methodology (for further specification on case studies see D5.3).

The two main factors that differentiate each pilot are the operational type (use) and its location. Regarding the use type of each building, there are case studies that belong to the residential sector but also to the tertiary one. Furthermore, certain pilots have mixed uses (e.g. concurrent residential and office usage can be found in the case of nZEB Smart House), allowing the methodology's validity to be tested in more complex cases. As the pilots are located in three different countries (Greece, Cyprus, and Germany), the methodology can be examined in various scenarios in terms of climate conditions, building constructions, and user preferences (e.g., comfort conditions or end-goals). Lastly, the EPC results can be compared with the respective values derived from the building EPC assessment according to the national or regional rating methodologies.

D^2EPC validation methodology considers output measures of the building's energy performance and will use measured energy data for the next generation EPCs. Building upon HYP's Gateway, D^2EPC establishes secure access to all major types of off-the-shelf sensors through standardized communication protocols (e.g. ZigBee, Z-wave), further enhanced and customized to ensure communication with any type of BMS and smart home device as well with the Business Stakeholder (ESCO) systems based on open standards. This energy information collection will further contribute to the human centric profiling that will deliver a set of comfort and behavioural indicators. The human profiling will be based on HYP's User Profiling Engine, which embeds, and trains enhanced integrated human comfort and activity models using information streams from sensor networks or other devices about the indoor environmental conditions. The activities profiling will utilize real-time energy data and ambient information in order to infer the impact of resident actions and comfort preferences on the building equipment and, as a result, to understand the boundary conditions under which humans will act in order to restore comfortable ambient conditions – including but not limited to thermal comfort, visual comfort, occupants' activity profiling, indoor air quality. The envisioned energy performance verification and credibility tool will enable the verification of the process, concerning the adequacy and operational status of all data collection infrastructure and thus ensure the reliability of the collected data.

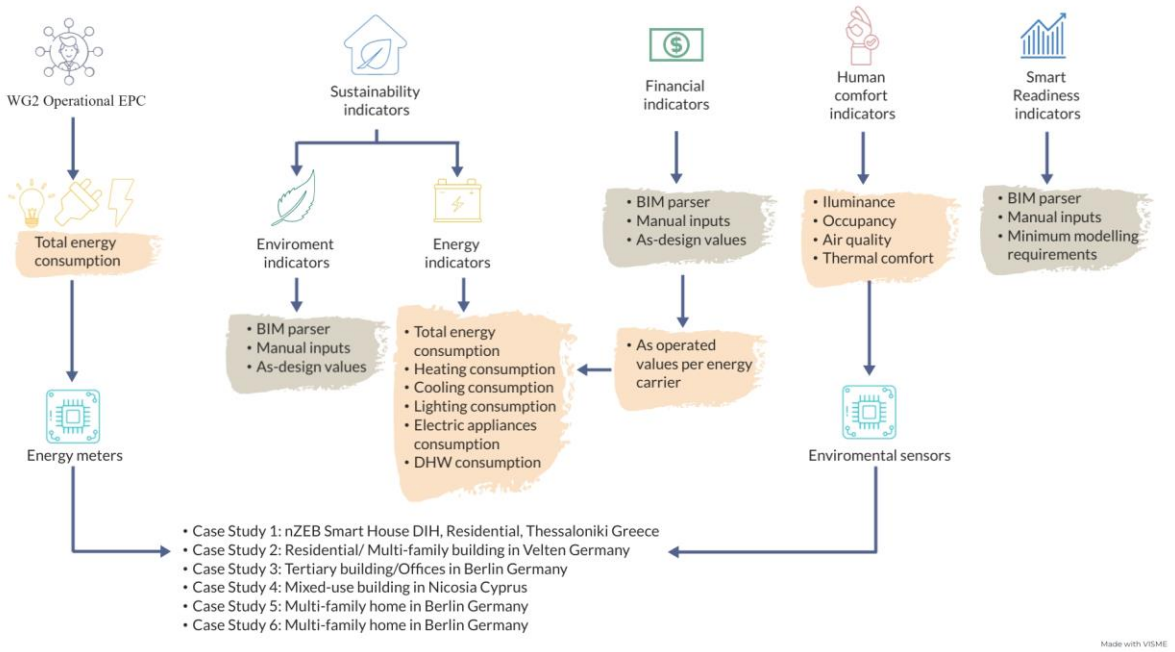


Figure 7: Demonstrator's physical and logical levels architecture diagram

5.1 Overall stakeholder engagement process

Stakeholders of D^2EPC case studies were identified through collaborative research, discussion, and debate activity converging on the stakeholder mapping.

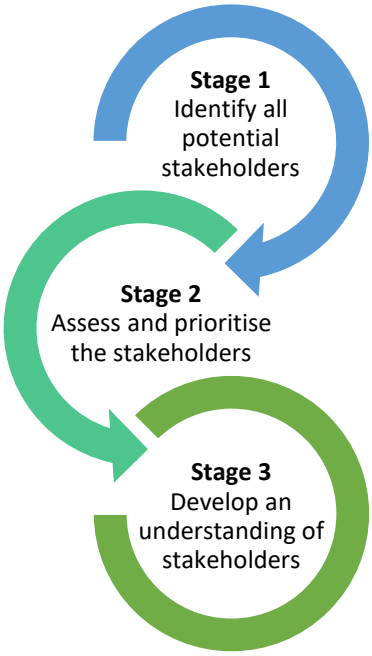


Figure 8: Stakeholder mapping stages

The D^2EPC platform is planned to engage the following stakeholders:

- **D^2EPC Platform Developer/ Administrator:** The team of people responsible for the platform's operation. Their main concern is to identify and solve the issues that emerge in the platform, as well as, to ensure that it is aligned with the regulations in effect through frequent updates.
- **EPC Designer/ Auditor:** The person responsible for the issuance of the EPC, who has an engineering background and additionally is qualified according to the D^2EPC standards.
- **Owner:** The owner of the property or multiple properties, which are managed under common access from one digital place.
- **Tenant of a building:** Besides the owner in the D^2EPC schema the tenants of the building also have access to the platform. They receive useful information regarding the asset, such as the energy consumption, the current EPC rating etc., as well as personalized suggestions towards encouraging their engagement in the increase of the building efficiency.
- **Facility Manager:** In the case of larger buildings, facility managers also have the opportunity to access the platform and to monitor the asset's operational condition, its maintenance needs or acquire certain fields of information (e.g. equipment datasheets).
- **Building Material/ Construction/ Services Industry:** Industry stakeholders have the ability to insert information about their services or products in the platform.
- **Real Estate Agencies, Financial Institutions/ Banks:** They can have a general overview of the building market in terms of energy efficiency. Such information may assist their decision-making process in various ways.
- **Authority, Policy Makers, Registries (b-Logbooks, Digital Passports):** They can have access to aggregated data that may contribute to the redefinition or the update of the current policies for the decarbonization of the building sector.
- **Utilities, ESCOs:** Similarly, to the industry stakeholders, utilities can upload characteristics about their services on the D^2EPC platform (e.g., energy pricing policies). Furthermore, they can have access to the energy consumption data of their customers.

This list of stakeholders matches the identified D^2EPC Business Groups and will be updated in the final version of this deliverable, depending on the achieved engagement of the proposed stakeholders.

The stakeholder involvement process is set in stages starting from a proper information campaign including reports, newsletters, social media, videos, passing by an elicitation stage deploying surveys and other methods of consultation. Another relevant stage organises meetings and workshops to engage with actors and start to build a collaborative co design framework. All the pilots have in common the compliancy with GDPR laws regarding the data owners consent for research purposes. They differ in the typology of ownership and therefore each pilot has declined the engagement process accordingly.

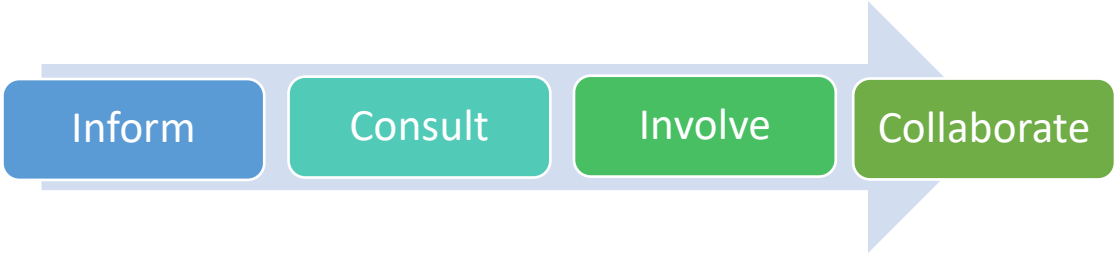


Figure 9: Stakeholder involvement process

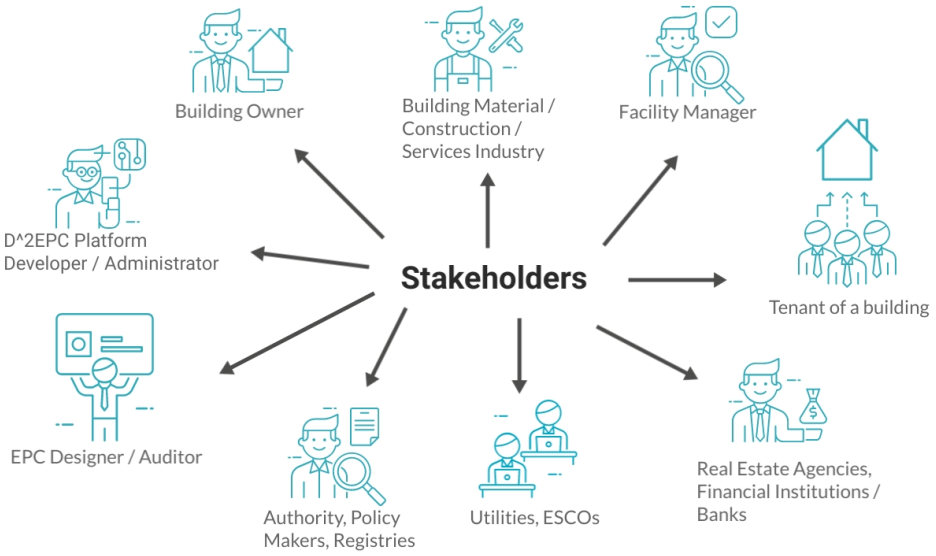


Figure 10: Target groups

Figure 11: Stakeholder engagement actions

A follow up stakeholder engagement plan will be set up to monitor the user requirements accomplishment to ensure methodological vigilance. The evaluation of the solution during pilots will assess user/ stakeholder acceptance and identify room for improvements. As a bottom-up experience made of training for assessors and users, is planned to be broadened and include any target-relevant stakeholder: housing associations, municipalities and real estate developers owning large building stocks.

6. Case Study #1: nZEB Smart House DIH

The first pilot building is as 316 m^2 rapid prototyping demonstration infrastructure shaped like a real residential household, located in Thessaloniki. The availability of a rich building documentation, as well as, the plethora of data from energy meters and indoor sensors, made this pilot site the ideal case study for the deployment of the developed methodologies and calculation tool within D^2EPC.

6.1 Installed equipment

Table 2 presents the already installed IoT devices in nZEB Smart house.

Table 2: nZEB Smart house installed IoT infrstructure

Type of Device	ID	Image	Installation Location	Connectivity	Data Visualization/Access	Measuring Interval
Luminance Sensor (Eltako FIH65B)	SH_Luminance_05		Zone 1 (Office)	EnOcean	SmartHome IOT Platfrom API	100 sec
Temperature-Humidity Sensor (Plugwise Sense)	SH_Temp_Hum_04		Zone 1 (Office)	ZigBee HA 2.0	SmartHome IOT Platfrom API	300 sec
CO2 Sensor (Thermokon SR04 CO2)	SH_C02_Temp_01		Zone 1 (Office)	EnOcean	SmartHome IOT Platfrom API	1000 sec
Luminance Sensor (Eltako FIH65B)	SH_Luminance_01		Zone 2 (Living Room)	EnOcean	SmartHome IOT Platfrom API	100 sec
Temperature-Humidity Sensor (Plugwise Sense)	SH_Temp_Hum_06		Zone 2 (Living Room)	ZigBee HA 2.0	SmartHome IOT Platfrom API	300 sec
CO2 Sensor (Thermokon SR04 CO2)	SH_C02_Temp_02		Zone 2 (Living Room)	EnOcean	SmartHome IOT Platfrom API	1000 sec
Energy_Meter (GAVAZZI EM270)	Energy_PCC		SmartHome PCC	Modbus RTU	SmartHome IOT Platfrom API	15 min
Energy_Meter (GAVAZZI EM340)	Energy_HVAC_OUT_01		HVAC_OUT_01	Modbus RTU	SmartHome IOT Platfrom API	15 min
Energy_Meter (GAVAZZI EM340)	Energy_HVAC_OUT_02		HVAC_OUT_02	Modbus RTU	SmartHome IOT Platfrom API	15 min

Although the aforementioned sensors cover the basic real data needs, additional equipment is planned to be installed in order to extract the entire set of human comfort & wellbeing indicators, described in the Deliverable 2.2 “Human-Centric indicators and user profiles for next generation EPCs v1”. In accordance to the guidelines provided in the Deliverable 3.5 “D^2EPC IoT platform & Interfaces v2”, the following sensors are expected to be deployed (the number of devices will be determined):

- The MCOHome A8-9 multisensor, for monitoring the TVOCs and PM2.5 concentrations
- The AEOTEC Multisensor 6 for monitoring different variables in additional spaces of the building

The deployment of the developed D^2EPC technologies on the pilot building is divided into their main stages (Preliminary, Intermediate and Final). Table 3 presents the applied TC in Case Study 1, elaborating on the month duration of each TC within the project. The following paragraphs present the efforts that are carried out during the Preliminary Testing Stage. The work within the following two stages will be included in the second version of this deliverable.

6.2 Deployment timeline

Table 3: Smart house TC deployment matrix

TC - Description		Months																						
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
TC-01	Extract and Verify Data from BIM																								
TC-02	Issue an D^2EPC asset EPC																								
TC-03	Issue an SRI report																								
TC-04	Asset Rating Indicator Assessment Report (LCC, LCA)																								
TC-05	Provide Design recommendations for performance improvements																								
TC-06	Asset Rating as a service																								
TC-07	Extract and Verify Data from Measurements for the Digital Twin																								
TC-08	Issue an D^2EPC operational EPC																								
TC-09	Operational Rating Indicator Assessment Report (LCC, HC&W)																								
TC-10	Provide Operational recommendations for performance improvements																								
TC-11	Operational rating as a service																								
TC-12	Provide (near) real-time building's energy performance information																								
TC-13	Provide information on as-designed/in-operation deviations																								
TC-14	Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort																								
TC-15	Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs																								
TC-16	Regional Level benchmarking and statistics comparison between regions																								
TC-17	Building performance benchmarking statistics for operational rating of pilot buildings and 3D visualization																								
TC-18	Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance																								
		Preliminary															**Intermediate**						**Final**		

6.3 Definition of Testing Stages

6.3.1 TC-01 -Extract and Verify Data from BIM

Case Study 1 BIM file has been used for the development of the BIM parser module. Furthermore, the BIM file has been updated to contain all the required fields by the D^EPC calculation methodology. D3.3 and D4.1 describe the process that has been used to achieve these results. At the moment the module is able to recognize, extract and verify all the documentation from all the building elements and technical systems included into the building.

6.3.2 TC-02 - Issue an D^2EPC asset EPC

Having available the building's documentation from TC-01, this pilot building has also been used to test the operation of the Asset Rating module. D4.1 demonstrates the results from the Asset Rating issuance.

6.3.3 TC-03 - Issue a SRI report

The Smart House has been used as the first pilot case for the preliminary deployment of SRI subcomponent of the Building Performance Module. A first version of the SRI report has been issued based on collected data and the results are demonstrated in D4.1.

6.3.4 TC-04 - Asset Rating Indicator Assessment Report (LCC, LCA)

Case Study 1 has also been used as the first pilot building for the deployment of the Asser Rating Indicator Assessment Report. D4.1 demonstrates the calculation results regarding the Financial Indicators.

6.3.5 TC-05 - Provide Design recommendations for performance improvements

This TC is closely related to the development of the Road mapping tool, under T4.2. Case Study 1 has been used as an exemplary building for the development of this tool. So far, the module is able to recognize existing deficiencies in the building envelope and provide some preliminary recommendations regarding possible upgrade of its underlying technical systems. Further details will be provided in D4.2.

6.3.6 TC-07 - Extract and Verify Data from Measurements for the Digital Twin

Access of the Information Management Layer to the existing IoT platform has been provided. Upon finalization of the D^2EPC Repository within this Preliminary Stage, this TC will be furtherly evaluated.

6.3.7 TC-08 - Issue a D^2EPC operational EPC

Data required for the calculation of the operational-based EPC are already available as per TC-07. The validation of this TC is expected to be completed by the end of the Preliminary Stage, upon further development of the Operational Rating Module of the Calculation Engine.

6.3.8 TC-09 - Operational Rating Indicator Assessment Report (LCC, HC&W)

Based on Case Study 1 historical data from the IoT Platform as well as results of the Asset Rating Module (TC-02), a first calculation of the Financial and various Human Comfort and Wellbeing indicators has been performed,

towards evaluating the respective subcomponents of the Building Performance Module. The results of the aforementioned evaluation are provided in D4.1.

6.3.9 TC-10 - Provide Operational recommendations for performance improvements

This TC is related to the development of the AI-driven Performance Forecasts module. Currently, the available data-streams are utilised to test the various AI algorithms. Further details will be provided in D4.2.

6.3.10 TC-12 - Provide (near) real-time building's energy performance information

This TC is in collaboration with TC-07. The development of the required user interfaces for the demonstration of building's energy performance on the Web-platform is currently under development.

6.3.11 TC-13 – Provide information on as-designed/in-operation deviations

A comparison of the as-operated/as-designed financial indicators (TC-09) has been carried out, based on data from the Asset Rating Module (TC-02) and the historical measurements from the Case Study 1 IoT Platform. The results are demonstrated in D4.1.

7. Case Study #2: Residential/Multi-family building in Velten Germany

This pilot building was constructed in 1907 and is located in Velten, which is a city in the northwest of Berlin. The building includes apartments used for residential purposes. Currently, the building apartments are occupied by tenants. The total living area of this building is 335m^2.

Figure 12: Residential/Multi-family building in Velten Germany

7.1 Installed equipment

This pilot is one of the six demonstration sites where the implementation of the concepts and solutions developed by the D^2EPc will be tested and validated. Two apartments will be examined in the scope of this project. The building is equipped with wireless sensors and smart meters that enable the close monitoring of electricity consumption, indoor air quality and environmental conditions. Weather data is currently being collected based on geographical coordinates.

Table 4 Devices legend and brands

Device	Image	Description	Where is it installed	Link
Multi sensor indoor		Measure: temperature, humidity and CO_2	In the living room	Link
Multi sensor outdoor		Measure: temperature and humidity	Outdoor	Link
Smart Thermostat		Room temperature, set point	In the living room	Link

Smart Home Controller		Connects thermostats and couples them with the Bosch Smart Home app	In the living room	Link
Electricity Meter		Measure: current-Voltage, active power, instantaneous power, total power consumption, partial consumption, power frequency	In the basement	Link
Gas meter		Measure gas consumption	In the basement	
Gateway		Data-logger for smart metering		

7.2 Deployment timeline

The timeline considers the installation of a dedicated DSL line in each building. One pilot test should be sufficient to be conducted for IoT devices' communication test to ThingsBoard. The refinement and validation of sub-metering (electricity and gas) should be further assessed and validated by the installer. The devices' integration time to ThingsBoard and the D^2EPC platforms will depend on the collaboration with the technical partners and time availability for each pilot. This deployment timeline assumes that there is the consent of end-users to conduct the activities described in the timeline.

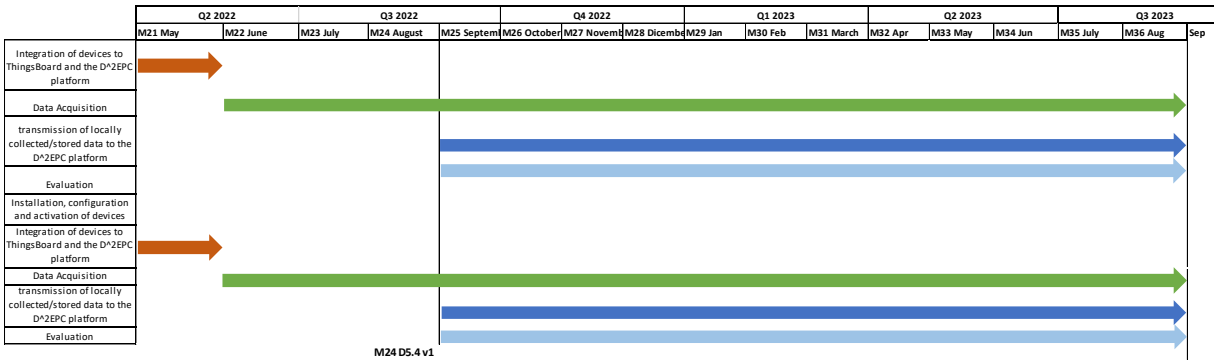


Figure 13: Overall deployment timeline CS2

The deployment of the sensors does not affect the operation of the building in general. The sensors are wireless and easy to install. Since devices do not rely on USB charging or Bluetooth, their functioning and connectivity are considered stable. Occasionally, battery life might be affected (i.e., shortened) if devices are not properly placed, for example, close to metal or magnetic objects, electric devices, or selective glass. In this case, access to the apartments where devices are deployed is needed to change the batteries, but this does not affect the building's operation. The installation of meters can shortly affect the regular provision of electricity or gas as power or gas supply need to be turned off for some time during installation. In addition, if unexpected issues arise, meters may need to be power cycled for further testing or trouble shooting.

In the pictures below, you find the spatial information on the placement of sensors in the building.

Table 5 Sensor Deployment Colour Code

	Multi sensor (indoor)
	Multi sensor (outdoor)
	Electricity meter
	Gas meter
	Thermostat
	Gateway

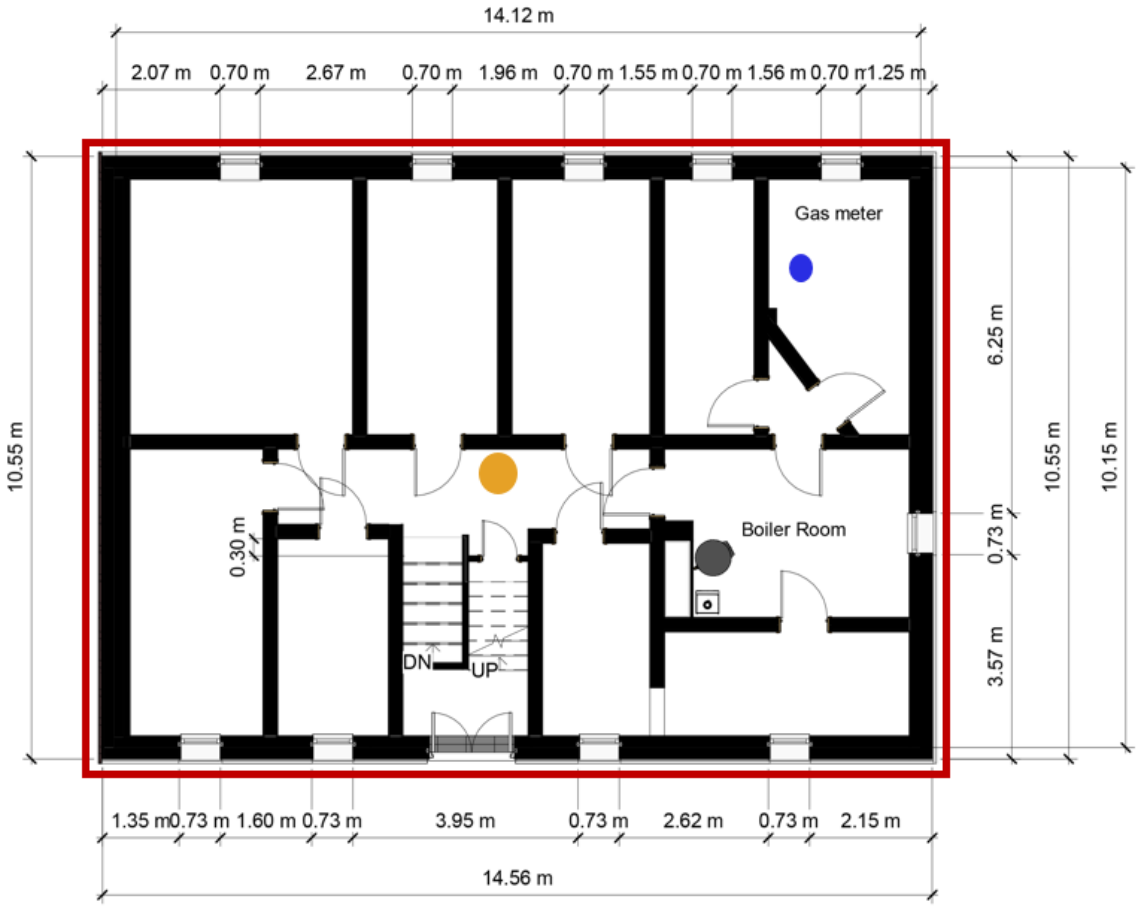


Figure 14: Basement

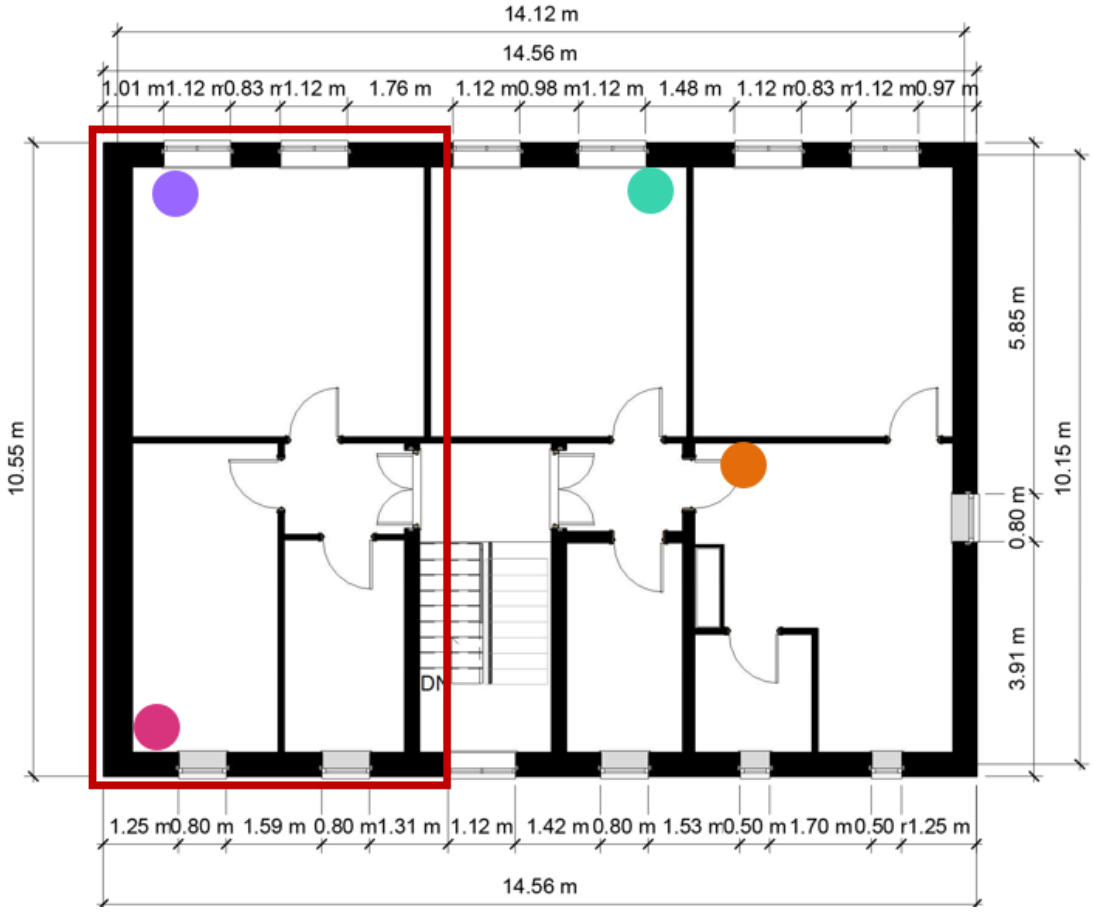


Figure 15: Apartment on the second floor

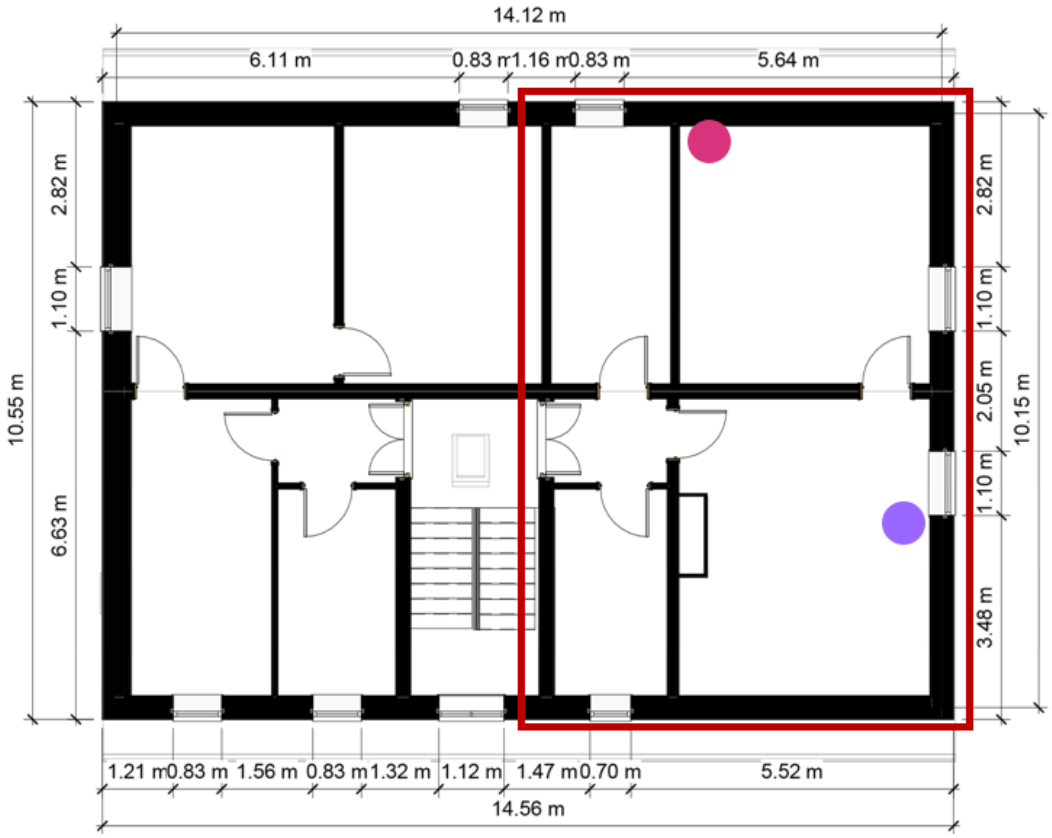


Figure 16: Apartment on the third floor

Table 6 Devices selected for the project

Device	Description	Where is it installed	Link
Multi sensor indoor	Measure: temperature, humidity and CO_2	In the living room	Link
Multi sensor outdoor	Measure: temperature and humidity	In the living room and outdoor	Link
Smart Thermostat	Room temperature, set point	In the living room	Link
Smart Home Controller	Connects thermostats and couples them with the Bosch Smart Home app	In the living room	Link
Electricity Meter	Measure: current-Voltage, active power, instantaneous power, total power consumption, partial consumption, power frequency	In the basement	Link
Gas meter	Measures gas consumption	In the basement	
Gateway	Data-logger for smart metering		

Table 7 IoT deployment in Velten

Scenario 1 - IoT deployment in Velten	
Scope for the D^2EPC project	2 apartments in a residential building
Number of devices installed	9
Type of devices and sensing parameters	
CO2, Temperature and humidity sensors (indoor)	2 sensors measuring indoor CO2, temperature and humidity (1 per apartment)
Temperature and humidity (indoor)	2 sensors measuring indoor temperature and humidity (stairways)
Temperature and humidity (outdoor)	**1** sensors measuring outdoor temperature and humidity
Electrical smart meters - wireless	2 smart meters measuring electricity consumption in kWh among other parameters as described in section 5.4
Weather data from service provider	Yes
Communication/network protocols	Sigfox and NB-IoT
Data transfer to D^2EPC platform (external server)	REST API, request method POST - authentication required[1]

[1] Method tested at the company (Cleopa GmbH) - process not implemented with D^2EPC partners yet. Authentication process is required before implementation of data transfer.

7.3 Definition of testing stages

More specifically, final tests of the D^2EPC solutions will be conducted to assess their technological efficiency and accomplishment of initial objectives. The tests follow a well-structured and neutral methodology based on a set of principles, methods and techniques/tools. The carefully selected indicators will be used to ensure achieved level of efficiency of every different software module and corresponding service.

Table 8 Definition of testing stages C2

TC - Description		Months																							
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
TC-01	Extract and Verify Data from BIM																								
TC-02	Issue an D^2EPC asset EPC																								
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TC-15	Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs																								
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TC-17	Building performance benchmarking statistics for operational rating of pilot buildings and 3D visualization																								
TC-18	Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance																								
		Preliminary															**Intermediate**						**Final**		

7.3.1 TC-01 -Extract and Verify Data from BIM

The BIM parser module will be tested using the BIM file from Case Study 2. The D^2EPC calculation technique will update the BIM file to include all the necessary fields required for the D^2EPC.

7.3.2 TC-02 - Issue an D^2EPC asset EPC

This pilot building will be used to test the functionality of the Asset Rating module thanks to the availability of the building's documentation from TC-01.

7.3.3 TC-03 - Issue a SRI report

Based on the data that was gathered, a preliminary version of the SRI report was published, and the findings are shown in D5.3. The Building Performance Module's SRI subcomponent for Study Case 2 will be released.

7.3.4 TC-04 - Asset Rating Indicator Assessment Report (LCC, LCA)

Case Study 2 additionally will follow an assessment report for the Asser Rating Indicator.

7.3.5 TC-05 - Provide Design recommendations for performance improvements.

This TC is directly tied to the creation of the Roadmapping tool. This TC will be further assessed after the D^2EPC Repository is completed during this preliminary stage.

7.3.6 TC-07 - Extract and Verify Data from Measurements for the Digital Twin

Access of the Information Management Layer to the existing IoT platform has been provided. Upon finalization of the D^2EPC Repository within this Preliminary Stage, this TC will be furtherly evaluated.

7.3.7 TC-08 - Issue a D^2EPC operational EPC

According to TC-07, the information needed to calculate the operational-based EPC is already accessible. Upon further development of the Operational Rating Module of the Calculation Engine, the validation of this TC will be utilised after the conclusion of the Preliminary Stage.

7.3.8 TC-09 - Operational Rating Indicator Assessment Report (LCC, HC&W)

The assessment will make use of data from the IoT Platform and findings from the Asset Rating Module (TC-02). In order to assess each subcomponent of the Building Performance Module, the Financial and different Human Comfort and Well-Being indicators will be first calculated. The following version will include the findings of the evaluation indicated above.

7.3.9 TC-10 - Provide Operational recommendations for performance improvements

This TC is associated with the creation of the module for AI-driven Performance Forecasts. The various AI algorithms are currently tested using the accessible data-streams, the pilot we will be able to test this case after the development tool will be concluded.

7.3.10 TC-12 - Provide (near) real-time building's energy performance information

This TC operates in conjunction with TC-07. The creation of the necessary user interfaces for the Web-platform demonstration of a building's energy performance is currently underway.

7.3.11 TC-13 – Provide information on as-designed/in-operation deviations

Based on information from the Asset Rating Module, a comparison of the as-operated/as-designed financial indicators (TC-09) will be done (TC-02). The outcomes will be presented in the deliverable's subsequent iteration.

7.4 Stakeholder engagement

Stakeholders directly included in the project were asked for their consent according to the GDPR law for any operational use of the measured or calculated data.

Interactions with tenants are addressed to better exploit the equipment potentialities provided. Especially with the firms implementing sensors and the final users, it is important to reach a stage of collaboration to receive their feedback and restart the learning process that reiteratively improves the service provided.

8. Case Study #3: Tertiary building/Offices in Berlin Germany

The third pilot building is occupied by a metalworking company and has a total area of 2235 m^2. It is in Berlin, Germany. The building can be divided into the following areas: the stainless-steel production hall 2, which is also hosting a plasma cutting machine, the production hall 1, the staff room, the work equipment warehouse, the lathe and milling shop, the polish and paint shop and four warehouses. The company's offices are located on the first floor, above the work equipment warehouse and turning and milling shops. The other areas are designed as industrial halls. The whole building (excluding offices) is included within the scope of the D^2EPC project.

Figure 17: Tertiary building/Offices in Berlin Germany

8.1 Installed equipment

The current IoT deployment in the Berlin pilot is demonstrated in the table below.

Table 9 IoT deployment CS3

Current IoT deployment in Berlin	
Scope for the D^2EPC project	Industrial building in Berlin - metal working company
Number of devices installed	4
Type of devices and sensing parameters	
CO2, Temperature and humidity sensors (indoor)	2 sensors measuring indoor CO2, temperature and humidity
Temperature and humidity (indoor)	2 sensors measuring indoor temperature and humidity
Weather data from service provider	Yes
Communication/network protocols	Sigfox
Data transfer to D^2EPC platform (external server)	REST API, request method POST[2]

[2] Method tested at the company (Cleopa GmbH) - process not implemented with D^2EPC partners yet. Authentication process is required before implementation of data transfer.

Figure 18: Map of installed devices CS3

Table 10: Scenario 2 - IoT deployment in Berlin

IoT deployment in Berlin	
Scope	Industrial building in Berlin - metal working company
PLAN Berlin	
Devices to be installed	**Number**
Gas meters - wired M-Bus	2-3
Electricity meter - wired M-Bus	1
THO (outdoor temperatur and humidity) – wired/wireless M-Bus	1
FlexSense (outdoor Temperature and humidity) - Sigfox	1
Data-logger - wired M-Bus	1
Internet (Router, 100MBit/s; 40MBit/s)	
Communication network protocols	

Sigfox, M-Bus
Data transfer to D^2EPC platform (external server)
REST API, request method POST

In this pilot, the installation of IoT devices did not affect the regular operation of the building. The devices were located at several points in the production halls, trying to avoid as much direct contact as possible with metal surfaces. Below it is present the envisioned IoT devices installed in the building.

8.2 Deployment timeline

The deployment timeline considers the IoT devices' communication tests to ThingsBoard as the starting point of data acquisition. The refinement and validation of sub-metering (electricity and gas) has been further assessed and validated by the installer. The devices' integration time to ThingsBoard and the D^2EPC platforms depends on the collaboration with the technical partners and the timetable of deployment stages for each pilot. The following deployment timeline assumes that the consent of end-users to conduct the activities was provided.

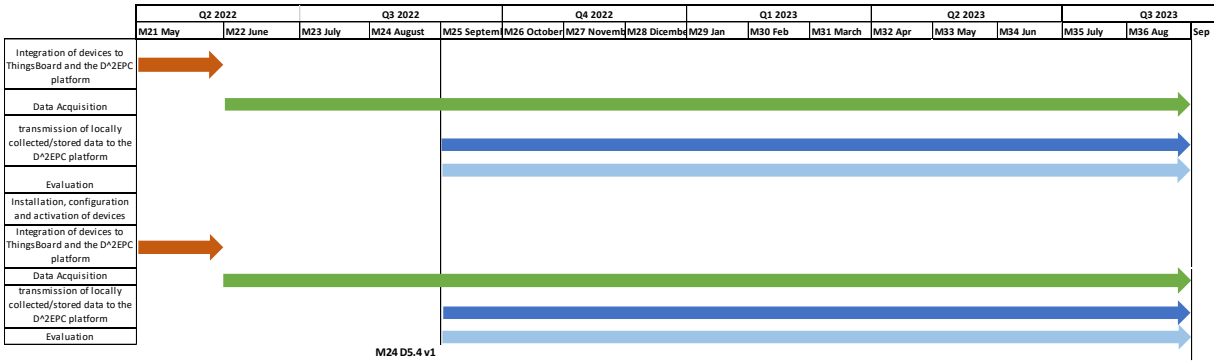

Figure 19: Overall deployment timeline CS3

Equipment tendering and Installation

- Identification of available IoT and availability of data for the pilots (according to D5.3 - Pilot Planning and Setup v1 – M18)
- Preparation of installation and/or data integration plans for all the pilots set of deadlines (round discussion with Pilot managers)
- Monitoring of IoT deployment processes and deadlines (installation or integration challenges)
- Pilot Risks and Mitigation Actions

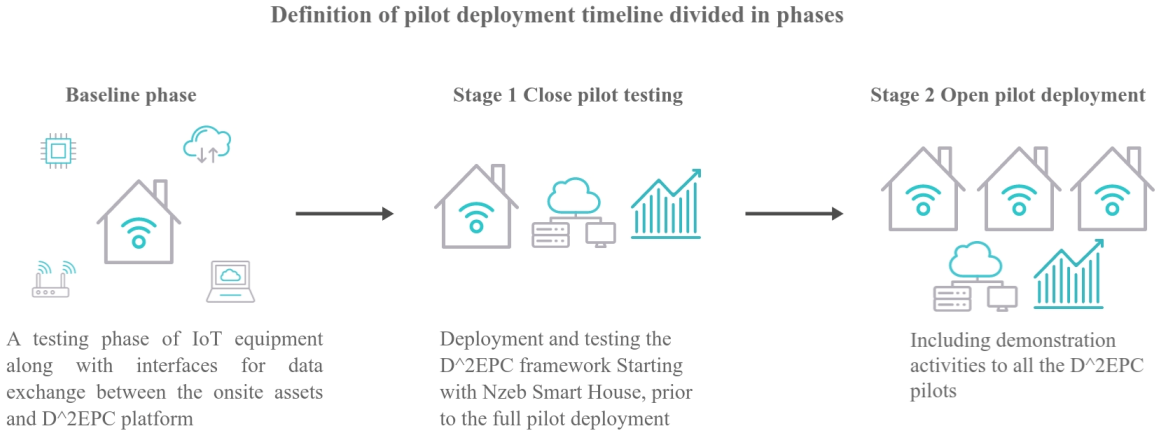

Figure 20: Definition of pilot deployment timeline divided in phases

8.3 Definition of testing stages

The following table describes the testing stages for CS3

Table 11 Definition of testing stages C3

TC - Description		Months																						
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
TC-01	Extract and Verify Data from BIM																								
TC-02	Issue an D^2EPC asset EPC																								
TC-03	Issue an SRI report																								
TC-04	Asset Rating Indicator Assessment Report (LCC, LCA)																								
TC-05	Provide Design recommendations for performance improvements																								
TC-07	Extract and Verify Data from Measurements for the Digital Twin																								
TC-08	Issue an D^2EPC operational EPC																								
TC-09	Operational Rating Indicator Assessment Report (LCC, HC&W)																								
TC-10	Provide Operational recommendations for performance improvements																								
TC-11	Operational rating as a service																								
TC-12	Provide (near) real-time building's energy performance information																								
TC-13	Provide information on as-designed/in-operation deviations																								
TC-14	Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort																								
TC-15	Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs																								
TC-16	Regional Level benchmarking and statistics comparison between regions																								
TC-17	Building performance benchmarking statistics for operational rating of pilot buildings and 3D visualization																								
TC-18	Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance																								
		Preliminary															**Intermediate**						**Final**		

8.3.1 TC-01 -Extract and Verify Data from BIM

The Case Study 3 BIM file has been used as a testing sample for the development of the BIM parser module. The BIM file will be updated to contain all the required fields by the D^2EPC calculation methodology.

8.3.2 TC-02 - Issue an D^2EPC asset EPC

Having available the building's documentation from TC-01, this pilot building will be used to test the operation of the Asset Rating module after his development during the intermediate phase. D4.1 demonstrates the results from the Asset Rating issuance.

8.3.3 TC-03 - Issue a SRI report

The SRI subcomponent of the Building Performance Module for the study case 3 was issued. A first version of the SRI report has been issued based on collected data and the results are demonstrated in D5.3. The SRI subcomponent of the Building Performance Module for the study cases 3 will be issued once all possible information will be available in the BIM file

8.3.4 TC-04 - Asset Rating Indicator Assessment Report (LCC, LCA)

Case Study 3 will follow an Asser Rating Indicator Assessment Report.

8.3.5 TC-05 - Provide Design recommendations for performance improvements

Upon finalization of the D^2EPC Repository within the Preliminary Stage, this TC will be furtherly evaluated and recommendations for performance improvements will be provided.

8.3.6 TC-07 - Extract and Verify Data from Measurements for the Digital Twin

Access of the Information Management Layer to the existing IoT platform has been provided. Upon finalization of the D^2EPC Repository within this Preliminary Stage, this TC will be furtherly evaluated.

8.3.7 TC-08 - Issue a D^2EPC operational EPC

Data required for the calculation of the operational-based EPC are already available as per TC-07. The validation of this TC is expected to be completed during the intermediate phase, upon further development of the Operational Rating Module of the Calculation Engine. After these steps the test case will be carried out for CS3.

8.3.8 TC-09 - Operational Rating Indicator Assessment Report (LCC, HC&W)

Data from the IoT Platform as well as results of the Asset Rating Module (TC-02) will be utilised for the assessment. The first calculation of the Financial and various Human Comfort and Wellbeing indicators will be performed, towards evaluating the respective subcomponents of the Building Performance Module. The results of the evaluation will be provided in the next version.

8.3.9 TC-10 - Provide Operational recommendations for performance improvements

This TC is related to the development of the AI-driven Performance Forecasts module. Currently, the available data-streams are utilised to test the various AI algorithms.

8.3.10 TC-12 - Provide (near) real-time building's energy performance information

This TC is in collaboration with TC-07. The development of the required user interfaces for the demonstration of building's energy performance on the Web-platform is currently under development.

8.3.11 TC-13 – Provide information on as-designed/in-operation deviations

A comparison of the as-operated/as-designed financial indicators (TC-09) will be carried out, based on data from the Asset Rating Module (TC-02). The results will be demonstrated in the next version of the deliverable

8.4 Stakeholder engagement

One of the most important collaborations is the one established with metalworking company's manager and with building owner. The collaboration could bring multiple benefits: reducing costs of retrofitting, address the building renewal by following an action program based on evidence regarding the expected performances ex post. Thus, the collected data will be evaluated in close cooperation with the involved stakeholders to identify opportunities for energy efficiency maximisation and overall energy performance improvement.

9. Case Study #4: Mixed-use building in Nicosia Cyprus

The fourth pilot building is in Nicosia, Cyprus and is owned by Frederick University. The building setup of energy-efficient practical structures and extended smart sensors connections, create the best conditions for testing out the technological advancements that are developed within the D^2EPC project. The amount of data and measurements provided by the installed equipment can be leveraged to gain insight into its operational features.

Figure 21: Frederick University New Wing façade

The building introduced in this case study is a multi-use building located in the area of Palouriotissa, Nicosia, Y. Frederick Str. (Longitude and Latitude 33°22’46.70 “E, 35°10’46.20 "N) with quite a diverse set of spaces, systems, and assets. Frederick University's new wing building is a two-story 2100 m^2 building, its volume is approximately 7,100m3 (included the basement floor/parking area), and it was built in 2007. The entire new wing building covered is divided into three separate zones monitored in detail, and in terms of energy monitoring, it provides a complete data flow that fully depicts the building’s status. The building consists of a basement (area of 450 m^2), ground floor (area of 545 m^2), and two floors (area of 545 m^2 on each floor). University's cafeteria is on the ground floor; on the first floor, there are three seminar halls of 220 students’ capacity, and offices are found on the second floor. The building can host up to 390 people. The total height of the building is 15.60 m from the basement floor to the terrace. The individual heights of the floors are 4.10 m for the typical floors and the ground floor. The services that are provided within the building include heating, cooling, ventilation, lighting, and electrical appliances.

9.1 Installed equipment

In the FRC building, there are 30 input meter data loggers and 45 input meter core data loggers for measuring the energy performance of the building, while 3 zone monitoring and remote sensors are responsible for measuring the carbon dioxide, temperature, and relative humidity. The measurements have started in the middle of June 2021 and will continue throughout the project. The measurement data is divided in a way, as seen in Table 70. Based on the measured values, the existing sensing equipment is categorized as follows.

Table 12 Measurement data for FRC building

Floor	Item			Measurements
Ground floor	Usage			▪ Canteen ▪ Elevator
1st floor	Usage	1st floor total lights	Lecture Theatre Large Lights	▪ Lecture Theatre L LIGHTS1 m11 ▪ Lecture Theatre L LIGHTS2 m13 ▪ Lecture Theatre L LIGHTS3 g13 ▪ Lecture Theatre L LIGHTS4 g14
			Lecture Theatre Small N Lights	▪ Lecture Theatre N LIGHTS1 k6 ▪ Lecture Theatre N LIGHTS2 m8
			Lecture Theatre Small S Lights	▪ Lecture Theatre S LIGHTS1 m6 ▪ Lecture Theatre S LIGHTS2 k11
			Utilities	▪ Lecture Corridor LIGHTS k7 ▪ Utilities South LIGHTS g11 ▪ Utilities North LIGHTS k13
		▪ 1st floor sockets		
2nd floor	Usage	Lights total POWER		▪ Lights OFFICE 1 ▪ Lights OFFICE 2 ▪ Lights OFFICE 2 ▪ Lights UTILITIES 1 ▪ Lights MEETING ROOM ▪ Lights OFFICE 12 ▪ Lights OFFICE 6 ▪ Lights PRINCIPAL OFFICE ▪ Lights CORRIDOR ▪ Lights OFFICE 10 ▪ Lights OFFICE 5 ▪ Lights OFFICE 3 ▪ Lights OFFICE 7 ▪ Lights OFFICE 11 ▪ Lights UTILITIES 2 ▪ Lights UTILITIES 3 ▪ Lights OFFICE 4 ▪ Lights OFFICE P1 ▪ Lights OFFICE 8
		▪ 2nd Floor Sockets		
Roof	Usage			▪ Power EVRV-G3| ▪ Power EVRV-G2| ▪ Power EVRV-G1| ▪ Power VRV-2F2| ▪ Power VRV-2F1|

The installed equipment in the pilot includes:

- Indoor conditions measurement devices (Temperature, Relative Humidity, CO_2) (HOBO MX1102A)
- 4 power meter data loggers (1xEG4130 Pro - 30 Input, 3xEG4115 – 15 Input).

Table 13 Occupancy, Surface area, and Volume per floor

Floor	Number of people	Surface area (m^2)	Volume (m^3)
Ground floor	35	467	1450
First floor	50	487	1450
Second floor	25	487	1450
Total	110	1441	4350

The D^2EPC indicators are related to the operational rating scheme, concerning:

- heating,
- cooling,
- lighting,
- appliances,
- domestic hot water,
- total consumption.

In Table 13 the occupancy, surface area, and volume per floor, as well as in total based on the actual measurements of the pilot building in Cyprus are presented.

a. Indicators' documentation

Based on the real-time measurements of the FRC's pilot case, the related to heating and cooling, lighting, and electrical appliances indicators are documented in Table 14- Table 16. The time step of the KPIs calculation is annual (June 21-May 22), biannual (June 21-November 21 and December 21-May 22 and per semester. These indicators have been calculated in relation to the occupancy, the surface area and the volume per floor of the building.

Table 14 Annual Indicators – June 2021-May 2022

Load	Annual Amount	Unit
Total Heating and Cooling	25.22	(kWh/m²)
	330.33	(kWh/Occupants)
	8.34	(kWh/m³)
Total Heating	7.31	(kWh/m²)
	95.76	(kWh/Occupants)
	2.41	(kWh/m³)
Total Cooling	17.91	(kWh/m²)
	234.57	(kWh/Occupants)
	5.93	(kWh/m³)
Total Lighting for 1st and 2nd floors	14.22	(kWh/m²)
	184.57	(kWh/Occupants)
	4.76	(kWh/m³)
Total Electrical Appliances	19.18	(kWh/m²)
	249.10	(kWh/Occupants)
	6.43	(kWh/m³)
Total Ground floor (October21 – May22)	69.60	(kWh/m²)
	928.76	(kWh/Occupants)
	22.42	(kWh/m³)
Total Power of the building	128.22	(kWh/m²)
	1692.76	(kWh/Occupants)
	41.95	(kWh/m³)

Table 15 Biannual indicators

Load	Amount		Unit
	Summer-Autumn	Winter-Spring	
Total Heating and Cooling	15.42	9.80	(kWh/m²)
	202.07	128.26	(kWh/Occupants)
	5.11	3.23	(kWh/m³)
Total Lighting for 1st and 2nd floors	6.84	7.38	(kWh/m²)
	88.74	95.83	(kWh/Occupants)
	2.29	2.47	(kWh/m³)
Total Electrical Appliances	10.93	8.25	(kWh/m²)
	141.94	107.16	(kWh/Occupants)
	3.67	2.76	(kWh/m³)
Total Ground floor (October21 – May22)	13.81	55.79	(kWh/m²)
	184.30	744.46	(kWh/Occupants)
	4.45	17.97	(kWh/m³)

Total Power of the building	47	81.22	(kWh/m²)
	617.05	1075.71	(kWh/Occupants)
	15.52	26.43	(kWh/m³)

Table 16 Seasonal Indicators

Load	Amount				Unit
	Summer	Autumn	Winter	Spring	
Total Heating and Cooling	9.89	5.53	4.18	5.62	(kWh/m²)
	129.59	72.48	15.54	73.51	(kWh/Occupants)
	3.28	1.83	3.55	1.85	(kWh/m³)
Total Lighting for 1st and 2nd floors	3.14	3.70	3.48	3.90	(kWh/m²)
	40.77	47.97	18.33	50.61	(kWh/Occupants)
	1.05	1.24	2.66	1.30	(kWh/m³)
Total Electrical Appliances	5.19	5.74	4.05	4.20	(kWh/m²)
	67.39	74.55	22.35	54.61	(kWh/Occupants)
	1.74	1.93	3.03	1.41	(kWh/m³)
Total Ground floor (October21 – May22)	-	13.81	24.32	31.47	(kWh/m²)
	-	184.30	136.33	419.89	(kWh/Occupants)
	-	4.45	18.17	10.14	(kWh/m³)
Total Power of the building	18.22	28.78	36.03	45.19	(kWh/m²)
	237.75	379.3	192.55	598.62	(kWh/Occupants)
	6.07	9.45	27.41	14.7	(kWh/m³)

9.2 Definition of testing stages

Table 17 Testing stages plan CS4

TC - Description		Months																						
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
TC-01	Extract and Verify Data from BIM																								
TC-02	Issue an D^2EPC asset EPC																								
TC-03	Issue an SRI report																								
TC-04	Asset Rating Indicator Assessment Report (LCC, LCA)																								
TC-05	Provide Design recommendations for performance improvements																								
TC-06	Asset Rating as a service																								
TC-07	Extract and Verify Data from Measurements for the Digital Twin																								
TC-08	Issue an D^2EPC operational EPC																								
TC-09	Operational Rating Indicator Assessment Report (LCC, HC&W)																								
TC-10	Provide Operational recommendations for performance improvements																								
TC-11	Operational rating as a service																								
TC-12	Provide (near) real-time building's energy performance information																								
TC-13	Provide information on as-designed/in-operation deviations																								
TC-14	Provide regular recommendation for improving operational energy performance & conditions in terms of health and comfort																								
TC-15	Regional Level Visualisation of dynamic (aspect of time) energy performance information for asset-based EPCs																								
TC-16	Regional Level benchmarking and statistics comparison between regions																								
TC-17	Building performance benchmarking statistics for operational rating of pilot buildings and 3D visualization																								
TC-18	Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance																								
		Preliminary															**Intermediate**						**Final**		

9.2.1 TC-01 -Extract and Verify Data from BIM

The BIM parser module is being developed using the BIM file from Case Study 4. The BIM file has also been updated to include all the fields needed for the D^2EPC calculation Currently, the module can identify, extract, and verify almost all documentation from all construction components and technological systems.

9.2.2 TC-02 - Issue an D^2EPC asset EPC

This pilot building will also been used to test the functionality of the Asset Rating module thanks to the availability of the building's documentation from TC-01.

9.2.3 TC-03 - Issue a SRI report

The SRI subcomponent of the Building Performance Module for the study case 4 was issued. The second pilot case for the initial deployment of the Building Performance Module's SRI subcomponent was the New Wing building.

9.2.4 TC-04 - Asset Rating Indicator Assessment Report (LCC, LCA)

The Asset Rating Indicator Assessment Report deployment has employed Case Study 4 as the second pilot building. Furthermore, the LCA analysis results have been presented in D2.3.

9.2.5 TC-05 - Provide Design recommendations for performance improvements

The development of the Road mapping tool, under T4.2, is strongly tied to TC-05. This tool was created using Case Study 4 as an example of a building. As of now, the module can identify current flaws in the building envelope and offer some early suggestions for potential upgrades to its underpinning technical systems.

9.2.6 TC-07 - Extract and Verify Data from Measurements for the Digital Twin.

The current IoT platform is in the process of gaining accessibility to the Information Management Layer. TC-06 will be further assessed after the D^2EPC Repository is completed during this preliminary stage.

9.2.7 TC-08 - Issue a D^2EPC operational EPC

It is anticipated that the validation of this TC will be finished by the conclusion of the Preliminary Stage, upon advancement of the Operational Rating Module of the Computation Engine.

9.2.8 TC-09 - Operational Rating Indicator Assessment Report (LCC, HC&W)

The Operational Rating Indicator Assessment Report deployment has employed Case Study 4 as a pilot building. The computation results for the Financial Indicators are shown in D4.1. Furthermore, the LCA analysis results have been presented in D2.3.

9.2.9 TC-10 - Provide Operational recommendations for performance improvements

TC-10 is associated with the creation of the module for AI-driven Performance Forecasts. The various AI algorithms are currently tested using the accessible data-streams.

9.2.10 TC-12 - Provide (near) real-time building's energy performance information

TC-12 works in tandem with TC-07. The creation of the necessary user interfaces for the Web-platform representation of a building's energy effectiveness is currently in progress.

9.2.11 TC-13 - Provide information on as-designed/in-operation deviations

Using information from the Asset Rating Module (TC-02) and by comparing it with the IoT Platform's measurements (TC-07), an analysis of the as-operated/as-designed financial indicators (TC-08) will be figured out.

9.3 Stakeholder engagement

User acceptance is key for achieving the expected impact of D^2EPC, thus user and stakeholder-centered design and innovation principles should be adopted, as well as active feedback and consultation from stakeholders to be pursued. Companies that dealing with building energy management systems, smart sensors, as well as energy supply companies are only a few of the stakeholders that should be targeted, in order to promote energy efficiency improvements. Thus, the collected data will be evaluated in close cooperation with the involved stakeholders to identify challenges and limiting factors in the building provided services.

10. Case Studies #5 and 6#: multi-family buildings in Berlin Germany

CS5 and CS6 are 100 years old, multi-apartment buildings, comprising also building segments oriented vertical to the street with one adiabatic side. For both, the same owner is one of the stakeholders.

The fifth pilot building is a multifamily structure located at Mendelstraße 5, 13817 Berlin-Pankow. The building has a total size of 2,929 square feet and has 17 flats. This case study is distinguished by the age of the structure, which was constructed in 1900. In the past ten years, the structure has been renovated. The building satisfies its energy needs with electricity and gas services.

Figure 22: Case Study 5 [1]

Case Study 6 is located in Neukoelln, Sonnenallee 159, in the centre of Berlin. It is a historical building consisting of three parts with dominant residential usage. The building was erected in 1918. It occupies a total building area of 2231m^2 and 29 apartments. District heating was installed in 1989 while there is no central infrastructure for cooling and ventilation.

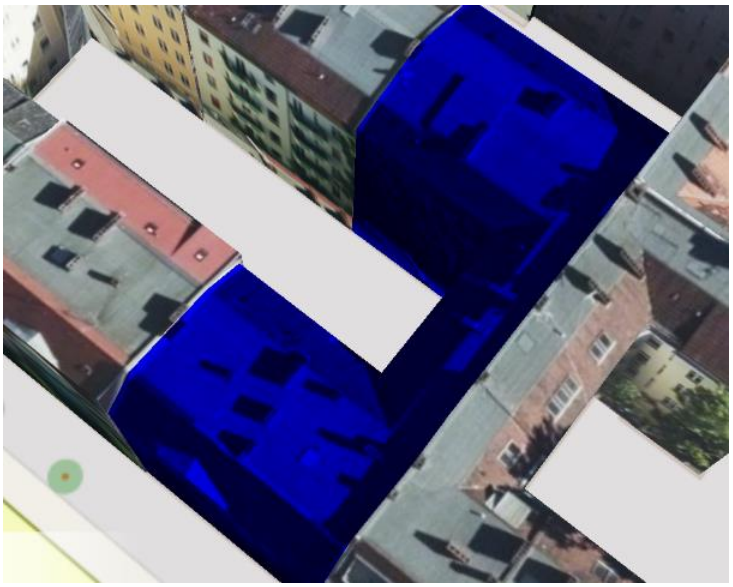

Figure 23: Case Study 6

10.1 Installed equipment

The sensor devices have been installed at certain residential apartments of **CS5**. The installed devices deliver the following data:

- Heat Pump geothermal EZ_WP2
- Heat Pump heat recovery from exhaust EZ_WP1
- Gas GZ_K
- Power Solar Thermal into heating system buffer WZ_KSP,
- Power Solar Thermal to heat pump 2 WZ_QKR.

Currently, a device from Legrand called Netatmo Homecoach [1] has been connected to a 4G modem, since not all the apartments have internet access available, a certain number of rooms were connected. This device measures:

- Temperature in °C
- Humidity in %
- CO_2 in ppm (optical measurements)
- Pressure in mbar
- Noise in dB

The devices are placed in living rooms where wall sockets are available, depending on the particularities of each apartment. Actual dashboard data from the Netatmo Apps can be retrieved, along with past measured data via a different API. The latter shall be provided for every hour of the past day to ensure the acceptance of the apartments' residents.

Regarding the **CS6**, Similar data acquisition devices (namely the Netatmo Homecoach) have been installed. The metering devices have been installed at some selected building's apartments, to measure a number of indoor conditions-related variables.

Since there is no building energy management system, no temperature data recordings are available. For the needs of the project, an official weather service [3] for the region can be utilized.

Up to now, no central metering electrical system of the building is available. If possible, such central meter will be installed by a measuring service provider.

Access to the existing heating demand meter has been requested from the district heating service provider, though heat demand data may also be retrieved from the energy supplier (FHW-Neukölln), as data are being recorded and transferred every 15 minutes (i.e. consumption in kWh, power in kW, inflow and return temperature and the amount of water (m^3/h).

10.2 Deployment timeline

The table below outlines the planned deployment timeline for both pilot sites.

Table 18 Deployment timeline Case Study 5 and 6

Phase	Q1/2022	Q2/2022	Q3/2022	Q4/2022	Q1/2023	Q2/2023	Q3/2023
Planning							
Procurement of room measurement devices							
API implementation							
Apartments Data acquisition							
Central meters data acquisition							
Evaluation							

10.3 Definition of testing stages

Table 19 Definition of testing stages - CS5

TC - Description		Months																						
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
TC-01	Extract and Verify Data from BIM																								
TC-02	Issue an D^2EPC asset EPC																								
TC-03	Issue an SRI report																								
TC-04	Asset Rating Indicator Assessment Report (LCC, LCA)																								
TC-05	Provide Design recommendations for performance improvements																								
TC-07	Extract and Verify Data from Measurements for the Digital Twin																								
TC-08	Issue an D^2EPC operational EPC																								
TC-09	Operational Rating Indicator Assessment Report (LCC, HC&W)																								
TC-10	Provide Operational recommendations for performance improvements																								
TC-11	Operational rating as a service																								
TC-12	Provide (near) real-time building's energy performance information																								
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TC-17	Building performance benchmarking statistics for operational rating of pilot buildings and 3D visualization																								
TC-18	Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance																								
		Preliminary															**Intermediate**						**Final**		

Table 20 Definition of testing stages - CS6

TC - Description		Months																							
		13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
TC-01	Extract and Verify Data from BIM																								
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TC-18	Provision and Visualisation of correlation of building infrastructure (construction materials/technical systems) and energy performance																								
		Preliminary															**Intermediate**						**Final**		

10.3.1 TC-01 -Extract and Verify Data from BIM

CS5 and CS6 BIM files will be used as a testing sample for the development of the BIM parser module. The BIM files have been updated to contain some of the required fields by the D^2EPC calculation method.

10.3.2 TC-02 - Issue an D^2EPC asset EPC

Having available the building's documentation from TC-01, the two case studies will be used to test the provision of Asset Rating module after its development during the intermediate phase.

10.3.3 TC-03 - Issue a SRI report

The SRI subcomponent of the Building Performance Module for the CS5 and CS6 will be issued once all possible information will be available in the BIM file.

10.3.4 TC-04 - Asset Rating Indicator Assessment Report (LCC, LCA)

CS5 and CS6 will follow an Asser Rating Indicator Assessment Report.

10.3.5 TC-05 - Provide Design recommendations for performance improvements

Upon finalization of the D^2EPC Asset Rating Module this TC will be furtherly evaluated and recommendations for performance improvements provided.

10.3.6 TC-07 - Extract and Verify Data from Measurements for the Digital Twin

The TC will be furtherly evaluated after the finalisation of the D^2EPC repository and the connection to the pilot cases will be established.

10.3.7 TC-08 - Issue a D^2EPC operational EPC

Data required for the calculation of the operational-based EPC will be available from TC-07. The validation of this TC is expected to be completed during the intermediate phase, upon further development of the Operational Rating Module of the Calculation Engine. After these steps the test case will be carried out for CS5.

10.3.8 TC-09 - Operational Rating Indicator Assessment Report (LCC, HC&W)

Data from the IoT Platform will be utilised for the assessment. The first calculation of the Financial and various Human Comfort and Wellbeing indicators will be performed, towards evaluating the respective subcomponents of the Building Performance Module. The results of the evaluation will be provided in the next version.

10.3.9 TC-10 - Provide Operational recommendations for performance improvements

This TC is related to the development of the AI-driven Performance Forecasts module. Once available specific data-streams will be utilised to test the various AI algorithms.

10.3.10 TC-12 - Provide (near) real-time building's energy performance information

This TC is in collaboration with TC-07. The development of the required user interfaces for the demonstration of building's energy performance on the Web-platform is currently under development.

10.3.11 TC-13 – Provide information on as-designed/in-operation deviations

A comparison of the as-operated/as-designed financial indicators (TC-09) will be carried out, based on data from the Asset Rating Module (TC-02). The results will be demonstrated in the next version of the deliverable.

10.4 Stakeholder engagement

The involvements of the tenants started with the distribution of the letters of consent. With regards to the automated data acquisition from heat meters contact to the district heating supplier was established. SEC covers the part of EPC issuers actively seeking for additional tenants in the vicinity of the installed access point to take the existing additional two Netatmo devices. The owner of the building was actively involved in the drawing phase of the renovation plan in BIM file.

11. Conclusions

The first version of D5.4 aimed at framing the validation and demonstration methodology and providing a general deployment timeline for testing stages in all the case studies.

The benchmarking activity will lead to the comprehension of how the new dynamic EPC has to perform on the pilots' site in each Energy Performance Category (A-F). The barriers and potentialities in comparison with the existing schemes comprise the difficulties to overcome in the data collection. The demonstration had to carry out data collection (in the context of the piloting and validation phase) and a set of large-scale validation tests to assess the technology and effectiveness of the proposed framework in real life conditions. For these reasons, the consortium had to comply with all European and national legislation and directives relevant to the country where the data collections were taking place. An analysis of each pilot building reveals the availability of required information according to the methodology, and the several D^2EPC components utilized to calculate the building's overall energy performance. On the other hand, the lack of permission to gather data highlights the risks for the implementation of the proposed methodology framework in certain countries (e.g. Germany). The evaluation of implementation, including measures to overcome such barriers, will be reported in the second publication of the present deliverable (M36).

The second version of the D5.4 will provide the definitive methodological framework for validation and demonstration. After that, the test cases will have reiteratively refined various aspects of the platform system architecture. Any interoperability issues during the project's implementation (between the D^2EPC modules, individual devices, network, and communication technologies) will be addressed and solved within the validations. The proposed solution will be designed to fit widely adopted technologies, as well as to be fully interoperable with project partners' technologies and products. Any interoperability issue will be reported in second version of the present deliverable.

12. References

[1] e+Zeit Ingenieure, "MFH: Anbau & Dachausbau für Wohnungserweiterung.," 29 08 2022. [Online]. Available: https://ezeit-ingenieure.de/projekt/mehrfamilienhaus-mendelstrasse/.

[2] "Netatmo," [Online]. Available: https://www.netatmo.com/en-eu/aircare/homecoach/specifications.

[3] Deutscher Wetterdienst, [Online]. Available: https://www.dwd.de/DE/leistungen/klimafaktoren/klimafaktoren.html. [Accessed 14 09 2022].

[4] J. Smith, "inteGRIDy sample reference," *EU,* pp. 1-2, 2016.