Evaluation Report for D^2EPC Pilots

The D^2EPC project has received funding from the EU's Horizon 2020 research and innovation programme under grant agreement No 892984

Project Acronym:	D^2EPC
Project Full Title:	Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness
Grant Agreement:	892984
Project Duration:	36 months (01/09/2020 – 31/08/2023)

DELIVERABLE 5.5
Evaluation Report for D^2EPC Pilots

Work Package:	WP5 - Demonstration and Impact Assessment
Task:	T5.4 Evaluation and Comparative assessment of NG EPC
Document Status:	Final
File Name:	D^2EPC_D5.5_ Evaluation Report for D^2EPC Pilots_KTU
Due Date:	31.08.2023
Submission Date:	31.08.2023
Lead Beneficiary:	KTU

Dissemination Level	
Public	☒
Confidential, only for members of the Consortium (including the Commission Services)	☐

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Version History

v	Author	Date	Brief Description
0.1	Paulius Spudys, KTU	9/5/2023	Initial draft, TOC
0.2	Paulius Spudys, Egle Klumbyte, KTU	29/05/2023	KPI1, KPI14 input
0.3	Nikos Katsaros, CERTH	1/6/2023	KPI6, KPI9 input
0.4	Paris Fokaides, Phoebe-Zoe Georgali, FRC	2/6/2023	KPI7, KPI12, KPI13 input
0.5	Christiana Panteli, CLEO	5/6/2023	KPI2, KPI10 input
0.6	Altmann Naghmeh, AEA, Thanos Kalamaris, HYP	6/6/2023	KPI16, KPI17 input, KPI8, KPI11, KPI15 input
0.7	Adrian Cano Cabañero, SGS	28/7/2023	KPI3, KPI4, KPI5 input
0.8	All contributing partners	28/7/2023	Information update
0.9	Paulius Spudys, Egle Klumbyte, KTU	17/08/2023	Data processing, formatting, main sections. Final version for review
1.0	Paulius Spudys, KTU	31/08/2023	Final version for submission

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Executive Summary

This report presents the final results of Task 5.4 Evaluation and Comparative assessment of NG EPC. The main objective of this task was to define and implement the methodology for evaluating and assessing the impact of the D^2EPC project from various perspectives – technical, economic, environmental, and social.

To assess the project's technological efficiency and achievement of its initial objectives, a list of Key Performance Indicators (KPIs) was defined, encompassing the comprehensiveness and acceptance of the solution by various stakeholders. The KPIs methodology defined utilizes input from EPC assessors, end-users, and project partners for the calculation of KPIs, considering their essence. A total of 17 KPIs were identified, based on the main expected impacts and initial objectives identified for the project. By providing comprehensive guidance, the methodology ensured a clear and consistent understanding of the indicators, enabling effective and accurate evaluation of the D^2EPC project's results. Moreover, the detailed descriptions and calculation methodologies served as valuable resources for the creation of comprehensive questionnaires to gather valuable feedback from the stakeholders.

A total of three questionnaires were delivered to different stakeholders, depending on the nature of the KPIs and the respondents' experience in the field of energy efficiency and EPC issuance procedures. Tailored questionnaires suited the specific needs of expertise of each stakeholder group, ensuring that the questions would be relevant to their field of knowledge. This allowed to gather accurate and valuable feedback of their experience. The classification of the questionnaires and the topics of the respondents' feedback is as follows:

- **EPC assessors** – acceptance and understanding of the D^2EPC platform and novel indicators; integration of operational rating, BIM technologies and SRI; drawbacks of current EPC schema and possible standards improvements; perception of the impact of the solution in energy sector.
- **Pilot End-users** - acceptance and understanding of D^2EPC platform and novel indicators; awareness of energy efficiency and operational rating; acceptance of EPCs; triggered renovation and energy savings.
- **Project partners** – improvement in absorptive capacity, market knowledge and exploitation of the results.

The results of the qualitative assessment delights that process has allowed the measurement of 17 key indicators to assess the technical, economic, environmental and social impacts of the D^2EPC project. Through both numerical analysis and qualitative surveys, it was possible to carry out a comprehensive assessment including the views of stakeholders. The high levels of the D^2EPC solution acceptance achieved confirm that the project has successfully achieved its objectives and expected impacts.

As this project delivered components and tools on a relatively high technology readiness level, this document also includes technology acceptance and impact assessment, by performing cost-benefit analysis exercises (CBA). The CBA methodology provides a comprehensive and accurate assessment of the costs and benefits associated with the D^2EPC solution, and to inform decision-making regarding its implementation.

The cost-benefit analysis (CBA) methodology for this task involves the identification and quantification of costs and benefits, as well as requirements of setting the timeframe for analysis. The methodology delivered also consists of discounting and sensitivity analysis parts. The findings of the cost-benefit analysis are presented in a clear and concise manner, detailing the financial implications and expected benefits.

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List of Acronyms and Abbreviations

Term	Description
AI	Artificial Intelligence
BCR	Benefit-Cost Ratio
BIM	Building Information Modelling
CBA	Cost-Benefit Analysis
EBPD	Energy Performance of the Buildings Directive
EPC	Energy Performance Certificate
EU	European Union
GHG	Greenhouse Gas Emissions
GIS	Geographic Information System
HC&W	Human Comfort & Wellbeing
IEQ	Indoor Environmental Quality
KPI	Key Performance Indicator
NPV	Net Present Value
OR	Operational Rating
SCC	Social Cost of Carbon
SRI	Smart Readiness Indicator
UI	User Interface

1 Introduction

1.1 Scope and objectives of the deliverable

This deliverable presents the results and actions taken to assess the D^2EPC project and its impacts in technical, environmental, economic and social terms. This includes defining the list of relevant KPIs for the evaluation procedure, as well as comprehensive definition of each KPI and its calculation methodology. The document also describes and delivers comprehensive questionnaires that were prepared under the task, as well as elaborates on the results of the assessment in written and graphical forms.

The Report also aims to form and define the cost-benefit analysis methodology, taking into account the identification and quantification of direct and indirect costs of the solution implementation. The presented methodology also includes criteria for setting the timeframe of the analysis, as well as taking into account discounting and sensitivity assessment. Cost-benefits analysis concludes with the indicative results.

1.2 Structure of the deliverable

The flow of information is presented in a coherent way in the document. Starting in Section 2, the impact assessment criteria for the D^2EPC project are presented and described.

The next section (Section 3) provides detailed definitions of the KPI assessment methods, a detailed description of each KPI and the calculation methodology.

Section 4 of the document provides a detailed description of the design of the CBA methodology as well as indicative results.

Section 5 presents the results of the evaluation of the D^2EPC project, including the visual and numerical representation of the KPI values. The results for each KPI are presented in an easily understandable way and described accordingly.

The document is finalised with conclusions section and annexes that constitutes additional material prepared for the evaluation and assessment purposes.

1.3 Relation to Other Tasks and Deliverables

The document "D^2EPC Pilot Project Evaluation Report" can be read as a stand-alone document. However, in order to gather all the information needed for the impact assessment of the project, this task was very much interlinked with others. T5.1 was responsible for organising the D^2EPC platform training workshop, during which relevant feedback was collected. In addition, pilot responsible partners (T5.3) were in charge of organising end-user workshops to present the tool and collect feedback from end-users of each case study. Other tasks related to the development of the D^2EPC platform and additional functionalities collaborated documenting KPIs and during report preparation. In overall, this task is interlinked with all work package activities in the sense that it presents the validation results of the D^EPC framework.

2 D^2EPC Evaluation based on Expected Impacts and Project Objectives

D^2EPC project is focused on the need for building decarbonization and presents a dynamic strategy to strengthen energy performance certificates for building performance improvement. The dynamic EPCs include important elements such as building performance monitoring, energy management, and renovation planning, thus contributing significantly to reducing energy consumption, minimizing environmental impacts, and enhancing occupants' quality of life. As the project has set its ambitious goals, expected impacts and foreseen objectives were identified during the proposal preparation phase. Given the importance of achieving the initial objectives, project evaluation and impact assessment procedures are based on the identification of key performance indicators derived from expected impacts and project objectives.

2.1 Expected Impacts

Table 1 presents a summary of expected impacts that were identified and relevant for the project assessment, as well as the target values that have been set to be achieved by the project.

Table 1. Expected impacts

Expected impact	Title	Success indicator and Target Value
Expected impact 1	Improved user-friendliness of EPCs in terms of clarity and accuracy of the information provided.	User acceptance rate of dEPCs >80%; Meet at least 90% of the existing goals of users for improved user-friendliness.
Expected impact 2	Enhanced user awareness of building energy efficiency.	Satisfaction rate of pilot participants >80%; Meet at least 90% of the existing goals of users for enhanced user awareness; Number of identified standards to be updated>10.
Expected impact 3	Primary energy savings triggered by the project (in GWh/year).	PES triggered by the project after entering market – full development: >80 GWh/year; Renovation plans triggered by D^2EPC demonstration: 70% of pilot users in favour of retrofitting.
Expected impact 4	Investments in sustainable energy triggered by the project (in million Euro).	Annual turnover due to D^2EPC implementation after entering market – full development: 56 million €/year; Renovation plans triggered by D^2EPC demonstration: 70% of pilot users in favour of retrofitting.
Expected impact 5	Reduction of the greenhouse gases emissions (in tCO_2-eq/year) and/or air pollutants (in kg/year) triggered by the project.	Reduction of GHG emissions after entering market – full development: 17,091 t CO_2-eq/year; Renovation plans triggered by D^2EPC demonstration: 70% of pilot users in favour of retrofitting.

Improving innovation capacity and the integration of new knowledge	Increasing partners' absorptive capacity.	Acquire and fuse new technological knowledge.
	Improving partners' market knowledge.	Enrich and update market-related knowledge.
	Enhancing exploitation potential.	Improvement in scientific publications, patents, licensing knowledge, as well as scientific networking.
Contribution to any other environmental and societal impacts	Boosting energy efficiency.	Market-related knowledge by interdisciplinary interaction, raising awareness, reduction of energy consumption.
	Upgrading Indoor Environmental Quality & Comfort.	Introduce a set of parameters that account not only for energy use, but also for human comfort and wellbeing .
	Improving renovation rate.	Increase renovation acceptance rate.

2.2 Project Objectives

Table 2 presents a summary of project objectives that were identified and relevant for the project assessment, as well as the target values that have been set to be achieved by the project.

Table 2. Project objectives

Project Objective	Title	Success indicator and Target Value
Objective 1	The introduction and establishment of the concept of the dynamic EPC, an operational certificate to be calculated and issued on a regular basis.	Establishment of the concept of dynamic EPCs, issued on a regular basis.
Objective 2	The definition of the drawbacks and discrepancies of the current EPC scheme, as well as the update of EU standards on the classification requirements of buildings.	Draft and delivery of a set of recommendations for the required upgrade of existing CEN standards, to enable the integration of the dynamic EPC concept.
Objective 3	The enhancement of EPCs through a novel set of indicators which cover environmental, financial, human comfort and technical aspects of new and existing buildings, aiming to simplify the understanding of buildings energy performance and to present a more comprehensive overview of the actual energy performance of buildings.	Introduction of human comfort related indicators for the energy assessment and certification of new and existing dwellings and non-dwellings.
Objective 4	The integration of actual operational data from buildings into the EPCs using advanced data collection infrastructure and BEPS tools integrated into BIM.	Development of the required Level 3 6D-BIM literacy for integration of calculation data into EPC software. Development of required buildings' digital twins allowing the integration of actual data into the EPC calculation procedure.

Objective 5	The integration of smart readiness rationale into the building's energy performance assessment and certification.	Introduction of SRI related indicators for the energy assessment and certification of new and existing dwellings and non-dwellings.
Objective 6	Intelligent operational digital platform for dynamic EPCs issuance and actual building performance monitoring and improvement, validated and demonstrated under realistic conditions.	User feedback consolidated and impact assessment. Introduction of geolocation representation of actual energy performance of buildings.

3 Key Performance Indicators and Calculation Methodology

This section provides a concise overview of the D^2EPC evaluation, focusing on expected impacts and project objectives. It outlines the assessment process, including the use of key performance indicators (KPIs) and methodologies to measure the project's success. By aligning with the predefined expected impacts and project objectives, this evaluation offers valuable insights into the achievement of its goals.

KPIs utilized during project evaluation are the main metrics for measuring the success and effectiveness of a project. Defined KPIs cover a wide range of aspects, including technical, economic, environmental and social aspects, and allow for a comprehensive assessment of project performance. Careful identification and evaluation of KPIs can provide valuable insights into the project's achievements, impacts and overall effectiveness. This section constitutes identification of the indicators that will be valuable for the project evaluation and impact assessment procedures.

Identification of indicators is based on the expected D^2EPC project impacts and initial objectives that were presented in Section 2 of this document. Formation of the methodology to assess the success of the project in meeting its objectives consists of comprehensive definition of identified indicators, which is presented in the first subsection for each indicator. Provided description defines the scope of the indicator, as well as the background valuable for the assessment and formation of the questionnaires. Each indicator description delivers basic KPI indicator table, that summarizes the main information and the connection with project expected impacts or objectives.

The second subsection for each indicator presents comprehensive methodology to be utilized for the assessment. By providing detailed guidance, the methodology ensured a clear and consistent understanding of the indicators, allowing an efficient and accurate assessment of the results of the D^2EPC project. In addition, the detailed descriptions and calculation methodologies served as valuable resources for the development of detailed questionnaires to gather valuable stakeholder feedback.

A total of three questionnaires were distributed to different stakeholders, tailored to their specific expertise in the field of energy efficiency and EPC issuance procedures. This customization ensured that the questions were relevant to each group's knowledge and needs, enabling the collection of accurate and valuable feedback. The questionnaires were classified based on the stakeholders' roles, and the topics of their feedback are as follows:

- **EPC assessors:** The questionnaire focused on assessing the acceptance and understanding of the D^2EPC platform and its novel indicators. It also covered aspects like the integration of operational rating, BIM technologies, and SRI. Additionally, the assessors provided insights into the drawbacks of the current EPC scheme and suggestions for possible improvements. Their perception of the solution's impact on the energy sector was also evaluated.
- **End-users:** This questionnaire aimed to gauge the acceptance and understanding of the D^2EPC platform and novel indicators introduced to EPC scheme. It assessed the end-users' awareness of energy efficiency and operational rating. Additionally, feedback on their acceptance of EPCs and the influence of the D^2EPC project on triggering renovations and achieving energy savings was documented.
- **Project partners:** The questionnaire focused on evaluating the improvement in absorptive capacity, market knowledge, and exploitation of results.

The thoughtful design of these questionnaires allowed for a comprehensive evaluation of the stakeholders' perspectives, providing valuable insights into the project's effectiveness and impact from various angles.

The collection of stakeholders' feedback was divided into several stages. The first stage involved the presentation of 10 key questions during the D^2EPC platform presentation sessions, which were organized under Task 5.1 activities. Separate sessions were conducted for EPC assessors and end-users, and live feedback was collected interactively. In the second phase, an extended questionnaire was distributed to attendees of workshops, providing sufficient time for the respondents to answer the questions.

It is worth noting that some aspects of the indicators described could not be evaluated due to the lack of user's interaction with the final version of the D^2EPC platform. As the platform was presented during the workshop, some aspects related to the use of the platform itself could not be assessed in depth, though access to the platform could be provided upon request. Nevertheless, the methodology and the definition are still presented in the document.

3.1 KPI1: Improved user-friendliness of EPCs

3.1.1 Indicator description

The user friendliness indicator for the D^2EPC service, which assesses the energy performance certificates (EPCs) of buildings, is derived from a questionnaire targeting both end-users at the pilot buildings and EPC assessors. This questionnaire aims to evaluate the impact of the D^2EPC project on the user-friendliness of EPCs. The indicator assesses multiple aspects related to the perception of user-friendliness, including ease of use, clarity of information, visual presentation, interactivity and responsiveness, error prevention and handling, performance and speed, help and support availability, and mobile responsiveness.

The awareness and usage of EPCs before the D^2EPC project implementation are evaluated through specific questions. For example, for end-users respondents, they are asked if they were aware of EPCs before the D^2EPC project and if they have ever accessed or requested an EPC for a building they live or lived in. Additionally, the frequency of using EPCs for making decisions about energy upgrades, property purchases, or rentals is assessed.

The core of the indicator lies in the perception of user-friendliness. Respondents evaluate the user-friendliness of EPCs after the completion of the D^2EPC project based on the layout and information provided.

By analysing the responses to this questionnaire, the user friendliness indicator provides insights into the effectiveness of the D^2EPC project in enhancing the user experience and improving the usability of EPCs. It captures tenants' and assessors perceptions, preferences, and suggestions, offering valuable feedback for further refinement of the D^2EPC service.

Table 3. KPI1 information

BASIC KPI INFORMATION	
Name	Improved user-friendliness of EPCs.
ID	K1
Expected Impact	User acceptance rate of dEPCs >80%; Meet at least 90% of the existing goals of users for improved user-friendliness.
Description	The "Improved user-friendliness of EPCs" Key Performance Indicator (KPI) in the D^2EPC project measures the level of clarity, ease of use, and comprehensibility of EPCs. It assesses factors such as intuitive design, clear information presentation, visual appeal, interactivity, error handling, performance, and availability of support resources to enhance the user experience.

Assessment Methodology	Pilot End-users and EPC Assessors surveys.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
	Evaluation Period		
Baseline Period	N/A	**Deployment Period**	N/A

3.1.2 Calculation methodology

To quantify the impact of the D^2EPC project on the improved user-friendliness of Energy Performance Certificates, D^2EPC will design and deliver a questionnaire targeting pilot end-users and EPC assessors. The methodology proposal for the questionnaire includes:

Introduction and Background

This section will introduce the purpose of the questionnaire, explaining that it aims to evaluate the impact of the D^2EPC project on the user-friendliness of EPCs.

Demographic Information

Basic demographic information about the respondents will be collected, such as age, gender, occupation, and length of tenancy in the building.

Awareness and Usage of EPCs

The respondents' awareness and usage of EPCs before the implementation of the D^2EPC project will be evaluated, based on the following questions:

1. Were you aware of Energy Performance Certificates (EPCs) before the D^2EPC project?
2. Have you ever accessed or requested an EPC for a building you live or lived in?
3. How often do you use EPCs when making decisions about energy upgrades, property purchases, or rentals?

Perception of User-Friendliness

The respondents' perception of the user-friendliness of EPCs after the completion of the D^2EPC project will be assessed based on the layout and information provided in the EPCs, and whether this is clear and easy to understand.

A non-exhaustive list of statements to assess the user-friendliness includes the following key criteria:

1. **Ease of Use:** Evaluate how easy it is for users to navigate through D^2EPC's interface and perform the desired tasks. Factors such as intuitive design, clear instructions, and logical organization of features and functions will be considered.
2. **Clarity of Information:** Assess how effectively the D^2EPC tool presents information related to energy performance. The tool will be assessed based on the need for the information to be clear, concise, and easily understandable to users with different levels of technical knowledge.
3. **Visual Presentation:** The visual design of the D^2EPC tool, including the layout, typography, colour scheme, and use of graphical elements.
4. **Interactivity and Responsiveness**: D^2EPC's responsiveness to user interactions will also be assessed. Real-time feedback, prompt response to user inputs, and offer interactive features that enhance engagement and usability will be assessed.
5. **Error Prevention and Handling:** D^2EPC will be evaluated on how it handles errors or incorrect inputs from users. Clear error messages provided, guidance on how to correct mistakes offered, and the occurrence of errors through smart validation mechanisms minimization will be assessed.

6. **Performance and Speed:** The tool's performance in terms of loading times, response times, and overall speed will be assessed. The smooth interaction of the tool without significant delays will be evaluated.
7. **Help and Support:** The availability and effectiveness of help and support resources, such as documentation, FAQs, tutorials, and user forums will be evaluated. These resources should assist users in understanding the tool's functionalities and resolving any issues they may encounter.
8. **Mobile Responsiveness:** Evaluate whether the tool is mobile-friendly and responsive, adapting well to different screen sizes and orientations. With the increasing use of mobile devices, a mobile-responsive design is essential for optimal user experience.

Additional Feedback

An open-ended section for respondents to provide any additional comments, suggestions, or concerns regarding the user-friendliness of EPCs and the impact of the D^2EPC project will be provided.

3.2 KPI2: Enhanced user awareness of building energy efficiency

3.2.1 Indicator description

The user awareness indicator for the D^2EPC service is derived from a comprehensive questionnaire targeting pilot users. This questionnaire aims to evaluate the impact of the D^2EPC project on the user awareness of building's energy efficiency. The indicator assesses the adequacy of D^2EPC user-oriented tools with regards to several aspects: (a) Understanding the benefits of information provided by D^2EPC, (b) motivation of continuous monitoring of building's performance, (c) motivation for energy upgrades and renovations, (d) change of Energy Consumption and Behavior Change. The previous user awareness before the D^2EPC project implementation is evaluated through specific questions based on national EPC schemes. Respondents were asked about their awareness of national EPC before the D^2EPC project and if they had ever accessed or requested an EPC for a building they live or lived in. Additionally, the understanding and sufficiency of information as well as their motivation for making decisions about energy upgrades is assessed.

By analysing the responses to this questionnaire, the "user awareness" indicator provides insights into the effectiveness of the D^2EPC project in enhancing the impact and usability of EPCs towards the energy efficiency targets. It captures tenants' perceptions, preferences, and suggestions, offering valuable feedback for further refinement of the D^2EPC service.

Table 4. KPI2 information

BASIC KPI INFORMATION	
Name	Enhanced user awareness of building energy efficiency
ID	K2
Expected Impact	Satisfaction rate of pilot participants >80%; Meet at least 90% of the existing goals of users for enhanced user awareness; Number of identified standards to be updated>10.
Description	The "Enhanced user awareness of building energy efficiency" Key Performance Indicator (KPI) in the D^2EPC project measures the sufficiency of Energy Performance Certificates (EPCs) in the following aspects: ○ understanding the benefits of information provided by D^2EPC ○ motivation of continues monitoring of building's performance ○ motivation for energy upgrades and renovations ○ change of energy consumption and Behavior Change

Assessment Methodology	Pilot End-users survey.		
Unit of Measurement	Likert scale converted to percentage of enhanced User awareness.		
	Evaluation Period		
Baseline Period	N/A	**Deployment Period**	Last 12 months of the project

3.2.2 Calculation methodology

To quantify the impact of the D^2EPC project on the improved user-awareness of building energy efficiency, D^2EPC will design and deliver a questionnaire targeting pilot users. The methodology proposal for the questionnaire includes:

Previous user Awareness and Actions

This section aims to assess the respondents' previous awareness of energy efficiency and their actions taken to improve energy efficiency in their buildings before participating in the D^2EPC project. The assessment is based on their experience with the national EPC schemes. The respondents' awareness will be evaluated with questions based on the following context:

1. Understanding of information provided by national EPC
2. Perceived sufficiency of information provided by national EPC
3. Motivation for energy efficiency upgrades and renovation

Understanding and Sufficiency of information

This section investigates the level of understanding and the perceived sufficiency of the information provided by D^2EPC towards increasing awareness of building's energy efficiency

D^2EPC User awareness and motivation

This section aims to assess the impact of the D^2EPC user-oriented tools on towards increasing the participants' awareness of their building's energy efficiency. The impact of the following D^2EPC tools are evaluated:

1. **Novel aspects of D^2EPC Energy performance certificates**: The effect of information provided by D^2EPC (SRI, LCA, LCC, Human centric Indicators) and the user's understanding of benefits towards increasing the user awareness.
2. **Road mapping tool for performance upgrade**: The effect of customized, cost-effective recommendations on enhancing understanding of energy efficiency in the decision-making process for building renovation.
3. **AI-driven Performance Forecasts**: The impact of machine learning techniques and data analytics used by D^2EPC in predicting and understanding the future energy performance of buildings.
4. **Performance Alerts & Notifications**: The impact of Performance Alerts & Notifications in providing accurate and customized recommendations for daily operations.
5. **Building Energy Performance Benchmarking**. The role of the benchmarking tool in comparing the actual performance of their building with that of other buildings and the improved awareness of the building users.
6. **BIM-based digital twins:** The effect of using BIM and digital twins on the quality and credibility of the EPC results and on the enhanced awareness of energy efficiency of the buildings users.

Energy Consumption and Behaviour Change

This section aims to Investigate any changes in the participants' energy consumption patterns and behaviours after using the D^2EPC platform as well as their motivation to implement energy efficiency measures.

Overall Satisfaction

This is an open section aiming to receive feedback on the participants' overall satisfaction with the D^2EPC project and their willingness for further engagement.

3.3 KPI3: Primary energy savings triggered by the project

3.3.1 Indicator description

In the face of climate change and increasing energy demands, the European Union (EU) has committed to ambitious energy efficiency targets to reduce its environmental footprint. Among the numerous strategies employed to achieve these objectives, the introduction of Energy Performance Certificates has played a significant role.

Energy Performance Certificates (EPCs) have emerged as a crucial tool in Europe's efforts to enhance energy efficiency and reduce greenhouse gas emissions. These certificates provide valuable insights into the energy performance of buildings, thereby promoting awareness among occupants and incentivizing energy-efficient measures.

To quantify energy savings, the simulated energy consumption of the building with energy-efficient measures (e.g., better insulation, energy-efficient appliances) is compared to a baseline scenario, representing the building's energy consumption without these measures.

The primary energy savings are derived from the reduction in energy consumption achieved by implementing the recommended energy-efficient measures.

The availability of EPCs empowers building occupants and potential buyers to make informed decisions based on a building's energy performance. Increased awareness often leads to behavioural changes, such as the adoption of energy-saving practices and the preference for energy-efficient buildings.

The correlation between Energy Performance Certificates and primary energy savings in Europe is evident, as EPCs play a vital role in driving energy conservation, fostering awareness, and encouraging the adoption of energy-efficient practices. Despite challenges, the potential benefits of energy-efficient buildings extend beyond energy savings, contributing significantly to climate change mitigation, energy security, and economic prosperity.

This indicator aims to calculate the reduction in primary energy consumption of buildings.

Table 5. KPI3 information

BASIC KPI INFORMATION	
Name	Primary energy savings triggered by the project
ID	K3
Expected Impact	PES triggered by the project after entering market – full development: >80 GWh/year; Renovation plans triggered by D^2EPC demonstration: 70% of pilot users in favour of retrofitting.
Description	The " Primary energy savings triggered by the project" Key Performance Indicator (KPI) in the D^2EPC project measures the amount of primary energy expected to be saved after implementing the energy efficiency measures recommended.

Assessment Methodology	Calculated. The primary energy savings are calculated as the difference between the primary consumption of the baseline period and the primary consumption of the deployment period.		
Unit of Measurement	GWh per year		
Evaluation Period			
Baseline Period	1 year	**Deployment Period**	Monitoring phase

3.3.2 Calculation methodology

According to data from the European Commission[1], the EU has a residential floor area of 33.65 billion m^2 (2020 data) of which 75% (according to Joint Research Centre[2]) is energy inefficient and should be renovated. That means a potential building stock of around 25.24 billion m^2 that could be renovated in order to become energy efficient.

Considering data from the European Commission[3], a 2.4% of that area is renovated annually. Assuming this target will be achieved when D^2EPC scheme enters the market, this translates into 603.05 million m^2 of residential buildings per year that can be renovated.

Following the methodology introduced during proposal preparation for this long term expected impact as well as end-user's feedback on renovation plans, two scenarios are calculated for potential primary energy saving triggered by the project, . Results are presented in Section 5.

3.4 KPI4: Investments in sustainable energy triggered by the project

3.4.1 Indicator description

The interplay between Energy Performance Certificates and investments in energy efficiency is crucial for driving primary energy savings in Europe. EPCs serve as valuable tools in motivating informed investment decisions, enabling building owners and occupants to contribute actively to sustainability goals. Overcoming challenges and barriers and implementing effective policies and financial incentives can accelerate energy efficiency investments, ultimately leading to substantial energy savings and environmental benefits.

This indicator aims to calculate the amount of money invested in energy measures following the recommendations of the road mapping tool of D^2EPC.

Table 6. KPI4 information

BASIC KPI INFORMATION	
Name	Investments in sustainable energy triggered by the project.
ID	K4
Expected Impact	Annual turnover due to D^2EPC implementation after entering market – full development: 56 million €/year; Renovation plans triggered by D^2EPC demonstration: 70% of pilot users in favour of retrofitting.

[1] https://building-stock-observatory.energy.ec.europa.eu/database/
[2] https://publications.jrc.ec.europa.eu/repository/handle/JRC122347
[3] https://building-stock-observatory.energy.ec.europa.eu/database/

Description	The amount of money invested in energy measures.		
Assessment Methodology	Counted.		
Unit of Measurement	Euro per year		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.4.2 Calculation methodology

According to the European Commission[4], EU building stock accounts for approximately 234 million residential buildings (2020 data). 75% of that stock is energy inefficient and should be renovated (according to Joint Research Centre[5]), providing a potential building stock of 175 million dwellings that could be renovated in order to become more energy efficient. Considering an annual renovation rate of 2.4% of the stock European Commission[6],it is obtained a potential of into 5.8 million residential buildings per year that can be renovated.

As previously, two scenarios are calculated for potential investments in sustainable energy triggered by the project. Results are presented in Section 5 Project Assessment Results.

3.5 KPI5: Reduction of the greenhouse gases emissions and air pollutants triggered by the project

3.5.1 Indicator description

As the global concern over climate change intensifies, it is becoming increasingly evident that reducing greenhouse gas emissions (GHG) is paramount for ensuring a sustainable future. One of the key tools in achieving this goal is the implementation of energy performance certificates (EPCs). These certificates play a crucial role in promoting energy-efficient practices in buildings and, in turn, contribute to the reduction of greenhouse gas emissions.

EPCs directly contribute to emission reduction strategies as they play a role in incentivizing energy-efficient building practices.

This indicator aims to calculate the amount of GHG emissions avoided due to the implementation of D^2EPC Project.

Table 7. KPI5 information

BASIC KPI INFORMATION	
Name	Reduction of the greenhouse gases emissions and air pollutants triggered by the project.
ID	K5
Expected Impact	Reduction of GHG emissions due to D^2EPC project after entering market – full development: 17,091 t CO_2-eq/year; Renovation plans triggered by D^2EPC demonstration: 70% of pilot users in favour of retrofitting.

[4] https://building-stock-observatory.energy.ec.europa.eu/database/
[5] https://publications.jrc.ec.europa.eu/repository/handle/JRC122347
[6] https://building-stock-observatory.energy.ec.europa.eu/database/

Description	The amount of greenhouse gases emissions and air pollutants avoided.		
Assessment Methodology	Calculated. The GHG reduction is calculated as the difference between the amount of GHG emitted on the baseline period and the quantity of GHG emitted on the deployment period.		
Unit of Measurement	Equivalent Tonnes of CO_2 per year		
	Evaluation Period		
Baseline Period	1 year	**Deployment Period**	Monitoring phase

3.5.2 Calculation methodology

Several assumptions must be made to calculate this indicator. Firstly, it is considered that the consumption of one MWh of electricity (EU-28 avg. energy mix), heating oil and natural gas is responsible for the emission of 0.444, 0.306 and 0.240 tons CO_2-eq respectively (considering latest LCA emission factors). It is also considered that most of the energy consumed in residential buildings in EU is for space-water heating/cooling and assuming that the energy that will be saved originates from 30% electricity-on grid, 35% heating oil and 35% natural gas.

Based on these assumptions, the calculations for the two scenarios are carried out using statistical building stock data obtained from EC databases. As before, the potential GHG emission reductions from the project have been calculated for the two scenarios and the results are presented in Section 5.

3.6 KPI6: The introduction and establishment of the dynamic EPC issued on a regular basis concept

3.6.1 Indicator description

D^2EPC aiming to set the grounds for the next-generation dynamic EPCs has developed a methodology for the regular assessment of building based on their operational performance. In this manner, it will lead to the enhancement of the actual energy performance of EU Member States' building stocks, and a more active role of next-generation EPCs in policy making will be enabled. The operational energy rating calculation follows specific guidelines and includes demands for indicators, such as heating, cooling, lighting, appliances, domestic hot water, total, etc. In particular, the project has recommended to include the following parameters:

- Types of buildings to which the D^2EPC operational rating will apply;
- Indicators of D^2EPC operational scheme (e.g. heating, cooling, lighting, appliances, domestic hot water, total);
- The reference values, based on which the rating will be calculated;
- Normalization practices for operational values;
- Frequency of issuance;
- Methods of measurement of actual consumption and details (e.g. instruments, responsibilities, etc.).

More details on the operational energy rating parameters and the D^2EPC operational rating approach are included as part of D5.1 & D5.6 of the D^2EPC Manual (v1 and v2 respectively).

In order to assess the establishment of the concept of dynamic EPCs, issued on a regular basis, the following performance aspects are considered and will be quantified:

- Number of dynamic EPCs issued (counted)
- Improvement of the building's EPC rating through the as-operated assessment, compared to the as-designed assessment (counted)
- Number of energy end-uses included in the operational rating (counted)
- dEPC issuance maximum parametrization and calculation time (counted)
- dEPC acceptance/understanding score (counted)

3.6.2 Calculation methodology

The following sections describe the calculation process towards assessing each of the indicator's aforementioned aspect.

3.6.2.1 Number of dynamic EPCs issued

The number of D^2EPC case studies for which a dynamic EPC was issued through the Web Platform. This is relevant to the case studies of the project and should reach the value of six (6).

3.6.2.2 As designed/as operated EPC assessment comparison

The asset-based and the operational-based EPC calculation results are compared on the same basis towards identifying differences and thus highlighting the importance of the operational assessment in improving the EPC validity.

3.6.2.3 Number of energy end-uses included in the operational rating

The number of the energy end-uses (heating, cooling, lighting etc.) that the operational rating calculation considers.

3.6.2.4 dEPC maximum parametrization & setup time

Total amount of time required for:

- Setup of the building instance (upload of BIM file and validation) and energy monitoring (registration of metering devices)
- Calculation of the operational rating EPC (historical data fetching, processing, visualization of the results)

The highest resulting amount of time will be considered for the case studies that will be tested.

3.6.2.5 Acceptance/understanding score

Score results based on dedicated questionnaires that will be distributed to EPC Assessors within organized sessions as part of T5.1 activities as well as building end-users' during pilot evaluation workshops. The methodology proposal for the questionnaire includes:

Perception of dynamic EPCs

The respondents' perception of EPCs, is based on the following questions:

1. Were you aware of the operational rating before the D^2EPC project?
2. Have you ever issued an EPC based on the operational/ calculated data?
3. Do you consider the operational rating methodology more accurate than the asset-based rating?

Acceptance of dynamic EPCs

The respondents' perception of the acceptance of EPCs after the demonstration of the D^2EPC project will be assessed based on the information provided in the EPCs and the user's experience by using the D^2EPC Digital Platform.
A non-exhaustive list of statements includes the following key criteria:

1. **Ease of Use:** Evaluate how easy it is for EPC assessors to navigate through DEPC's interface and realize the EPC calculation process. Factors such as intuitive design, clear guidance/ parametrization and calculation time will be considered.
2. **Clarity & Completeness of Information:** Assess how effectively the D^2EPC tool presents information related to operational energy performance and corresponding operational indicators.
3. **Visual Presentation:** The visual design of the D^2EPC tool, including the layout, typography, color scheme, and use of graphical elements.
4. **Interactivity and Responsiveness**: D^2EPC's responsiveness to user interactions will also be assessed. Real-time feedback and prompt response to user inputs will be assessed.
5. **Missing information and Validation:** D^2EPC will be evaluated on how it requires missing information or handles incorrect inputs from users and identifies errors during validation.
6. **Performance and Speed:** The tool's performance in terms of providing the results for the operational rating in a reasonable amount of time will be assessed.

Additional Feedback

An open-ended section for EPC Assessors/ end-users to provide any additional comments, suggestions, or concerns regarding the overall acceptance and understanding of dynamic EPCs and the impact of the D^2EPC project will be provided.

3.7 KPI7: Drawbacks and discrepancies of the current EPC scheme, contribution to standards

3.7.1 Indicator description

The drawbacks and discrepancies indicator for the EPC scheme evaluates the existing shortcomings and inconsistencies within the current framework. This indicator aims to identify and address the issues that hinder the accurate assessment and standardization of energy performance in buildings, while also contributing to the development and implementation of energy performance standards. A comprehensive assessment is conducted through a combination of data analysis and stakeholder consultations.

Through data analysis, the indicator identifies common patterns and trends regarding the drawbacks and discrepancies of the EPC scheme. Stakeholder consultations, including input from building owners, energy assessors, regulatory bodies, and policymakers, are conducted to gather qualitative feedback and insights. These consultations provide an opportunity to discuss the identified issues, propose potential solutions, and gather recommendations for improving the EPC scheme. Furthermore, D^2EPC recognizes the significance of operational energy performance and has played a pivotal role in establishing a specialized European working group, CEN/TC 371/WG 5. This dedicated group focuses on addressing operational energy performance concerns and actively contributes to the advancement of EPCs in this domain.

The core of the indicator lies in understanding the challenges and limitations of the current EPC scheme and its impact on energy performance assessment and standardization. By addressing the identified drawbacks and discrepancies, the indicator aims to enhance the accuracy, reliability, and effectiveness of EPCs in evaluating energy performance in buildings. The findings and recommendations from this indicator contribute to the refinement and improvement of the EPC scheme, ensuring its alignment with international standards and best practices.

Table 8. KPI6 information

BASIC KPI INFORMATION			
Name	Drawbacks and discrepancies of the current EPC scheme, contribution to standards		
ID	K7		
Expected Impact	Contribution to standardization activities		
Description	The drawbacks and discrepancies indicator assesses the existing shortcomings and inconsistencies in EPC scheme, aiming to identify and address issues that hinder accurate assessment and standardization of energy performance in buildings. Through data analysis and stakeholder consultations with building owners, energy assessors, regulatory bodies, and policymakers, it identifies patterns and trends, gathering qualitative feedback. This indicator also examines the EPC scheme's contribution to energy performance standards and regulations. By addressing identified drawbacks, it enhances the accuracy and reliability of EPCs, ensuring alignment with international standards. The findings guide refinements to improve the EPC scheme and enhance energy performance evaluation in buildings.		
Assessment Methodology	EPC Assessors survey.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.7.2 Calculation methodology

Introduction and Background

The calculation methodology for KPI7 involves a comprehensive assessment of the existing EPC scheme, with a focus on identifying drawbacks, discrepancies, and contributions to energy performance standards. The calculation procedure includes data analysis and stakeholder consultations to gather qualitative feedback and insights.

Data Analysis:

The indicator utilizes data analysis to identify common patterns and trends regarding the drawbacks and discrepancies of the current EPC scheme. Data sources such as EPC records, performance evaluations, and relevant documentation are analyzed to identify inconsistencies and shortcomings within the framework.

Stakeholder Consultations:

To gather qualitative feedback and insights, stakeholder consultations are conducted. The consultations entail various parties involved in the EPC scheme, including building owners, energy assessors, regulatory bodies, and policymakers. These consultations provide an opportunity to discuss the identified issues, propose potential solutions, and gather recommendations for improving the EPC scheme.

Identification of Drawbacks and Discrepancies:

The data analysis and stakeholder consultations are aimed at identifying the drawbacks and discrepancies within the current EPC scheme. The focus is on understanding the challenges and limitations that hinder the accurate assessment and standardization of energy performance in buildings. Inconsistencies in assessment methodologies, variations in data quality, challenges in data collection and verification, discrepancies in reporting and labelling, and lack of alignment with international energy performance standards are among the aspects assessed.

Contribution to Standards:

The indicator also examines the contribution of the D^2EPC scheme to the development and implementation of energy performance standards and regulations. It evaluates how the D^2EPC scheme aligns with international standards and best practices. The assessment considers the extent to which the D^2EPC scheme has contributed to the advancement and establishment of energy performance standards, such as those established by CEN/TC 371 and various product or systems committees (TC 089, TC 156, TC 169, TC 228, and TC 247).

Refinement and Improvement:

The findings and recommendations from the drawbacks and discrepancies indicator contribute to the refinement and improvement of the EPC scheme. The aim is to enhance the accuracy, reliability, and effectiveness of EPCs in evaluating energy performance in buildings. By addressing the identified drawbacks and discrepancies, the indicator aims to ensure that the EPC scheme aligns with international standards, best practices, and the evolving needs of energy performance assessment.

The calculation methodology of KPI7 involves a comprehensive assessment of the existing EPC scheme, focusing on identifying drawbacks, discrepancies, and contributions to energy performance standards. The combination of data analysis and stakeholder consultations provides valuable insights for improving the EPC scheme and promoting alignment with international standards and best practices.

3.8 KPI8: The enhancement of EPCs through the coverage of environmental, financial, human comfort and technical aspects

3.8.1 Indicator description

D^2EPC extends the energy assessment of new or existing dwellings by covering different aspects related to the life-cycle of a building, the indoor ambient conditions and the costs of the building operation in the context of consumed energy. Therefore, within the project, a set of key performance indicators is incorporated with a twofold purpose. On the one hand, these indicators allow for monitoring the building's performance from an environmental, comfort and financial scope on predefined intervals. On the other hand, based on the calculated results, specific recommendations are delivered to the end-users towards improving the building's indoor conditions and operation in an energy efficient way.

Impact indicator 8 aims to highlight the level of raised awareness and attractiveness of an enhanced EPC that is not merely limited to the reporting of energy efficiency. To achieve this, D^2EPC's impact in regards to the embedded indicators is quantified via specific questions addressed to the building assessors and users. Hence, dedicated demonstration activities are planned to provide the necessary space for the interaction between the project partners and the interested parties. Within these activities, it is attempted to broaden the participants' understanding on the concepts of building energy performance and efficiency in accordance with the newly-introduced aspects. Furthermore, the participants are asked to provide their feedback via circulated questionnaires which will be later analysed to evaluate the project's impact on enhancing EPCs. Specifically, they are invited to express their familiarity with the current EPC scheme (per country) and provide their opinion in regards to the ease of comprehension, acceptance and expected added-value separately for the environmental, comfort and financial indicators. Lastly, participants are requested to provide ideas and recommendations for contributing to the improvement of D^2EPC's innovative framework.

Table 9. KPI7 information

BASIC KPI INFORMATION			
Name	The enhancement of EPCs through the coverage of environmental, financial, human comfort and technical aspects		
ID	K8		
Expected Impact	User acceptance rate of dEPCs >80%; Meet at least 90% of the existing goals of users for improved user-friendliness		
Description	The "Enhancement of EPCs through the coverage of environmental, financial, human comfort and technical aspects" Key Performance Indicator (KPI) in D^EPC measures the impact of the project on the enhancement of Energy Performance Certificates (EPCs) by extending its scope to different aspects. This KPI examines the ease of comprehension, added-value, acceptance and attractiveness of the incorporated performance indicators by addressing specific question to building users and assessors.		
Assessment Methodology	Pilot End-users and EPC Assessors surveys.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.8.2 Calculation methodology

The respondents' feedback on the innovative aspects incorporated in D^2EPC will be utilised to measure the project's level of impact on the enhancement of future EPCs. Below, a list of the pillars that the impact assessment will be focused on:

1. **Ease of Comprehension:** Evaluate how comprehensible are the advanced topics examined within the D^2EPC indicators framework. Training sessions will be offered to assessors and end-users to give them context in regards to the project's indicators. Then, they will be requested to provide feedback related to the grade of complexity and overall level of understanding.
2. **Added—value:** D^2EPC indicators will be evaluated in regards to the added-value that they offer in a new-age EPC. Respondents will be requested to grade the indicators in the context of:
    a. *Focus and Relevance*: How much the embedded Indicators help to focus attention on the examined aspects.
    b. *Decision Support*: Do the D^2EPC Indicators serve as a valuable tool for decision-making. By providing reliable and timely information, they assist in evaluating the effectiveness of policies, strategies, and interventions in regards to indoor conditions and building operation
    c. *Communication and Accountability*: Indicators enhance communication by providing a common language and framework for discussing complex topics. They facilitate dialogue among stakeholders, helping to align interests, measure progress, and hold entities accountable. Indicators make it easier to communicate achievements, challenges, and goals effectively.
    d. *Early Warning Systems*: Indicators can act as early warning systems by detecting deviations, risks, or potential issues. By monitoring key indicators, organizations and

policymakers can anticipate problems, initiate preventive measures, and respond promptly to emerging challenges.

e. *Benchmarking and Best Practices*: Indicators enable benchmarking, allowing for comparisons against established standards or best practices. They help identify gaps, set targets, and encourage continuous improvement. Indicators allow organizations to measure their performance relative to peers and learn from successful practices.

3. **Acceptance:** The incorporated indicators are calculated based on various static and dynamic elements extracted from the building. For this reason, IoT equipment and detailed building characterisation need to be available in order to provide the appropriate input and enable the KPI calculation. Respondents will be requested to express their point of view on the level of acceptance of the newly-introduced framework in EU level judging by the multiple requirements that arise by such an implementation.
4. **Attractiveness:** The D^2EPC indicators framework will be evaluated in terms of raised attractiveness of a performance certificate. More specifically, the respondents will be requested to express their opinion on how much they consider this innovative KPI framework is able to stimulate building stakeholders to proceed with an issuance of an EPC, beyond legal obligations.

3.9 KPI9: The integration of actual operational data from buildings into the EPCs using advanced data collection infrastructure and BEPS tools integrated into BIM

3.9.1 Indicator description

The use of advanced design models and tools such as Building Information Modelling (BIM), as well as inverse modelling through the creation of buildings' digital twins can turn EPC into a tool which would enable holistic technical, economic and environmental approaches for the design and operation of sustainable buildings. D^2EPC aims to enrich BIMs with operational data taken from BEPS and/or IoT-based data collection infrastructure and make use of the available and increasing number of building energy-related data from sensors, smart meters, connected devices and building systems. This indicator is evaluated considering the following performance aspects:

- The number of Building Digital Twin instances created (counted)
- The number of available building data streams integrated by the Building Digital Twin (counted)
- The amount of time for issuance of the asset-based EPC (counted)
- The amount of information extracted from BIM towards forming the Digital Twin/calculating the asset and operational rating (calculated)
- BIM acceptance/understanding score in EPC issuing process (counted)

3.9.2 Calculation methodology

The following sections describe the calculation process for assessing each of the indicator's aforementioned aspect.

3.9.2.1 Number of Building Digital Twin instances created

The number of D^2EPC case studies for which a BIM-based Digital Twin instance was created.

3.9.2.2 Number of available building data streams integrated by the Building Digital Twin

The number of sensing/metering equipment in the D^2EPC case studies that are able to stream the collected data and are integrated and accessible through the corresponding Building Digital Twin.

3.9.2.3 Amount of time for issuance of the asset-based EPC

The amount of time required for issuance of the asset-based EPC, utilizing the BIM-based Digital Twin and compared against the average time needed when following national assessment methodologies.

3.9.2.4 Amount of information extracted from BIM towards forming the Digital Twin/calculating the asset and operational rating

The amount of information that is parsed from the BIM file towards creating a Digital Twin instance and, following, to calculate the asset-based and operational-based EPCs. Equivalently, the calculation can rely on the amount of additional information required by the validation mechanisms (general validation during upload, validation when calculating the asset and operational rating) in the form of distinct data attributes that need to be provided manually by the user. Thus, the amount of extracted information for each of the three aforementioned tools can be calculated as:

$$BIM\ information\ extraction = 1 - \frac{Number\ of\ manually\ input\ data\ attributes}{Number\ of\ all\ data\ attributes}$$

3.9.2.5 BIM Acceptance/understanding score

Score results based on dedicated questionnaires that will be distributed to EPC Assessors within organized sessions as part of T5.1 activities. The methodology proposal for the questionnaire includes:

Perception of BIM Usage

The respondents' perception of EPCs, is based on the following questions:

1. Were you aware of the BIM concept before the D^2EPC project?
2. If yes, are you aware of Industry Foundation Classes (IFC) specification?
3. Have you ever issued an EPC based on data coming from BIM?
4. Do you consider BIM is mature enough to facilitate and automate EPC issuance process?

Acceptance of BIM Usage

The respondents' perception of the acceptance of BIM Usage after the demonstration of D^2EPC project will be assessed based on the user's experience by using the D^2EPC Digital Platform.
A non-exhaustive list of statements includes the following key criteria:

1. **Ease of Use:** Evaluate how easy it is for EPC assessors to navigate through D^2EPC's interface and utilize the information provided by BIM. Factors such as intuitive design, clear guidance and parametrization will be considered.
2. **Visual Presentation:** The visual design of the D^2EPC BIM-based digital twin, including the layout, typography, information and use of graphical elements.
3. **Interactivity and Responsiveness**: D^2EPC's responsiveness to user interactions will also be assessed. Real-time feedback and prompt response to user inputs will be assessed.
4. **Missing information and Validation:** D^2EPC will be evaluated on how it requires missing information or handles incorrect inputs from users and identifies errors during BIM validation.
5. **Performance and Speed:** The tools performance in terms of extracting the necessary information from BIM in a reasonable amount of time and how this simplifies the overall process will be assessed.

Additional Feedback

An open-ended section for EPC Assessors to provide any additional comments, suggestions, or concerns regarding the overall acceptance and understanding of BIM usage and the impact of the D^2EPC project will be provided.

3.10 KPI10: The integration of smart readiness rationale into the building's energy performance assessment and certification

3.10.1 Indicator description

The integration of smart readiness rationale into the building's energy performance assessment and certification is assessed through a comprehensive methodology that incorporates stakeholder engagement and data analysis. The indicator aims to evaluate the effectiveness of integrating smart readiness concepts into the assessment and certification of building energy performance.

Stakeholder consultations are conducted to gather insights from building owners, energy assessors, technology providers, and policymakers. These consultations enable the identification of key aspects related to the integration of smart readiness, such as data collection and analysis methods, and the impact of smart solutions on energy performance. Data analysis is performed to assess the effectiveness of integrating smart readiness rationale into energy performance assessments and certifications.

By analyzing stakeholder input and data analysis results, the integration of smart readiness rationale indicator provides insights into the effectiveness and benefits of incorporating smart technologies into energy performance assessments and certifications. It highlights the positive impact of smart readiness on energy efficiency, building performance, and occupant comfort. The findings from this indicator contribute to the refinement and improvement of energy performance assessment practices, promoting the adoption of smart technologies for more sustainable and efficient buildings.

Table 10. KPI10 information

BASIC KPI INFORMATION			
Name	The integration of smart readiness rationale into the building's energy performance assessment and certification		
ID	K10		
Expected Impact	Integration of the SRI into the EPC		
Description	The integration of smart readiness into energy performance assessment and certification is evaluated through stakeholder engagement and data analysis. This indicator assesses the effectiveness of incorporating smart technologies in evaluating building energy performance. Stakeholder consultations and data analysis provide insights into key aspects, such as data collection methods and the impact of smart solutions. The indicator highlights the positive impact of smart readiness on energy efficiency, building performance, and occupant comfort. Findings contribute to refining energy performance assessments and promoting sustainable and efficient buildings.		
Assessment Methodology	EPC Assessors survey.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.10.2 Calculation methodology

Awareness and Usage of Smart Readiness:

1. Evaluate the assessors' awareness and prior usage of smart readiness concepts in the context of energy performance assessment and certification.
2. Include questions to determine if the assessors were familiar with smart readiness concepts before the evaluation.
3. Assess the assessors' level of experience and frequency of integrating smart technologies in their assessments.

Perception of Effectiveness:

1. Assess the assessors' perception of the effectiveness of integrating smart technologies, particularly smart readiness, in evaluating building energy performance.
2. Utilize a Likert scale or other rating scales to measure the assessors' level of agreement or acceptance.
3. Evaluate specific aspects related to the integration of smart readiness, such as data collection methods, impact on energy performance evaluation, and benefits for energy efficiency, building performance, and occupant comfort.

Additional Feedback:

1. Provide an open-ended section for assessors to provide any additional comments, suggestions, or concerns regarding the integration of smart readiness into energy performance assessment and certification.
2. Encourage assessors to share their experiences, insights, and recommendations for further improvement.

3.11 KPI11: Demonstration and validation of intelligent dynamic platform for dynamic EPC

3.11.1 Indicator description

D^2EPC aims to extend the current EPC scheme by introducing a digital and dynamic nature to the assessment of a building's energy performance. For this reason, an innovative web platform is developed to be applied into actual demonstration buildings with operational environment and delivered to end-users and EPC assessors. The platform is equipped with various, state-of-the-art services towards exploiting the digital nature of the new-age EPC and transforming energy performance certification to a holistic digital solution that goes beyond the reporting of energy efficiency.

The D^2EPC modules embodied in the digital platform cover various modern concepts related to the building energy assessment and provide the platform's users with different applications and interfaces unlocking innovative functionalities. There are three main components that act as extensions to the digital EPC. i) The WebGiS tool which introduces geolocation representation of actual energy performance of buildings by utilizing the GIS data warehouse. ii) The "added-value services suite which delivers AI-driven performance forecasts, recommendations for improving the energy efficiency and building operation and an alerting engine able to report any performance downgrade. iii) The "extended dEPCs applications toolkit" which contains modules that allow for monitoring of any deployed IoT infrastructure and enable the building's classification and benchmarking.

Impact indicator 11 focuses on evaluating the added-value of the integrated tools that extend the capabilities of the digital platform. Within D^2EPC, a series of activities take place to demonstrate the project's integrated solutions to EPC assessors and building users. The participants are also invited to provide their feedback on the modules presented during demonstration. The input will be later analyzed to quantify the impact of D^2EPC's web platform on upgrading current EPCs to a digitalized certificate. The indicator 11 is directly correlated with the successful completion and implementation of the entirety of designed innovations to the real operational environments of D^2EPC pilots. The final version of the digital platform is the determining factor that increases the impact of D^2EPC in the new-age of building energy certification.

Table 11. KPI11 information

BASIC KPI INFORMATION			
Name	Demonstration and validation of intelligent dynamic platform for dynamic EPC		
ID	K11		
Expected Impact	User acceptance rate of D^2EPC platform extensions >80%;		
Description	The "Demonstration and validation of intelligent dynamic platform for dynamic EPC" Key Performance Indicator (KPI) in D^2EPC focuses on evaluating the added-value of the integrated tools that extend the capabilities of the digital platform. It examines the introduced extensions on a basis of multiple factors (e.g., user experience, performance, innovations and others). This assessment aims to capture the end-users' and EPC assessors' view on the platform extensions from different scopes towards quantifying their impact on enhancing digital EPCs.		
Assessment Methodology	Pilot End-users and EPC Assessors surveys.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.11.2 Calculation methodology

The respondents' perception of the added-value of the "WebGIS tool", the "Added-value services suite" and the "Extended dEPCs applications toolkit" after the completion of the project will be assessed based on their feedback on a number of factors relevant to the toolkit under study:

All Extensions

The respondents' perception of the added-value of the "WebGIS tool", the "Added-value services suite" and the "Extended dEPCs applications toolkit".

1. **Improved Customer Experience:** Assess how the extensions enhance the overall customer experience. This covers features like personalised energy usage insights, building comparison with the relevant building stock, monitoring building operation and conditions, alerting mechanisms and others
2. **Innovation and Future-readiness:** Evaluate how much the extensions increase the potential for driving innovation and preparing for future energy industry trends.
3. **User Interface and Ease of Use:** Assess the tools' user interfaces (UI) and overall usability. Consider the intuitiveness of the interface, ease of navigation, and the availability of user-friendly tools and features.
4. **Performance and Scalability:** Assess the tools' performance in handling large datasets and complex analyses. Consider its processing speed, memory usage, and ability to scale up to accommodate growing data volumes or more demanding analytical tasks.

Added-value services suite

1. **Enhanced Decision-making:** Consider how the extension tools (AI-driven Performance forecasts and roadmapping tools) provide valuable insights and data-driven analytics to support informed decision-making. Grade features such as real-time monitoring, predictive analytics, optimization algorithms and energy efficiency recommendation engines.
2. **Cost Savings:** Assess how the extensions (AI-driven Performance forecasts and Road mapping tool) reduce costs associated with energy consumption.
3. **Environmental Sustainability:** Consider how the toolkit promotes and facilitates the adoption of sustainable energy practices based on the projected energy consumption and the provided recommendations towards optimising the energy usage.

WebGIS tool

1. **Visualization:** Assess the tool's visualization capabilities for creating maps and visual representations of spatial data. Consider the available symbology options, labelling capabilities, map layout functionality, and the ability to create visually appealing and informative maps and visualizations.
2. **Spatial Analysis Capabilities:** Evaluate the tool's ability to perform spatial analysis tasks. Consider the range of analytical functions provided, such as proximity analysis, spatial statistics, overlay operations, network analysis, and suitability modelling.

3.12 KPI12: Increasing partners' absorptive capacity

3.12.1 Indicator description

Increasing partners' absorptive capacity is assessed through a methodology that focuses on enhancing the ability of partners to acquire, assimilate, and apply new knowledge and skills related to energy performance improvement. The indicator aims to evaluate the impact of capacity-building efforts on partners' absorptive capacity within the energy sector.

A combination of training programs, workshops, knowledge-sharing sessions, and collaborative initiatives is implemented to enhance partners' absorptive capacity. These activities aim to improve partners' understanding of energy performance concepts, technologies, and best practices, as well as their ability to effectively implement energy efficiency measures.

The indicator measures various dimensions related to partners' absorptive capacity, including their knowledge acquisition, application of learned knowledge in practice, adoption of innovative approaches, integration of energy efficiency measures into decision-making processes, and ability to disseminate knowledge to relevant stakeholders.

Through the analysis of partners' feedback, the indicator provides insights into the effectiveness of capacity-building initiatives in increasing partners' absorptive capacity. It captures partners' perceptions, skills development, and knowledge transfer, offering valuable feedback for further improvement of capacity-building efforts.

By assessing partners' absorptive capacity, the indicator contributes to the refinement and optimization of capacity-building programs, fostering a more knowledgeable and skilled energy sector workforce. The findings and recommendations from this indicator support the development of effective strategies for increasing partners' ability to implement and sustain energy performance improvements, ultimately driving progress towards a more energy-efficient future.

Table 12. KPI12 information

BASIC KPI INFORMATION	
Name	Increasing partners' absorptive capacity

ID	K12		
Expected Impact	Improve the absorptive capacity of partners for D^2EPC outcomes		
Description	Increasing partners' absorptive capacity is evaluated through capacity-building initiatives that enhance partners' ability to acquire, apply, and disseminate knowledge related to energy performance improvement. Training programs, workshops, and collaborative activities are implemented to improve partners' understanding and implementation of energy efficiency measures. The indicator measures dimensions such as knowledge acquisition, application in practice, and dissemination to stakeholders. Analysis of feedback and performance assessments provides insights into the effectiveness of capacity-building efforts, supporting the development of strategies for sustainable energy performance improvements.		
Assessment Methodology	Survey among D^2EPC partners		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.12.2 Calculation methodology

Introduction and Background:

- Provide an overview of the purpose and objectives of the calculation methodology.

Capacity-Building Initiatives:

- Document the implemented training programs, workshops, and collaborative activities to enhance partners' ability to acquire, apply, and disseminate knowledge related to energy performance improvement.
- Document the improvement of partners' understanding and implementation of energy efficiency measures.
- Tailor the capacity-building initiatives to address partners' specific needs and challenges.

Knowledge Acquisition:

- Assess partners' knowledge acquisition by evaluating their participation and engagement in capacity-building initiatives.
- Collect data on partners' attendance, completion of training programs, and participation in workshops.
- Measure partners' knowledge acquisition through pre- and post-assessments or surveys to evaluate knowledge gained.

Application in Practice:

- Evaluate partners' application of acquired knowledge in practice.
- Monitor partners' implementation of energy efficiency measures in their projects or initiatives.
- Gather data on the extent to which partners have integrated the acquired knowledge into their decision-making processes and actions.

Dissemination to Stakeholders:

- Assess partners' efforts to disseminate knowledge related to energy performance improvement to relevant stakeholders.

- Collect data on partners' communication activities, such as organizing dissemination events, publishing reports, or sharing best practices.
- Measure the reach and impact of partners' dissemination efforts on stakeholders' awareness and adoption of energy performance improvement measures.

Analysis of Feedback and Performance Assessments:

- Analyze feedback from partners regarding the effectiveness of capacity-building initiatives in enhancing their absorptive capacity.
- Conduct performance assessments to evaluate partners' progress and improvement in energy performance practices.
- Consider partners' feedback and performance results as indicators of the effectiveness of capacity-building efforts.

3.13 KPI13: Improving partners' market knowledge

3.13.1 Indicator description

Improving partners' market knowledge is assessed through a comprehensive methodology aimed at enhancing partners' understanding of the energy performance market dynamics, trends, and opportunities. The indicator focuses on evaluating the impact of initiatives on partners' market knowledge within the energy sector.

Various activities, such as market research, workshops, training programs, and knowledge-sharing sessions, are implemented to enhance partners' market knowledge. These initiatives aim to improve partners' understanding of market trends, emerging technologies, policy frameworks, and business models related to energy performance.

The indicator measures multiple dimensions related to partners' market knowledge, including their awareness of market dynamics, knowledge of available energy performance solutions, understanding of customer needs and preferences, awareness of market barriers and drivers, and ability to identify and seize business opportunities.

Through the analysis of partners' feedback, market assessments, and case studies, the indicator provides insights into the effectiveness of initiatives in improving partners' market knowledge. It captures partners' perceptions, knowledge acquisition, and ability to adapt strategies to market conditions, offering valuable feedback for further enhancement of market knowledge initiatives.

By assessing partners' market knowledge, the indicator contributes to the refinement and optimization of initiatives, fostering a more informed and adaptive energy sector workforce. The findings and recommendations from this indicator support the development of effective strategies for partners to better navigate and capitalize on market opportunities, ultimately driving progress towards a more sustainable and competitive energy market.

Table 13. KPI13 information

BASIC KPI INFORMATION	
Name	Improving partners' market knowledge
ID	K13
Expected Impact	Improve the partners knowledge of the market
Description	Improving partners' market knowledge is evaluated through initiatives that enhance their understanding of energy performance market dynamics, trends, and opportunities. Activities such as market research, workshops, and training programs aim to improve partners' awareness of market trends, customer preferences, and business opportunities. The indicator

	measures dimensions like market awareness, knowledge of energy performance solutions, and ability to identify opportunities. Analysis of feedback and market assessments provides insights into the effectiveness of initiatives, enabling the development of strategies for a more competitive and sustainable energy market.		
Assessment Methodology	Survey among D^2EPC partners.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
	Evaluation Period		
Baseline Period	N/A	**Deployment Period**	N/A

3.13.2 Calculation methodology

Capacity-Building Initiatives:

- Implement initiatives such as market research, workshops, and training programs to enhance partners' understanding of energy performance market dynamics, trends, and opportunities.
- Tailor these initiatives to address partners' specific needs and challenges in acquiring market knowledge.

Knowledge Acquisition:

- Assess partners' knowledge acquisition by evaluating their participation and engagement in capacity-building initiatives.
- Collect data on partners' attendance, completion of training programs, and participation in workshops focused on market knowledge enhancement.
- Measure partners' knowledge acquisition through pre- and post-assessments or surveys to evaluate the improvements in their understanding of energy performance market dynamics.

Application in Practice:

- Evaluate partners' ability to apply the acquired market knowledge in their business practices.
- Monitor partners' implementation of energy performance solutions in alignment with market trends and customer preferences.
- Gather data on the extent to which partners have integrated market knowledge into their decision-making processes, product offerings, and marketing strategies.

Dissemination to Stakeholders:

- Assess partners' efforts to disseminate market knowledge to relevant stakeholders.
- Collect data on partners' communication activities, such as organizing dissemination events, publishing reports, or sharing best practices related to energy performance market trends and opportunities.
- Measure the reach and impact of partners' dissemination efforts on stakeholders' awareness and adoption of energy performance solutions.

Analysis of Feedback and Market Assessments:

- Analyze feedback from partners regarding the effectiveness of capacity-building initiatives in improving their market knowledge.
- Conduct market assessments to evaluate partners' progress and improvement in understanding energy performance market dynamics, trends, and opportunities.
- Consider partners' feedback and market assessment results as indicators of the effectiveness of capacity-building efforts in enhancing partners' market knowledge.

3.14 KPI14: Enhancing exploitation potential

3.14.1 Indicator description

Enhancing exploitation potential is assessed through a comprehensive methodology aimed at evaluating the effectiveness of initiatives in maximizing the utilization and commercialization of energy performance solutions. The indicator focuses on assessing the impact of these initiatives on the exploitation potential within the energy sector.

Various activities, such as market assessments, technology assessments, business development programs, and entrepreneurship support, are implemented to enhance exploitation potential. These initiatives aim to identify and leverage opportunities for scaling up and commercializing energy performance solutions.

The indicator measures multiple dimensions related to exploitation potential, including market demand and viability analysis, technology readiness and scalability assessment, identification of value chains and business models, intellectual property protection, access to finance and funding mechanisms, and market entry strategies.

Through the analysis of feedback from partners, the indicator provides insights into the effectiveness of initiatives in enhancing exploitation potential. It captures stakeholders' perceptions, success stories, and lessons learned, offering valuable feedback for further enhancement of exploitation potential initiatives.

By assessing exploitation potential, the indicator contributes to the refinement and optimization of initiatives, fostering a more conducive environment for the widespread adoption and commercialization of energy performance solutions. The findings and recommendations from this indicator support the development of effective strategies for maximizing the value and impact of energy performance solutions, ultimately driving progress towards a more sustainable and economically viable energy sector.

Table 14. KPI14 information

BASIC KPI INFORMATION			
Name	Enhancing exploitation potential		
ID	K14		
Expected Impact	Enhance the exploitation potential of DEPC partners		
Description	Enhancing exploitation potential is evaluated through initiatives that maximize the utilization and commercialization of energy performance solutions. Activities such as market and technology assessments, business development programs, and entrepreneurship support aim to identify opportunities for scaling up and commercializing solutions. The indicator measures dimensions including market demand, technology readiness, value chains, intellectual property, and finance mechanisms. Analysis of partner feedback provides insights into the effectiveness of initiatives, supporting the refinement of strategies to maximize the value and impact of energy performance solutions in creating a sustainable and economically viable energy sector.		
Assessment Methodology	Survey among D^2EPC partners.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.14.2 Calculation methodology

Initiative Implementation:

- Implement various activities such as market assessments, technology assessments, business development programs, and entrepreneurship support.
- These initiatives aim to maximize the utilization and commercialization of energy performance solutions by identifying and leveraging opportunities for scaling up and commercializing these solutions.

Data Collection:

- Design and distribute a survey among D2^EPC partners to gather feedback on the effectiveness of the initiatives in enhancing exploitation potential.
- Collect quantitative and qualitative data through the survey, focusing on partners' perceptions and experiences related to the different dimensions of exploitation potential.

Dimensions of Exploitation Potential:

- Assess market demand and viability by evaluating partners' perception of market trends, customer preferences, and the potential for solution adoption.
- Evaluate technology readiness and scalability by examining partners' assessment of the technological maturity and potential for scaling up their energy performance solutions.
- Identify value chains and business models by analyzing partners' understanding of the key stakeholders, value creation processes, and business strategies in the energy sector.
- Consider intellectual property protection by assessing partners' awareness and implementation of strategies for safeguarding their intellectual property.
- Evaluate access to finance and funding mechanisms by gathering data on partners' experiences and success in securing financial resources for scaling up their solutions.
- Assess market entry strategies by examining partners' approaches to entering new markets and expanding their reach.

Data Analysis and Evaluation:

- Analyze the survey data to identify trends, patterns, and key findings related to the effectiveness of the initiatives in enhancing exploitation potential.
- Calculate the percentage of acceptance for each dimension of exploitation potential by converting Likert scale responses into a standardized measurement.
- Evaluate the overall performance of the initiatives in enhancing exploitation potential based on the aggregated survey results.

3.15 KPI15: Upgrading indoor environmental quality

3.15.1 Indicator description

A part of the innovative indicators framework introduced within D^2EPC corresponds to the KPIs that enable the monitoring of Indoor Environmental Quality (IEQ). The indoor conditions are assessed in the context of three IEQ pillars, the Thermal and Visual comfort of the occupants and the Indoor Air Quality (IAQ).

Through this set of KPIs it is attempted to increase the quality of the building's ambient conditions by measuring various well-established metrics and calculating the respective performance indicators on predefined intervals. This procedure allows for monitoring the progression of the examined spaces. In cases when deterioration of the indoor conditions is observed in any space, a tailored recommendation engine delivers a series of suggested actions to the end-users that will contribute to the improvement of indoor conditions.

Impact indicator 15 focuses on measuring the level of effectiveness of the Human Comfort and Wellbeing (HC&W) KPIs in improving the indoor environmental conditions. As an established target of indicator 15, 90% of the intervention spaces within the building under study should increase their performance or be at least maintained on the same levels in regards to the recalculated results.

Table 15. KPI15 information

BASIC KPI INFORMATION	
Name	Upgrading indoor environmental quality
ID	K15
Expected Impact	- Information provision to the user for the building's comfort & Wellbeing performance - Alert the user in cases when the indoor conditions deteriorate and provide a list of actions to improve them (e.g., increase or lower the indoor temperature, better space ventilation, more incoming light etc.) - User acceptance rate of dEPCs Indoor Environmental Indicators >80%.
Description	The " Upgrading indoor environmental quality " Key Performance Indicator (KPI) in D^2EPC measures the impact of the project and specifically the HC&W framework on the improvement of indoor ambient conditions. This KPI examines the respondent's feedback on a set of questions that aims to shed light on the perception of different stakeholders in regard to the added-value of the framework introduced within D^2EPC to monitor and improve the indoor ambient conditions of the building.
Assessment Methodology	Pilot End-users and EPC Assessors surveys.
Unit of Measurement	Likert scale converted to percentage of acceptance.
Evaluation Period	
Baseline Period	**Deployment Period**

3.15.2 Calculation methodology

The respondents' perception of the ease of comprehension and added-value of the Indoor Environmental Indicators after the completion of the project will be assessed based on their feedback on a number of questions. Indicatively:

1. What is the level of your understanding in regards to the indoor environmental quality indicators implemented in the building?
2. Do you find the indoor environmental quality indicators helpful in understanding the overall indoor conditions within the building?
3. To what extent do the indoor environmental quality indicators influence your perception of the building's environmental performance?
4. How likely would you consider the indoor environmental quality indicators to influence your behavior or actions regarding the indoor ambient conditions within the building?
5. How effective do you find the indoor environmental quality indicators in identifying potential issues or areas for improvement within the building?
6. Do the indoor environmental quality indicators provide you with a sense of control or empowerment over your indoor environment?
7. How well do the indoor environmental quality indicators align with your personal preferences and expectations regarding indoor comfort and well-being?

8. Do you believe that the indoor environmental quality indicators would influence your decision to use certain areas or spaces within the building more frequently than others?
9. Do you believe that the indoor environmental quality indicators would enhance your overall satisfaction and experience as an occupant of the building?
10. Would you recommend the implementation of similar indoor environmental quality indicators in other buildings?
11. Which set of the Indoor Environmental indicators (Thermal Comfort, Visual Comfort, Indoor Air Quality) do you consider to provide the most and least added-value.

3.16 KPI16: Boosting energy efficiency

One of the main tools included in the Energy Performance of the Buildings Directive (EPBD) to raise awareness about the energy performance of the building is the EPC. EPC has undergone through some stages of acceptance and application area since its launch in 2012. It has become from a document to be presented at the point of sale or rent to a document useful for the policy makers for providing subsidy, for financial institutions to provide loans and for the owner to take action regarding the implementation of renovation measures etc. However, the major proposed effect – raising energy efficiency - has failed to materialise, especially in the renovation sector. In the majority of the EPC schemes, the calculation does not include the user behaviour nor reflects the changes that the building has experienced, mostly due to the issuing frequency of not less than 10 years.

The majority of the EPC schemes around Europe are based on asset rating, which means a document is calculated according to a predefined condition (predefined default values). This allows better comparison of buildings regarding energy efficiency in the same category and age band. The renovation recommendations included in the EPCs have a general character and are often not tailor-made for the respective building. Therefore, the resident is not motivated to take action in retrofitting the building.

Furthermore, the user-behaviour has a not negligible impact on the energy consumption of the building (including lighting, water, household appliances, etc.). Therefore, having information on the real consumption and the ways to reduce energy by energy experts and monitoring devices is key.

The EPC is calculated by an EPC issuer (in most European countries), who is trained and can support the tenants to understand the performance of the building during the energy audits and suggest the needed renovation steps for the betterment of the performance of the buildings.

3.16.1 Indicator description

Through the characteristics of the dEPC as in D^2EPC, the monitoring devices and calculations of the energy consumption of the building are presented to the end-user in a dynamic real time way. This way the tenant can see how the behaviour affects the performance and can contribute to the efficiency of the building through tailored renovation. In the project, there have been a number of meetings and workshops interacting EPC-issuers, energy experts and consultants with users of the pilot buildings, introducing the designed dEPC tool and platform.

Table 16. KPI16 information

BASIC KPI INFORMATION	
Name	Boosting energy efficiency
ID	K16
Expected Impact	Increasing energy efficiency and reduction of energy consumption (electricity use for the household appliances and heating/cooling) by dEPCs >30%;

Description	The "boosting energy efficiency" Key Performance Indicator (KPI) in the D^2EPC project measures the level of raising awareness to reduce energy consumption by using the energy efficient household appliances and behaviour changes.		
Assessment Methodology	Pilot End-users survey.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.16.2 Calculation methodology

The assessment of end-users' perception was carried out through partners' meetings with users and tenants of the pilot buildings and the answers to the questions discussed with them. The methodology proposal for the questionnaire aimed to assess their motivation to reduce their energy consumption and make behaviour changes in their daily routine.

3.17 KPI17: Improving renovation rate

The definition of the renovation rate is not exactly clear and differs among the partner countries. Basically, the renovation rate puts a measured value in reference to a reference value, whereas the reference value could be all buildings or buildings in need of renovation. Possible metrics could be:

- Building- or household-related renovation rate;
- Area-weighted renovation rate;
- Individual measures or only comprehensive renovations (Individual measures play an important role in decreasing the energy need for buildings. In terms of the Building Renovation Passports or individual renovation roadmaps, their importance could increase;
- Energy-weighted renovation rate: takes into account the energy saved through thermal renovation.

Improving the renovation rate is a challenging task and has been on the list of actions to reach the climate change targets of every country. The current annual rate of deep renovation in the EU is only 0.2% on average[7]. If the EU is to achieve both its 2030 climate target and climate neutrality by 2050, this needs to increase dramatically (by a factor of 15) to 3% by 2030 and be maintained until 2050.

Deep renovation is a process that, in one or, if not possible, a few steps, reduces the building energy demand, depending on its typology and climatic zone. It achieves the highest possible energy savings and leads to very high-efficiency performance, with the remaining minimum energy demand being fully covered by renewable energy. The deep renovation also provides an optimal level of indoor environmental quality for the well-being of the building occupants.

Deep renovation takes into account key building elements that need to be addressed and, where this cannot be done in one go, carefully be planned in single renovation steps. For example, this can be done using Building Renovation Passports that outline the choice of energy saving measures and

[7] Source: Deep Renovation: Shifting from exception to standard practice in EU Policy, BPIE 2021, Hélène Sibileau et al, https://www.bpie.eu/publication/deep-renovation-shifting-from-exception-to-standard-practice-in-eu-policy/ 30.05.2023

renewable energy installations to be carried out, avoiding any lock-in effects. So there are multiple benefits from the deep renovation.

3.17.1 Indicator description

People often act and decide out of habit, that is in their nature. However, discreet decision-making aids, so-called nudges, which aim to educate us to act sustainably, are helpful to act, especially if there are good intentions behind the behavioural change. Nudging aims to steer habits in a positive direction without prohibitions and rules. This can only be achieved if people are allowed to decide voluntarily and rigid behaviour patterns are easy to break. Nudging tries to address the emotional part of human decision-making. People do not always make their decisions rationally. The observation of behavioural changes in the energy consumption (through monitoring devices) can be considered as nudging which can support taking actions.

Through the tailor-made renovation recommendations developed in the project within the D^2EPC platform, the tenants have the possibility of setting the steps for the (deep) renovation of the building and at the same time monitor the results through the calculation machine and generated saving (savings at energy and monetary level).

Table 17. KPI17 information

BASIC KPI INFORMATION			
Name	Improving renovation rate		
ID	K17		
Expected Impact	Implementing renovation measures by dEPCs >60% depending on the age of the building;		
Description	The "improving renovation rate" Key Performance Indicator (KPI) in the D^2EPC project measures the decreasing energy consumption by implementing renovation measures such as insulation of exterior walls and roof, replacement of the windows, and modernising the heating/cooling system.		
Assessment Methodology	Pilot End-users and EPC Assessors surveys.		
Unit of Measurement	Likert scale converted to percentage of acceptance.		
Evaluation Period			
Baseline Period	N/A	**Deployment Period**	N/A

3.17.2 Calculation methodology

Investigating explicit numbers of the individual metrics is very extensive as necessary numbers are often not available and would have to be elicited separately through statistical surveys or analysis of other sources of data (e.g., subsidy systems). Therefore, an evaluation is partly done through experts' judgement and partly through the discussions carried out during the stakeholder meetings and workshops. During the last period of the project, workshops with EPC issuers as well as meetings with users of the pilots were arranged. The perception of the stakeholders was evaluated and infused in the overall evaluation of the KPI.

4 The Cost Benefit Analysis

The CBA methodology will aim to provide a comprehensive and accurate assessment of the costs and benefits associated with the D^2EPC solution, and to inform decision-making regarding its implementation.

The cost-benefit analysis (CBA) methodology for this task will involve the following steps:

1. Identification of Costs and Benefits;
2. Quantification of Costs and Benefits;
3. Timeframe for Analysis;
4. Discounting;
5. Sensitivity Analysis;
6. Presentation of Results;
7. Iterative Process;
8. Socio-Economic Impact Assessment.

4.1 Identification of Costs and Benefits

The first step will be to identify all the costs and benefits associated with the implementation of the D^2EPC solution. This will include both direct and indirect costs and benefits. Energy Performance Certificates (EPCs) provide a standardized way to assess the energy efficiency of buildings, and their implementation can lead to both direct and indirect benefits.

Direct benefits of implementing EPCs include:

1. Improved Energy Efficiency: EPCs provide information on the energy efficiency of a building, highlighting areas for improvement and potential energy-saving measures. This can lead to reduced energy consumption and lower energy bills for occupants.

2. Increased Property Value: Buildings with higher energy efficiency ratings are often considered more desirable by buyers or tenants, leading to increased property values and potentially higher rental or sale prices.

3. Compliance with Regulations: In many countries, it is mandatory to have an EPC when selling or renting out a property. Implementing EPCs can ensure compliance with regulations and avoid potential legal penalties.

Indirect benefits of implementing EPCs include:

1. Reduced Carbon Footprint: Improving the energy efficiency of buildings can reduce greenhouse gas emissions, contributing to global efforts to mitigate climate change.

2. Health and Comfort: Energy-efficient buildings can provide a more comfortable and healthier living environment for occupants, with better insulation, ventilation, and air quality.

3. Economic Benefits: Implementing EPCs can lead to job creation and economic growth in the energy efficiency and renewable energy industries.

Implementing Energy Performance Certificates (EPCs) for buildings can come with both direct and indirect costs, which can vary depending on factors such as the size and complexity of the building, the type of assessment required, and the level of detail and quality of the EPC report.

Direct costs of implementing EPCs may include:

1. Assessment Costs: The cost of conducting an EPC assessment can vary depending on the size and complexity of the building, as well as the qualifications and experience of the assessor.

2. Certification Fees: In some jurisdictions, there may be a fee for registering and certifying EPCs.

3. Implementation Costs: Once an EPC assessment is complete, there may be costs associated with implementing energy-saving measures recommended in the report, such as upgrading insulation or replacing inefficient heating or cooling systems.

Indirect costs of implementing EPCs may include:

1. Administrative Costs: Implementing EPCs can require additional administrative and record-keeping tasks for property owners and managers, which can add to their workload and potentially increase costs.

2. Compliance Costs: In some cases, implementing EPCs may require changes to building codes and regulations, which can come with additional costs for regulatory compliance.

3. Market Effects: Depending on the results of the EPC assessment, the market value of a property may be impacted, which can have both positive and negative effects on property owners and tenants.

While implementing EPCs can come with some direct and indirect costs, the potential benefits in terms of improved energy efficiency, reduced operating costs, and increased property value may outweigh these costs in the long run.

4.2 Quantification of Costs and Benefits

The second step will be to quantify the costs and benefits in monetary terms wherever possible. This will involve estimating the monetary value of each cost and benefit using appropriate techniques and data sources.

Once all the costs and benefits associated with the implementation of the D^2EPC assessment have been identified, the next step is to quantify them in monetary terms wherever possible. This involves estimating the monetary value of each cost and benefit using appropriate techniques and data sources.

- To estimate the value of direct benefits, the cost of energy savings can be calculated by estimating the energy consumption reduction associated with the D^2EPC tools and multiplying it by the cost of energy per unit.
- The increased property value resulting from higher energy efficiency ratings can be estimated by comparing the sale or rental prices of buildings with different energy efficiency ratings. This can be done using regression analysis or hedonic modelling, which controls for other factors that may impact property value, such as location and size.
- To estimate the value of indirect benefits, the social cost of carbon (SCC) can be used to calculate the monetary value of reduced greenhouse gas emissions. The SCC represents the economic cost of the damage caused by each additional ton of carbon dioxide emitted into the atmosphere. It is typically estimated using integrated assessment models that consider the impacts of climate change on agriculture, health, and infrastructure, among other sectors.
- To estimate the cost of implementing EPCs, the cost of the assessment, certification, and implementation of energy-saving measures can be estimated using data from previous EPC assessments and industry benchmarks. The cost of compliance with regulations and administrative tasks can also be estimated based on relevant legislation and industry standards.

Once all the costs and benefits have been quantified, they can be compared to determine whether the benefits outweigh the costs. This can be done by calculating the net present value (NPV) of the project, which considers the time value of money and the discount rate. The discount rate reflects the opportunity cost of capital and is typically set based on the prevailing interest rate or the rate of return required by investors.

4.3 Timeframe for Analysis

The timeframe for the CBA will be determined based on the expected life of the D^2EPC solution and the expected time it will take to realize the benefits.

The timeframe for the CBA will be determined based on the expected life of potential buildings upgrades resulting from the D^2EPC assessment and the expected time it will take to realize the benefits. The expected life of the D^2EPC impact will depend on factors such as technological obsolescence, maintenance requirements, and changes in regulatory requirements. The expected time to realize the benefits will depend on factors such as the implementation timeline, the time required for energy-saving measures to take effect, and changes in market conditions.

The timeframe for analysis should be long enough to capture all the costs and benefits associated with the implementation of the D^2EPC impact including those that occur over the lifetime of the solution. For example, if the expected life of an upgrade measure imposed by the D^2EPC assessment is 10 years, the timeframe for analysis should be at least 10 years to capture all the costs and benefits associated with the solution.

However, the timeframe for analysis may need to be extended if there are significant benefits that will occur after the expected life of the D^2EPC assessment. For example, if implementing the D^2EPC solution leads to changes in building codes or regulations that result in long-term energy savings, the timeframe for analysis may need to be extended to capture these benefits.

It is important to note that the timeframe for analysis should be flexible and adaptable to changes in technology, market conditions, and regulatory requirements. If there are significant changes during the implementation of the D^2EPC assessment that impact the costs or benefits, the timeframe for analysis may need to be adjusted accordingly.

The selection of an appropriate timeframe for analysis is critical to ensure that the CBA provides an accurate assessment of the costs and benefits associated with the D^2EPC impacts. An inadequate timeframe for analysis may result in an incomplete or inaccurate assessment, leading to poor decision-making regarding the implementation of the solution.

4.4 Discounting

The costs and benefits will be discounted to account for the time value of money.

Discounting is a financial concept that considers the time value of money. It is an adjustment made to future costs and benefits to reflect the fact that a euro today is worth more than a euro in the future. This is because money can be invested and earn interest, meaning that a euro received in the future is worth less than a euro received today.

In the context of the cost-benefit analysis (CBA) for the D^2EPC project, the costs and benefits associated with the implementation of the solution will be discounted to account for the time value of money. Discounting is a necessary step in the CBA process because it allows decision-makers to compare costs and benefits that occur at different points in time. By adjusting the future costs and benefits to their present value, decision-makers can determine whether the benefits of the implementation of D^2EPC tools are worth the costs of implementation.

The discount rate used in the CBA will be based on the prevailing market interest rate. This rate reflects the return on investment that could be earned by investing the money that would be spent on implementing the D^2EPC solution. The higher the market interest rate, the greater the discount rate, and the more heavily future costs and benefits will be discounted.

Discounting is an important consideration when conducting a CBA because it ensures that all costs and benefits are evaluated in a consistent manner. It allows decision-makers to compare the costs and benefits of different projects, even if those costs and benefits occur at different points in time. It is important to note that discounting can have significant effects on the results of a CBA. If the discount rate is too high, future benefits may be discounted too heavily, making the benefits of the project seem less significant. On the other hand, if the discount rate is too low, future costs may be discounted too lightly, making the costs of the project seem less significant.

4.5 Sensitivity Analysis

Sensitivity analysis will be performed to assess the impact of changes in key assumptions and parameters on the results of the CBA.

Sensitivity analysis is a method used to assess the impact of changes in key assumptions and parameters on the results of a cost-benefit analysis (CBA). It involves identifying the most critical assumptions and parameters in the analysis and varying them to see how the results change. This is important because CBAs often involve many uncertain assumptions, and varying these assumptions can lead to different conclusions.

The sensitivity analysis is the fifth step of the CBA methodology and follows the quantification of costs and benefits. It aims to provide decision-makers with an understanding of the level of uncertainty in the CBA results and to identify the assumptions and parameters that have the greatest impact on the results.

The sensitivity analysis process involves the following steps:

1. Identify the key assumptions and parameters: The first step is to identify the assumptions and parameters that are most critical to the results of the CBA. These are the assumptions and parameters that have the most significant impact on the costs and benefits of the D^2EPC project.

2. Determine the range of values: Once the critical assumptions and parameters have been identified, the next step is to determine the range of values over which they will be varied. This can be based on expert judgment, historical data, or a combination of both.

3. Vary the assumptions and parameters: The next step is to vary the critical assumptions and parameters over the defined range of values. This can be done by using sensitivity analysis software or by manually adjusting the values in the CBA model.

4. Analyse the results: After varying the assumptions and parameters, the results of the CBA are analysed to determine the impact on the costs and benefits resulting from the implementation of the D^2EPC tools. This can be done by comparing the results of the sensitivity analysis to the baseline results or by calculating the changes in the net present value (NPV) or benefit-cost ratio (BCR).

5. Interpret the results: The final step is to interpret the results of the sensitivity analysis and to communicate them to decision-makers. This involves identifying the critical assumptions and parameters that have the most significant impact on the results and presenting the range of potential outcomes based on the sensitivity analysis.

Sensitivity analysis is an essential tool in the CBA methodology because it helps decision-makers to make informed decisions in the face of uncertainty. It provides decision-makers with a range of potential outcomes and helps them to understand the risks associated with the proposed solution. By identifying the critical assumptions and parameters, sensitivity analysis can also guide further research and data collection to reduce uncertainty and improve the accuracy of the CBA results.

4.6 Presentation of Results

The presentation of results in a CBA is a crucial step in informing decision-making regarding the implementation of a solution. The results of the CBA will be presented in a clear and concise manner using appropriate presentation mediums. The results of the CBA will be summarized and will include the following elements:

1. Executive Summary: A brief summary of the key findings of the CBA, including the estimated costs and benefits of implementing the D^2EPC solution.
2. Introduction: An overview of the purpose and scope of the CBA, the methodology used, and the assumptions made.
3. Results: A detailed presentation of the estimated costs and benefits associated with the implementation of the D^2EPC assessment, including both direct and indirect costs and benefits. The results will be presented in a clear and concise manner using tables, graphs, and charts, where appropriate.
4. Sensitivity Analysis: A sensitivity analysis will be conducted to evaluate the robustness of the results to changes in key assumptions and parameters. The results of the sensitivity analysis will be presented in the report.
5. Discussion: A discussion of the key findings of the CBA, including a comparison of the costs and benefits, the implications for decision-making, and any limitations or uncertainties associated with the analysis.
6. Conclusion: A conclusion summarizing the key findings of the CBA and the implications for decision-making.
7. Appendices: Any additional information or data that supports the analysis, such as detailed calculations or data sources.

Executive Summary:

CBA aims to provide a comprehensive and accurate assessment of the costs and benefits associated with the D^2EPC solution, and provide information which will affect the decision-making process regarding the implementation, or not, of proposed energy saving measures.

Based on the examined scenarios which are described below, under the scope of this CBA, the importance of critical factors such as the interest rate, the unit cost of energy and the size/consumption of the building unit under consideration are highlighted and graphically presented.

Introduction

As described in Section 4.1, the expected Improved Energy Efficiency through the application of EPC and the proposed energy-saving measures, will lead to a reduced energy consumption and lower energy bills for occupants which is considered the main direct benefit of the EPC process.

This can be translated in monetary terms, by multiplying this energy consumption reduction by the cost of energy per unit.

For the scope of this CBA, a baseline scenario was developed, considering the below characteristics:

The baseline scenario

According to literature[8] the average energy consumption in the EU is 1.3 toe/dwelling in 2019. There are large disparities between countries, even after adjustment to the same climate, ranging from 0.5 toe/dwelling in Malta to 2.3 toe/dwelling in Luxembourg.

For the scope of the analysis, an average monthly energy consumption of 800kWh was assumed for a residential unit. A unit cost of energy of €0.25/kWh was also assumed based on literature data (Figure 1).

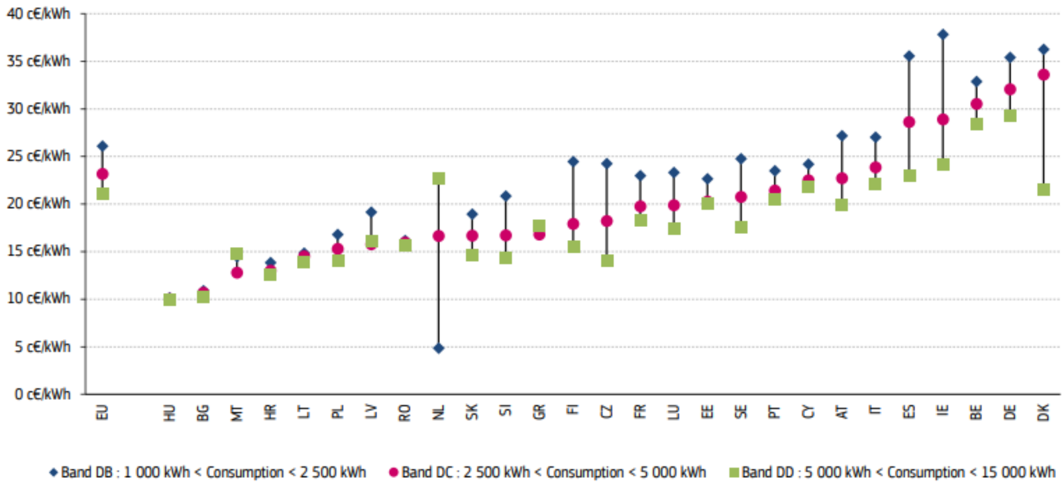


Figure 1. Household electricity prices, September 2021 – all taxes included[9]

Regarding direct costs, an indicative amount of €3,500 was taken into consideration for the scope of the CBA and is assumed to include the cost for the assessment, certification and implementation of energy measures. Of course, the actual amount will vary according to the extent of the proposed energy saving measures and their implementation.

For all the investigated scenarios, a timeframe of 25-years was considered for the analysis.

Table 18. Characteristics of Baseline scenario

Type of Unit:	Residential
Monthly Average Energy Consumption [kWh]	800
Cost of Energy Unit [€/kWh]	0.25
Indicative Costs of EPC [€]	3,500
Expected Reduction of Energy Consumption [%]	5 to 25
Interest rate [%]	2.5
Analysis timeframe [years]	25

Sensitivity analysis - Alternative scenarios

The calculation of total money savings per year was based on the assumption that the proposed energy saving measures will lead to a reduction of energy consumption.

[8] https://www.odyssee-mure.eu/publications/efficiency-by-sector/households/household-eu.pdf

[9] Retail electricity prices - Quarterly report On European electricity market. Market Observatory for Energy DG Energy Volume 14 (issue 3, covering third quarter of 2021)

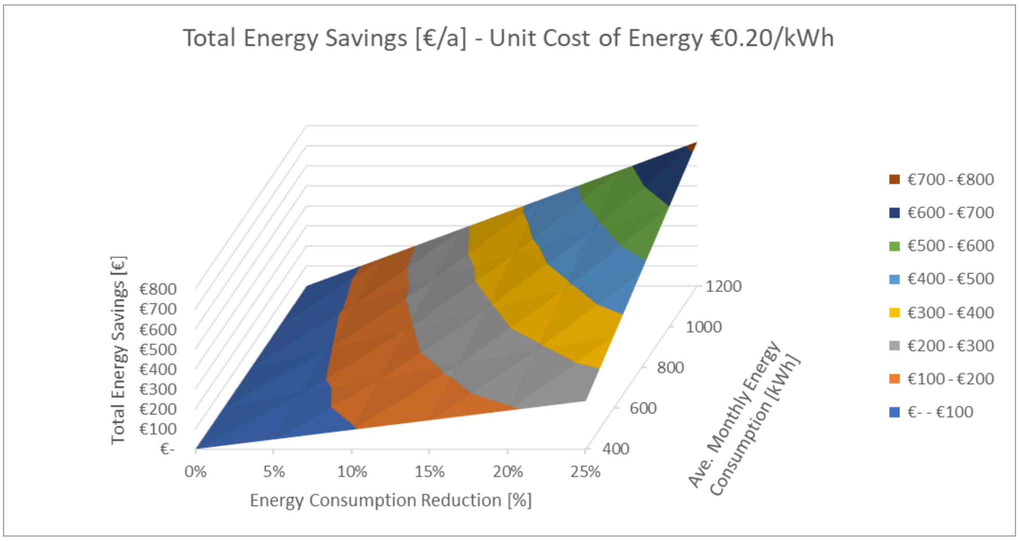
The percentage of energy consumption reduction, estimated to be within the range of 5% to 25%, consists the basis for the first group of alternative scenarios that have been investigated.

For the scope of the analysis the below parameters were also varied and a sensitivity analysis was conducted:

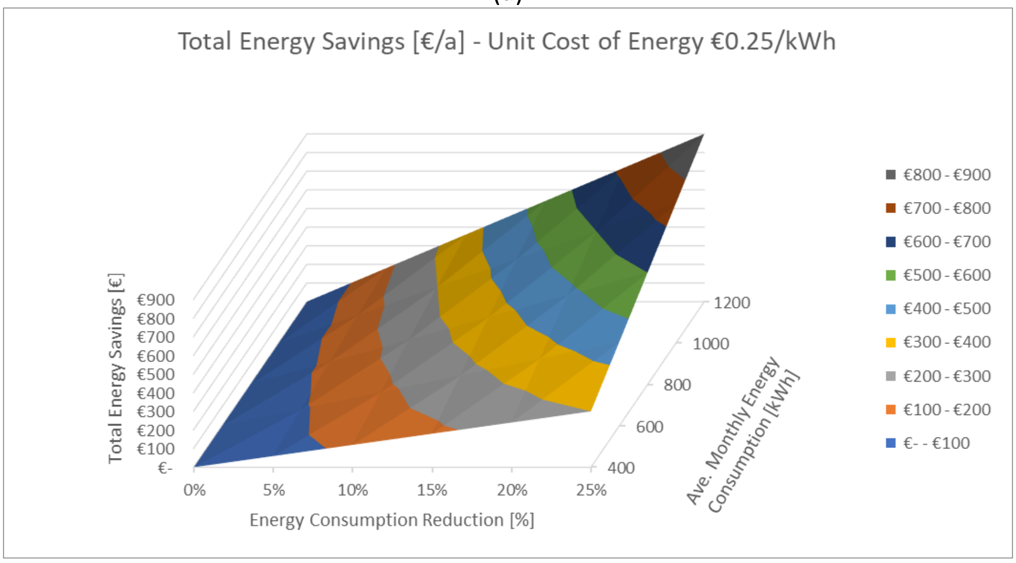
- Unit cost of Energy: €0.20/ kWh to €0.40/kWh
- Monthly Average Energy Consumption: 400 to 1200 kWh
- Interest Rate: 2% to 3.5%

CBA Results

The total annual savings in Euros, for different energy unit costs and various average monthly energy consumptions, over the expected reduction after EPC implementation, are presented in Figure 2**.**



(a)



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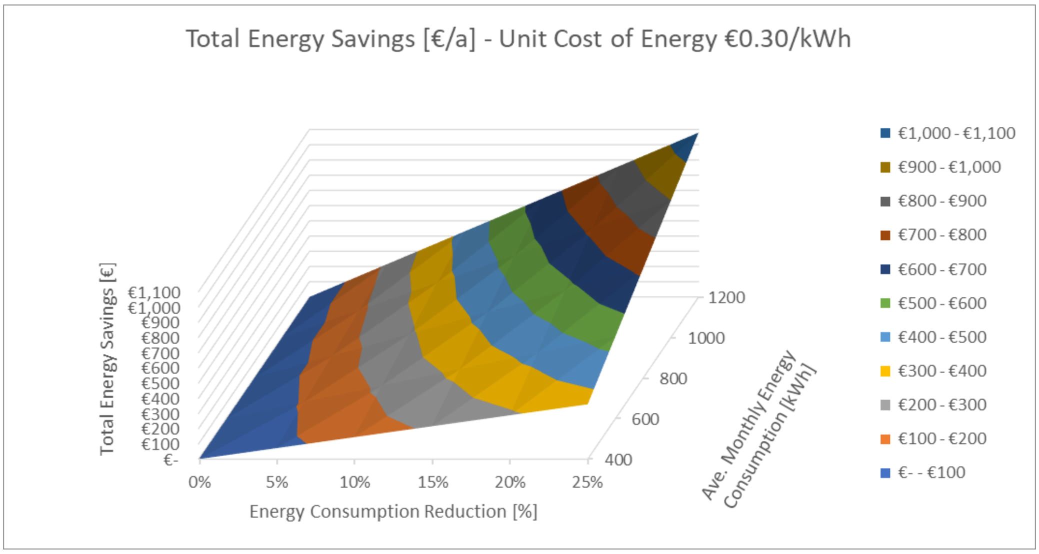

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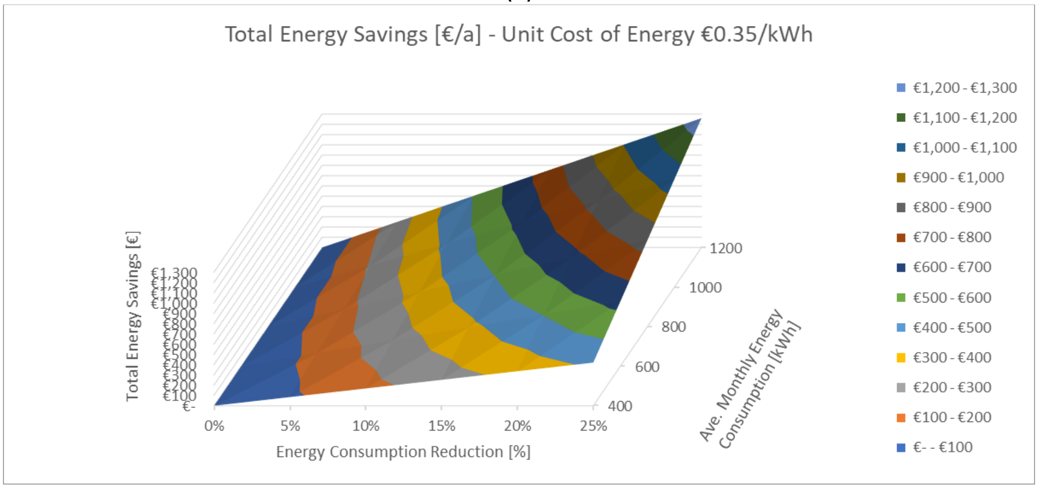

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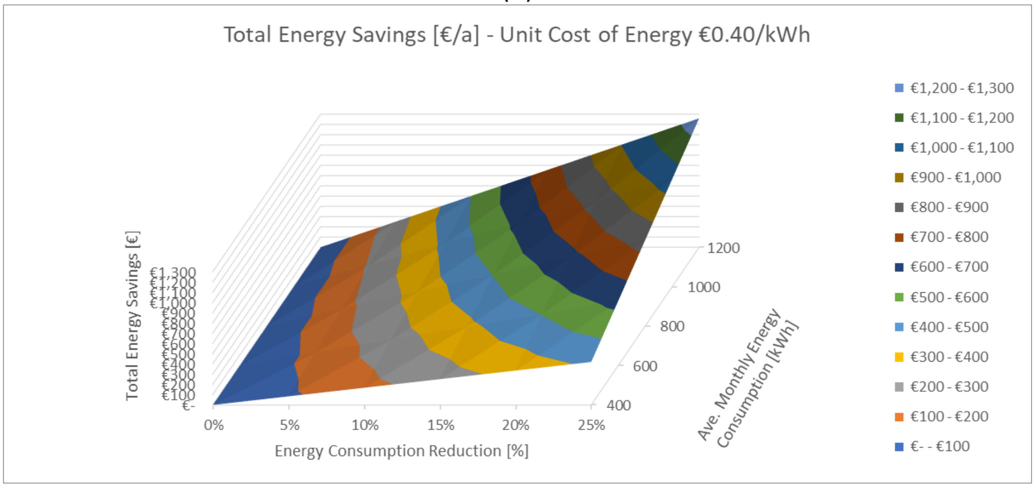


(e)

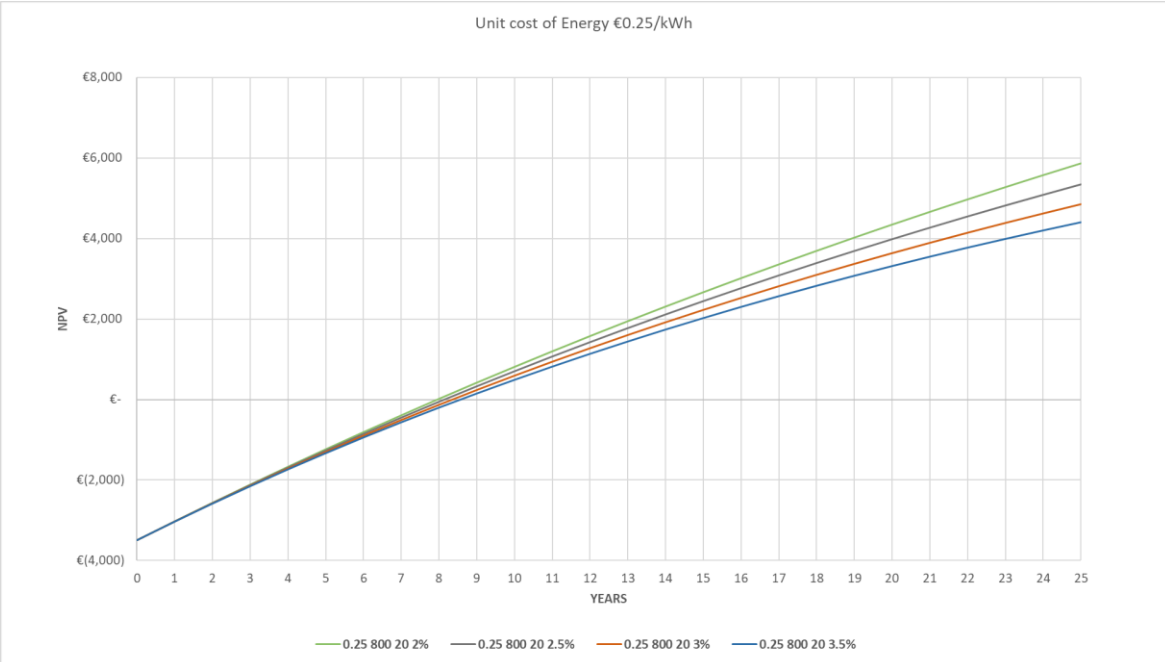
Figure 2. Annual Energy Savings with variation of Unit cost of Energy in a) 0.20 €/kWh; b) 0.25€/kWh; c) 0.30 €/kWh, d) 0.35 €/kWh, e) 0.40 €/kWh

The NPV and Internal Rate of Return (IRR) of total of 100 different scenarios were calculated and tabulated as shown in Figure 3 below:

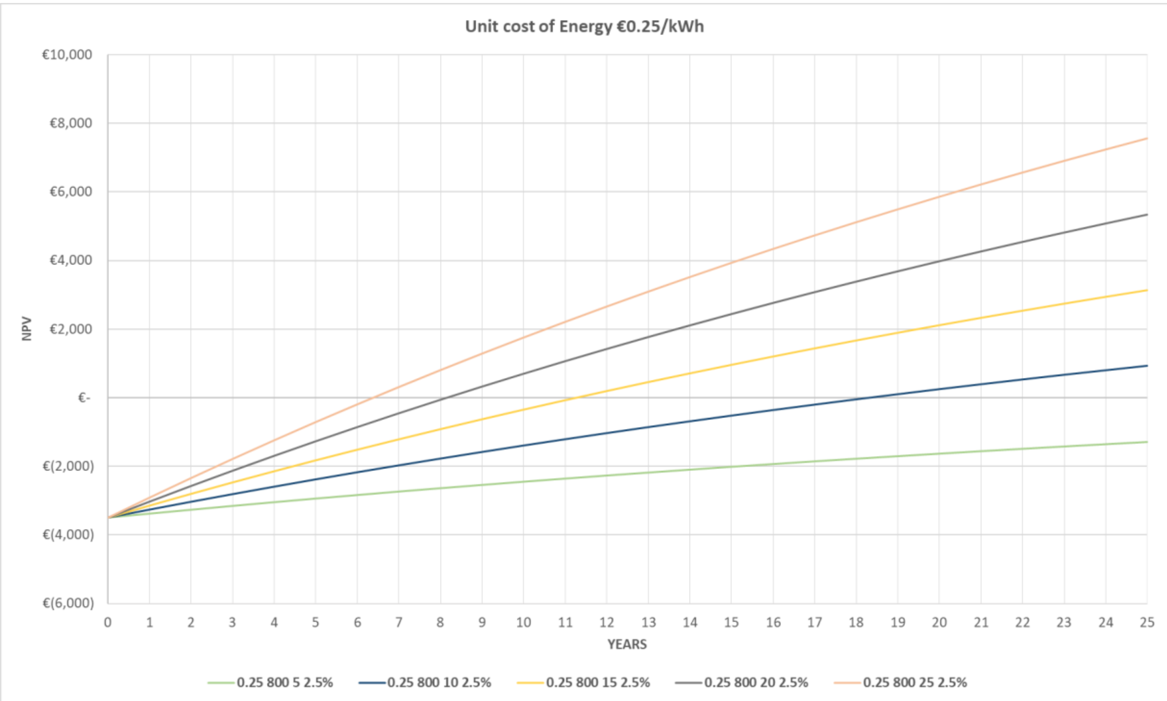
NET PRESENT VALUE (25 y)			
Unit Cost of Energy €/kWh			0.25
Ave. Monthly Energy Consumption			800
Energy Consumption Reduction [%]			10
Interest rate			2.5%
Estimated Direct Cost [€]			€ 3,500
Year	Cashflow	Present Value	ΣNPV
0	-€ 3,500	-€ 3,500.00	-€3,500.00
1	€ 240.00	€ 234.15	-€3,265.85
2	€ 240.00	€ 228.44	-€3,037.42
3	€ 240.00	€ 222.86	-€2,814.55
4	€ 240.00	€ 217.43	-€2,597.13
5	€ 240.00	€ 212.13	-€2,385.00
6	€ 240.00	€ 206.95	-€2,178.05
7	€ 240.00	€ 201.90	-€1,976.15
8	€ 240.00	€ 196.98	-€1,779.17
9	€ 240.00	€ 192.17	-€1,586.99
10	€ 240.00	€ 187.49	-€1,399.50
11	€ 240.00	€ 182.91	-€1,216.59
12	€ 240.00	€ 178.45	-€1,038.14
13	€ 240.00	€ 174.10	-€ 864.04
14	€ 240.00	€ 169.85	-€ 694.18
15	€ 240.00	€ 165.71	-€ 528.47
16	€ 240.00	€ 161.67	-€ 366.80
17	€ 240.00	€ 157.73	-€ 209.07
18	€ 240.00	€ 153.88	-€ 55.19
19	**€ 240.00**	**€ 150.13**	**€ 94.93**
20	€ 240.00	€ 146.47	€ 241.40
21	€ 240.00	€ 142.89	€ 384.29
22	€ 240.00	€ 139.41	€ 523.70
23	€ 240.00	€ 136.01	€ 659.71
24	€ 240.00	€ 132.69	€ 792.40
25	€ 240.00	€ 129.45	€ 921.85
NPV	921.85		
IRR	4.66%		

Figure 3. Example of Calculated NPV & IRR of baseline scenario

Figure 4 that follows, presents the calculated NPV for the baseline scenario assuming a constant monthly average energy consumption of 800 kWh (baseline scenario) and unit cost of energy while the interest rate and the percentage of energy consumption reduction are variables.



(a)



(b)

Figure 4. Calculated NPV for baseline scenario with variable a) interest rate in %; b) Estimated Energy Consumption Reduction in %

The impact of unit cost of energy is clearly depicted in Figure 5 below.

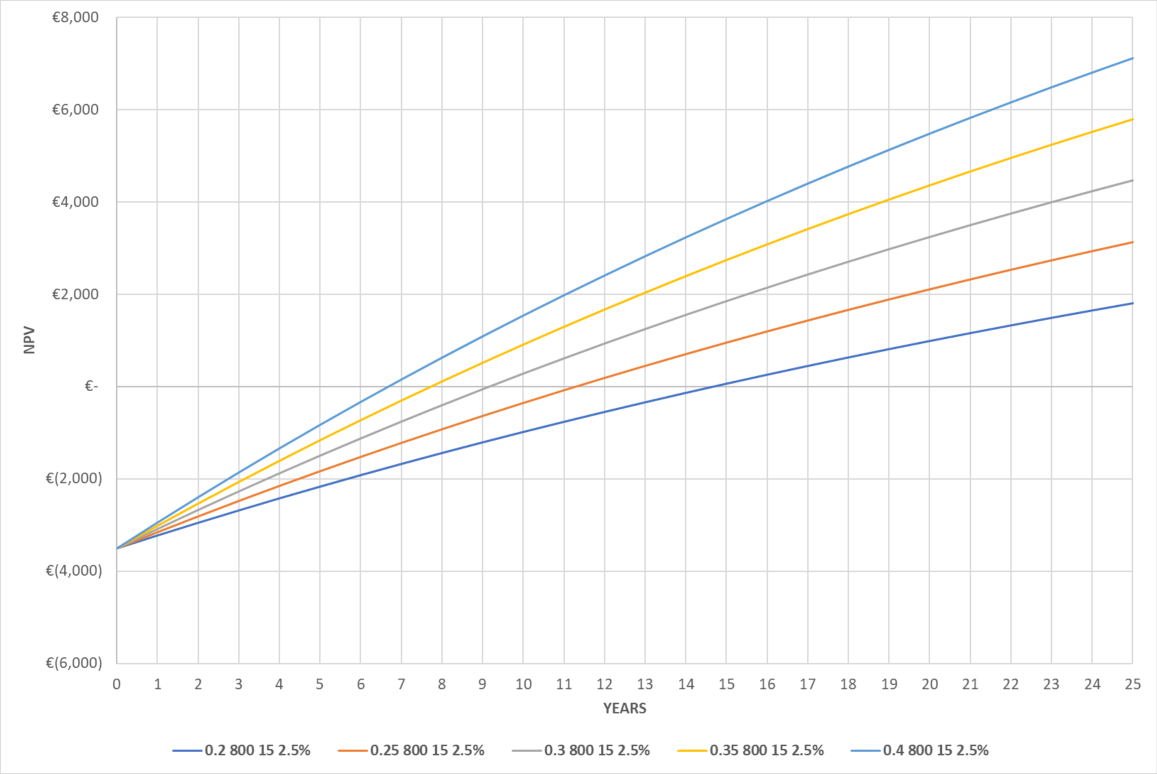


Figure 5. The effect of unit cost of energy on calculated NPV for constant interest rate and estimated energy consumption reduction

Based on the above figures, it can be concluded that the unit cost of energy and the expected percentage of energy reduction are critical for the financial performance of any proposed solution under an EPC assessment and certification process.

Additional scenarios can be further examined by taking into account the actual energy consumption of the building unit under investigation as well as the calculated, if possible, of the total costs related to the EPC process. Quantified indirect costs and benefits can also be part of the CBA.

5 Project Assessment Results

Following a detailed analysis of the feedback gathered from stakeholders and involved parties, this chapter presents the outcomes of the project evaluation, including the results of the calculations and an assessment of whether the D^2EPC project has achieved its objectives and expected impacts. The results section is structured to present the results for each KPI individually, which allows to delve deeper into the specifics of feedback and analysis.

The evaluation of the results of the questionnaires was carried out using a Likert-scaling methodology, which allows the inclusion of the weight of a response where the most negative answer will have a significant negative impact on the overall result and vice versa.

5.1 KPI1: Improved user-friendliness of EPCs

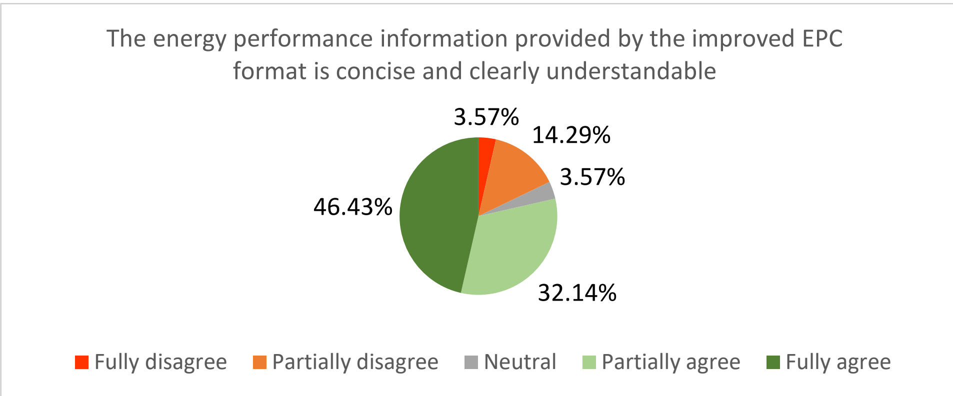
5.1.1 EPC assessors' assessment

KPI1 calculation methodology included evaluation of EPC assessors and end-users' perception of the improved user-friendliness of NG EPCs. As it is presented in Figure 6 (a), EPC assessors' opinions are divided regarding the energy performance information provided by the improved EPC format. Most of the EPC assessors who took part perceived that the information provided as concise and clear, while others may not perceive it as fully concise and easily comprehensible. Despite differences of opinion, the information clarity rate is still relatively high 75.89% (Table 19).

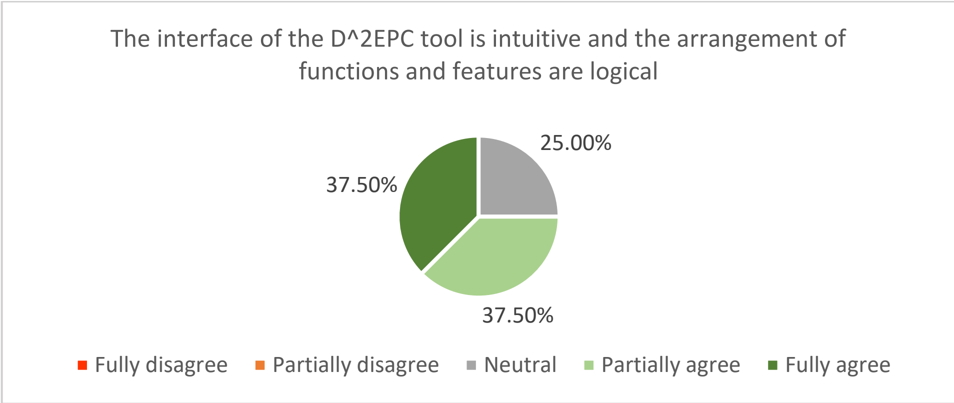
Considering the intuitiveness and the functional arrangement of the D^2EPC tool features, most of respondents evaluated it positively or strongly positively (Figure 6 (b)), which resulted in the intuitiveness acceptance rate of 78.13%.

All respondents were positive about the layout of D^2EPC tool, as well as the use of graphical elements and its colour schemes (Figure 6 (c)). The 75% of strong agreement resulted in an outstanding visual acceptance rate of 93.75%.

To summarize the EPC assessors' perception of user-friendliness of D^2EPC platform, the total acceptance rate was calculated to be **82.59%.**



(a)



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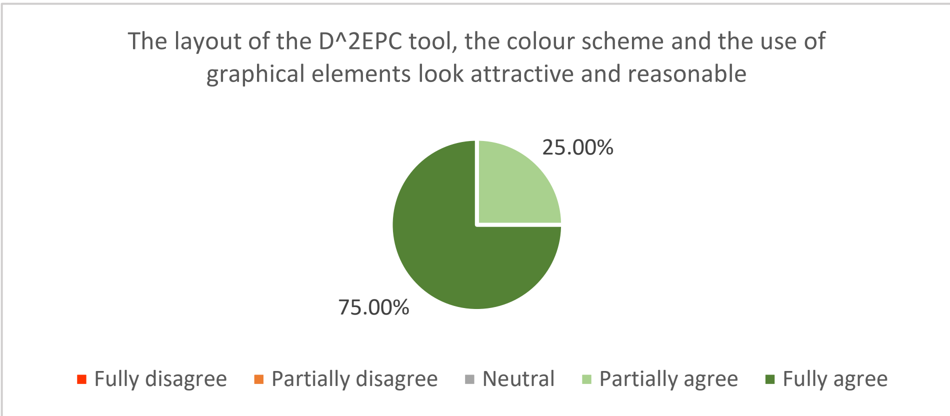


(c)

Figure 6. a), b), c) EPC assessors' evaluation graphs

Table 19. KPI1 EPC assessors' acceptance rates

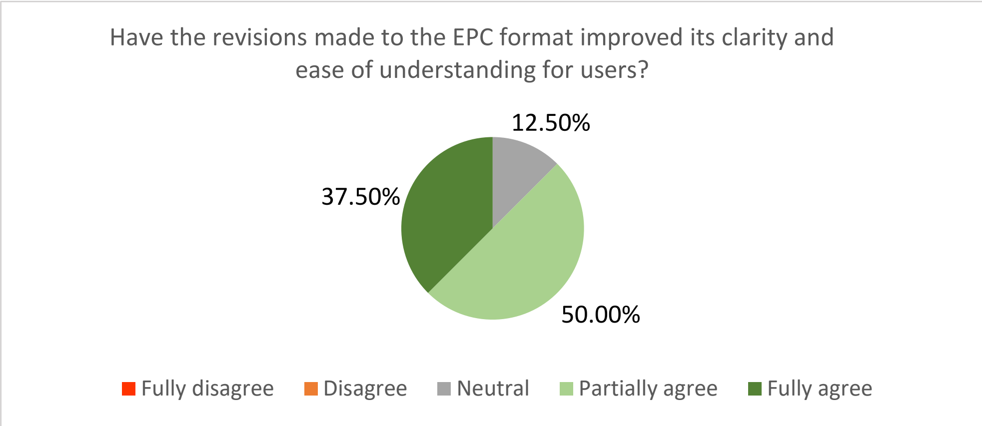
Definition	Value
Information clarity rate	75.89%
Intuitiveness acceptance rate	78.13%
Visual acceptance rate	93.75%
Total acceptance rate	**82.59%**

5.1.2 End-Users' assessment

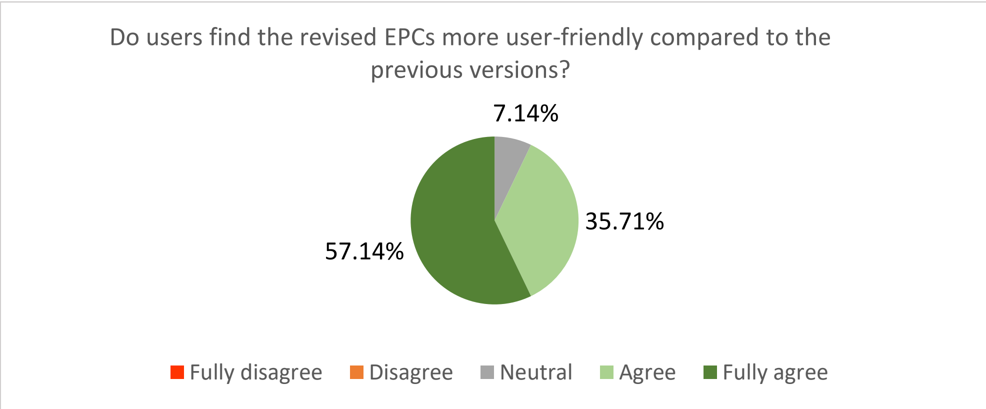
The results of the end-user survey suggest that improvements to the EPC format and the D^2EPC tool features have improved the clarity of the information provided in the EPCs. In particular, information clarity rate was calculated to be 81.25% (Table 20), which is higher than EPC assessors' rate for the same criteria. End-users provided their strongly positive opinion that revised EPC scheme is more user-friendly compared to previous version. When converted into numerical values, the user-friendliness rate was 87.50% (Table 20).

Considering the intuitiveness and the functional arrangement of the D^2EPC tool features, most of respondents evaluated it positively or strongly positively (Figure 7 (c)), which resulted in the intuitiveness acceptance rate of 82.14%.

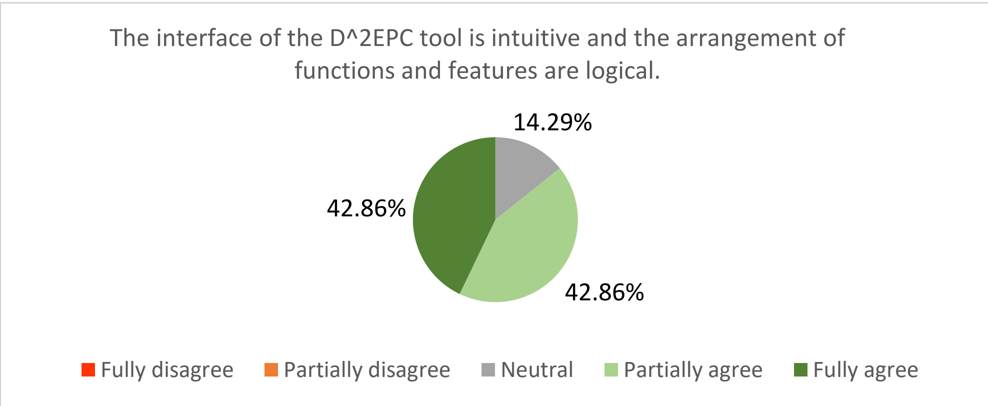
All respondents were very positive about the layout of D^2EPC tool, as well as the use of graphical elements and its colour schemes (Figure 7 (d)). The 85.71% of strong agreement resulted in an outstanding visual acceptance rate of 96.43%.


Have the revisions made to the EPC format improved its clarity and ease of understanding for users?
12.50%
37.50%
50.00%
Fully disagree
Disagree
Neutral
Partially agree
Fully agree

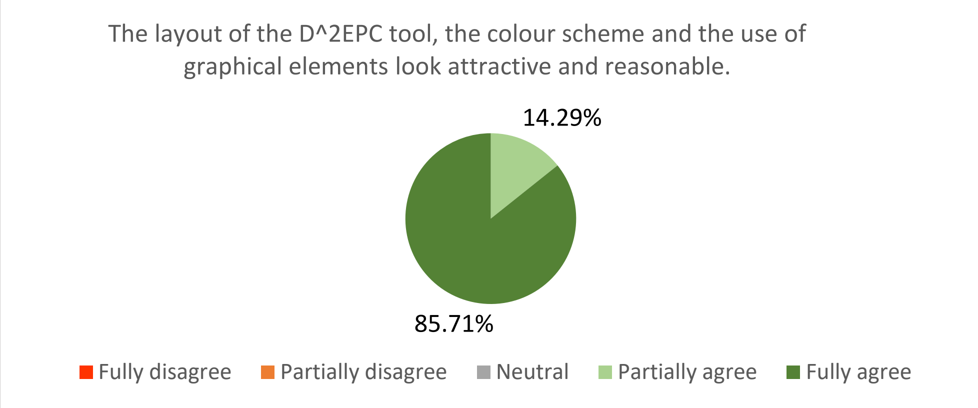
(a)


Do users find the revised EPCs more user-friendly compared to the previous versions?
7.14%
35.71%
57.14%
Fully disagree
Disagree
Neutral
Agree
Fully agree

(b)


The interface of the D^2EPC tool is intuitive and the arrangement of functions and features are logical.
14.29%
42.86%
42.86%
Fully disagree
Partially disagree
Neutral
Partially agree
Fully agree

(c)



(d)

Figure 7. a), b), c), d) End-users' evaluation graphs

Table 20. KPI1 end-users' acceptance rates

Definition	Value
Information clarity rate	81.25%
Improved user-friendliness rate	87.50%
Intuitiveness acceptance rate	82.14%
Visual acceptance rate	96.43%
Total acceptance rate	**86.83%**

Table 21. Total user-friendliness rate

Definition	Value
EPC assessors' acceptance rate	82.59%
End-users' acceptance rate	86.83%
Total user-friendliness rate	**84.71%**

Summarising the feedback from the EPC assessors on the ease of use of the NG EPC and the views of the end-users, it can be concluded that the improvements have been evaluated very positively by all stakeholders. EPC assessors' feedback resulted in 82.59% of improved user-friendliness rate, while end-users had a better opinion on the improvements with 86.83% (Table 21). Overall value of the improved user-friendliness of EPCs indicator is calculated to be 84.71%.

5.2 KPI2: Enhanced user awareness of building energy efficiency

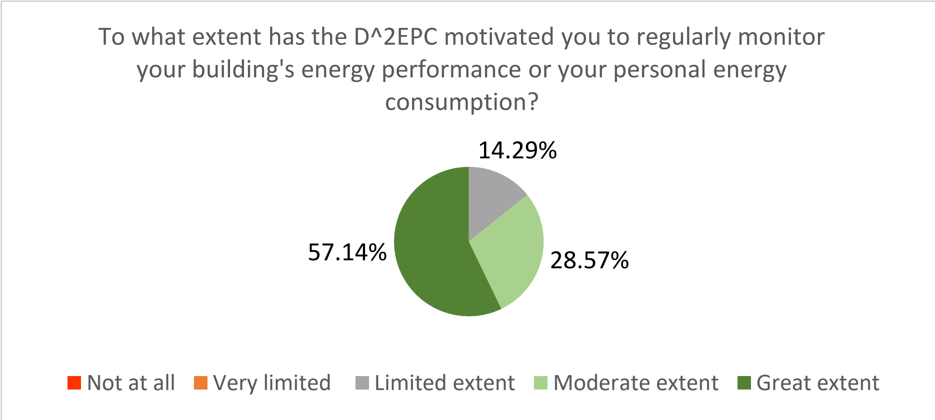
5.2.1 End-Users' assessment

KPI2 calculation methodology evaluated the impact of the D^2EPC project on the user awareness of building's energy efficiency. Considering end-user's motivation towards monitoring their building's energy consumption, most of responders evaluated it positively or strongly positively (Figure 8 (a)), which resulted in the motivation rate of 85.71%.

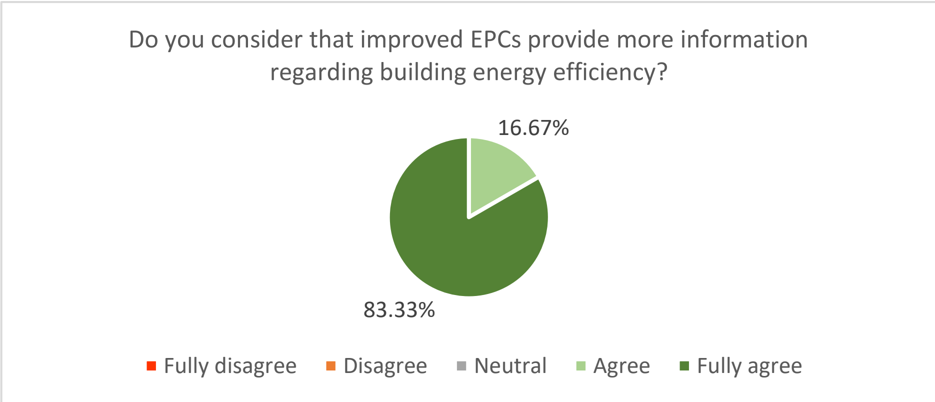
A strong positive opinion was recorded with regards to the level of information provided by D^2EPC. In particular, all responders evaluated positively that improved EPCs are providing more information on building's energy efficiency (Figure 8 (b)).

Similarly, most of the responders (82.14%) evaluated positively or strongly positively that D^2EPC project improved their awareness of the importance of building's energy efficiency (Figure 8 (c)).

To summarize the end-user's awareness of building energy efficiency, the total enhancement rate was calculated to be 88.10%. The results from all sections are summarized in Table 22.



(a)



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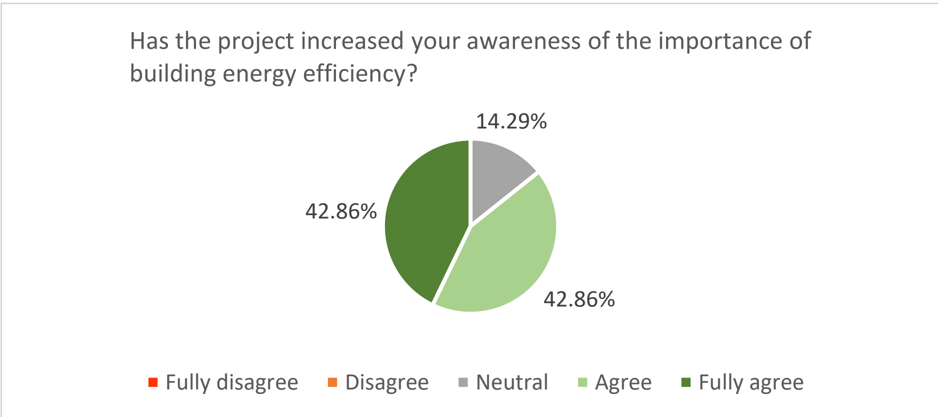


(c)

Figure 8. a), b), c) End-users' evaluation graphs

Table 22. KPI2 end-users' acceptance rates

Definition	Value
Motivation rate	85.71%
Improved information rate	96.43%

Increased energy efficiency awareness rate	82.14%
Total improved energy efficiency awareness rate	**88.10%**

Considering the overall pilot user's satisfaction (Figure 9), the majority of end-user's rated 'very satisfied' or 'somewhat satisfied' their experience in D^2EPC project while a smaller percentage rated as neutral or somewhat dissatisfied. Despite difference of opinion, the overall pilot satisfaction is still relatively high 85.71% (Table 23).

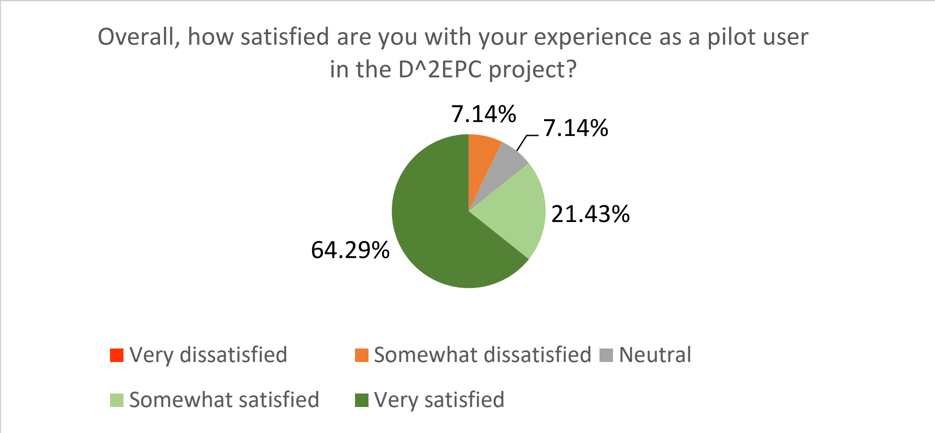


Figure 9. Users' satisfaction graph

Table 23. Satisfaction rate of pilot participants

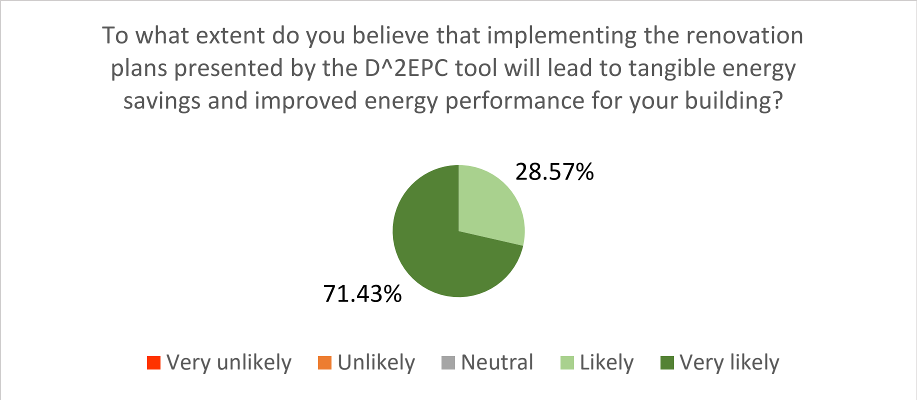
Definition	Value
Participants satisfaction rate	**85.71%**

5.3 KPI3: Primary energy savings triggered by the project

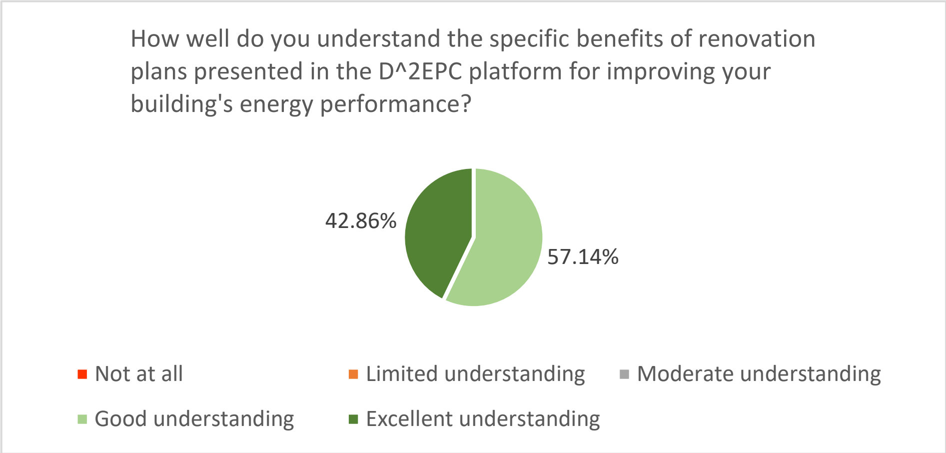
5.3.1 End-Users' assessment

The results of the end-user survey confirm that all asked users believe that implementing the renovation plans presented by the D^2EPC tool will lead to energy savings and improved energy performance of their buildings. 71.43% of the users strongly confirmed that opinion (Figure 10 (a)). In addition, all users confirmed that the specific benefits of renovation plans presented in the D^2EPC platform for improving building's energy performance are well understood. 42.86% of the users evaluated it as an excellent understanding and 57.14 % evaluated it a as a good understanding (Figure 10 (b)).

Lastly, in relation to the question about if the customised recommendations provided by the road mapping tool will encourage users to consider renovation plans, 85.72% evaluated it very positively or positively, 7.14% evaluated it neutrally and 7.14% evaluated it very negatively (Figure 10 (c)).



(a)



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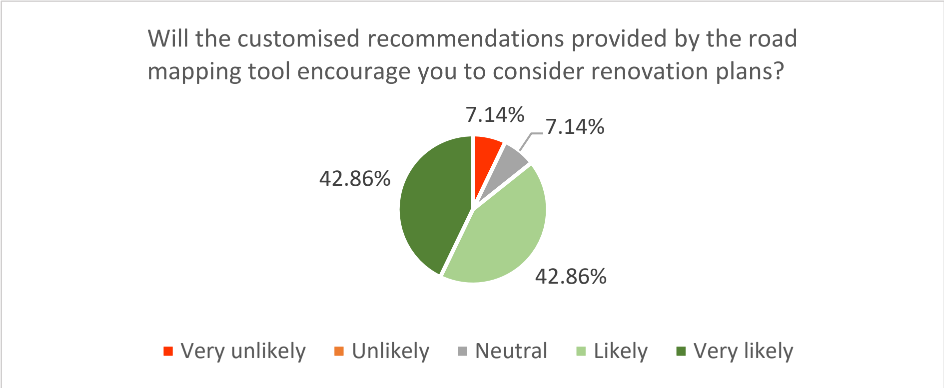


(c)

Figure 10. a), b), c) End-users' evaluation graphs

Table 24. KPI3 End-users' acceptance rates

Definition	Value
Renovation suggestions acceptance rate	92.86%
Renovation benefits understanding rate	83.33%
Renovation trigger rate	87.50%
Total renovation acceptance rate	**89.14%**

To sum up, as Table 24 shows, the total renovation acceptance rate provided by end users surveys is calculated to be 89.14%. This renovation acceptance rate is further used for calculations in Scenario 2 - Calculations based on D^2EPC Pilots.

5.3.2 Primary energy savings calculations

Based on the methodology presented in the KPI description section introduced during the project preparation phase, the following assumptive calculations were made for two scenarios:

Scenario 1 – Calculations based on EU Statistics

Considering an average energy consumption of 85.75 kWh/m2 (European Commission[10]), a minimum 45% energy savings potential from deep renovation, a 70% renovation rate triggered by EPCs and a 0.2% penetration rate of the D^2EPC in the EU certification market, the annual future savings induced by D^2EPC, can be estimated at 32.58 GWh per year. According to Annex IV of the Directive 2012/27/EU[11] a default coefficient of 2.5 can be applied for savings in kWh of electricity, whereas the respective value for fossil fuels can be taken as 1.171. Assuming that the energy savings come originally from 30% electricity and 70% fossil fuels, the total PES triggered by D^2EPC will reach **49.52 GWh/year.**

Scenario 2 – Calculations based on D^2EPC Pilots

Considering an average energy consumption of 163.15 kWh/m2 (which is the average consumption for residential D^2EPC Pilots), a minimum 45% energy savings potential from deep renovation, a 89% renovation rate (data obtained from questionnaires, Table 24) triggered by EPCs and a 0.2% penetration rate of the D^2EPC in the EU certification market, the annual future savings induced by D^2EPC, can be estimated at 78.93 GWh per year. According to Annex IV of the Directive 2012/27/EU[12] a default coefficient of 2.5 can be applied for savings in kWh of electricity, whereas the respective value for fossil fuels can be taken as 1.171. Assuming that the energy savings come originally from 30% electricity and 70% fossil fuels, the total PES triggered by D^2EPC will reach **119.38 GWh/year.**

5.4 KPI4: Investments in sustainable energy triggered by the project

Based on the information presented in the KPI description section, the following assumptive calculations were made for two scenarios to assess potential investment in sustainable energy triggered by the project.

Scenario 1 – Calculations based on general EU data

Considering a 70% renovation rate triggered by EPCs and a 0.2% penetration rate of the D^2EPC in the EU certification market, the building renovation decisions induced by D^2EPC after entering market – full development, can be estimated at 5,869 buildings. According to report on European building stock renovation potential[13], the average renovation cost in EU is 11.724 €/building. Considering that cost, an investment in sustainable energy of **68,8 million € per year** can be triggered by the project.

Scenario 2 – Calculations based on D^2EPC Pilots

[10] https://building-stock-observatory.energy.ec.europa.eu/database/
[11] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0027
[12] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32012L0027
[13] https://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU(2016)587326_EN.pdf

Considering an 89% renovation rate (data obtained from questionnaires, Table 24) triggered by EPCs and a 0.2% penetration rate of the D^2EPC in the EU certification market, the building renovation decisions induced by D^2EPC after entering market – full development, can be estimated at 7,474 buildings. According to European building stock renovation potential report, the average renovation cost in EU is 11.724 €/building. Considering that cost, an investment in sustainable energy of **87,6 million € per year** can be triggered by the project.

5.5 KPI5: Reduction of the greenhouse gases emissions and air pollutants triggered by the project

Based on the assumptions presented in the KPI description section, the following assumptive calculations were made for two scenarios to assess potential reduction of GHG emissions and air pollutants triggered by the project.

Scenario 1 – Calculations based on EU Statistics

Considering an average energy consumption of 85.75 kWh/m2 (European Commission, 2023[14]), a minimum 45% energy savings potential from deep renovation, a 70% renovation rate triggered by EPCs and a 0.2% penetration rate of the D^2EPC in the EU certification market, the annual future savings induced by D^2EPC after entering market – full development, can be estimated at 32.58 GWh per year. Applying the previous percentages for energy distribution per application in households and the corresponding emission factors for electricity, heating oil and natural gas, an estimated **10.57 tons CO2-eq/year** can be saved due to D^2EPC implementation.

Scenario 2 – Calculations based on D^2EPC Pilots

Considering an average energy consumption of 163.15 kWh/m2 (which is the average consumption for residential D^2EPC Pilots), a minimum 45% energy savings potential from deep renovation, a 89% renovation rate (data obtained from questionnaires, Table 24) triggered by EPCs and a 0.2% penetration rate of the D^2EPC in the EU certification market, the annual future savings induced by D^2EPC after entering market – full development, can be estimated at 78.93 GWh per year. Applying the previous percentages for energy distribution per application in households and the corresponding emission factors for electricity, heating oil and natural gas, an estimated **25.60 tons CO2-eq/year** can be saved due to D^2EPC implementation.

5.6 KPI6: The introduction and establishment of the dynamic EPC issued on a regular basis concept

5.6.1 EPC assessors' assessment

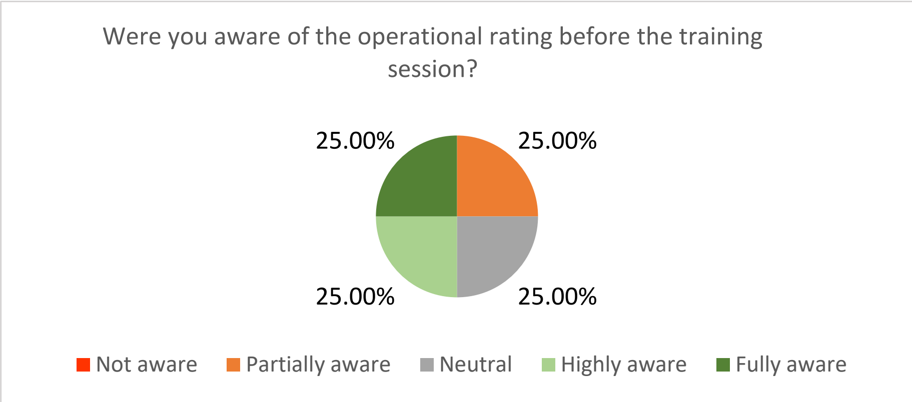
In order to assess the establishment of the concept of dynamic EPCs, the perception of EPC assessors and end-users' concerning the operational rating has been evaluated through a set of questions. As presented in Figure 11(a), EPC assessors' opinion on the level of knowledge of operational rating is divided, though no results indicated absence of knowledge of the scheme. Most of the assessors that participated have issued EPCs based on the operational rating (rarely, often or very often) while a small percentage (25%) haven't issued an operational EPC, though being aware of the methodology.

The majority of the EPC assessors with a relatively high percentage of 62.5% (Figure 11 (c)) agree that the operational rating is more accurate than the asset rating which resulted in an 68.75% acceptance rate of the operational rating Table 25).

[14] https://building-stock-observatory.energy.ec.europa.eu/database/

All respondents were positive or neutral about the D^2EPC tool calculation process for operational rating, which resulted in an outstanding D^2EPC operational assessment acceptance rate of **80.36%**.

To summarize the EPC assessors' perception of dynamic EPCs (dEPCs), the total acceptance rate was calculated to be **74.55%.**



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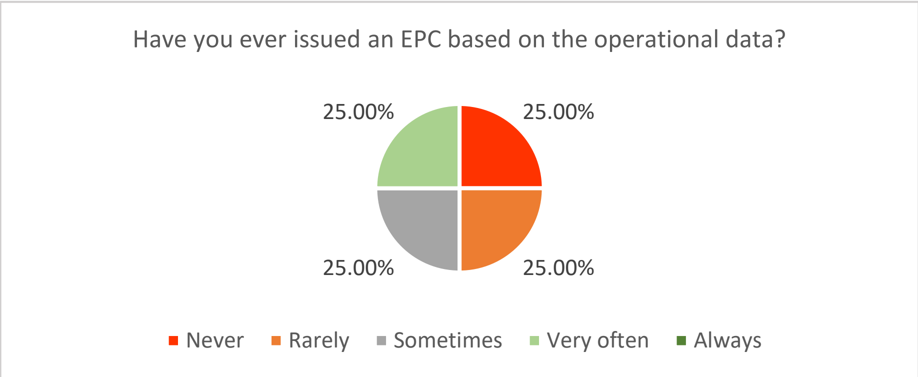

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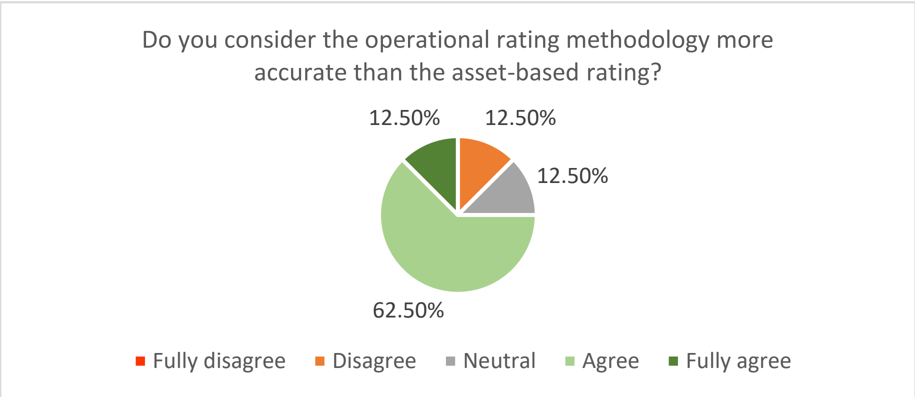
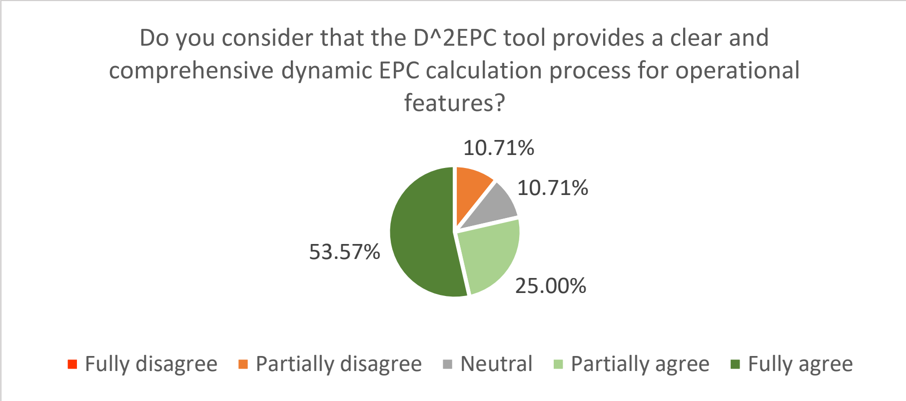


(c)



(d)

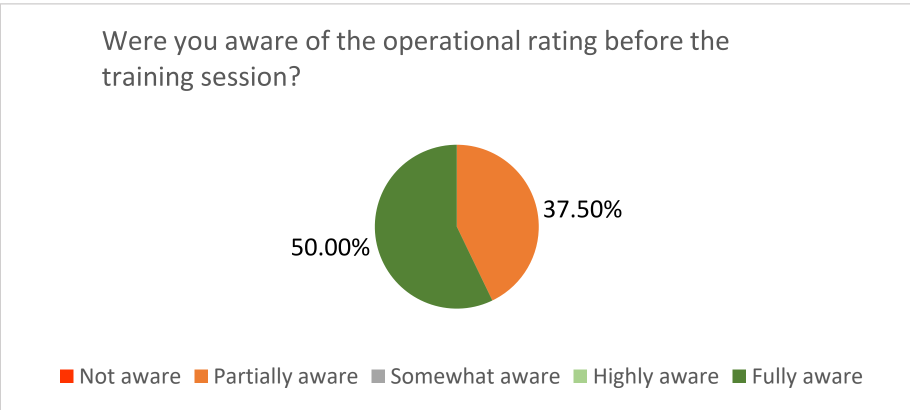
Figure 11. a), b), c), d) EPC assessors' evaluation graphs

Table 25. KPI6 EPC assessors' acceptance/understanding rates

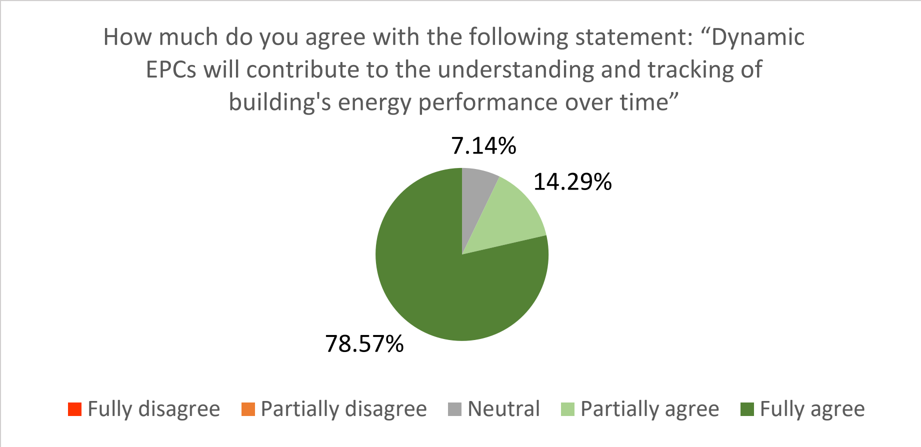
Definition	Value
Awareness rate	62.50%
Application rate	37.50%
Total awareness rate	**50.00%**
Operational rating acceptance rate	68.75%
D^2EPC operational assessment acceptance rate	80.36%
Total dEPC acceptance rate	**74.55%**

5.6.2 End-Users' assessment

The perception of building end-users' concerning the operational rating has been evaluated as well through a set of questions. In particular, all D^2EPC end-users where fully or partially aware of the operational rating prior to the training session for the presentation of the D^2EPC platform and results, as indicated in Figure 12 (a), which resulted in a 67.86% awareness rate. This percentage is quite similar to the awareness rate of the EPC Assessors (62.50% as shown in Table 25). In addition, D^2EPC end-users were highly in favour of dynamic EPCs in the sense that they contribute to understanding and tracking of building's energy performance over time with a remarkable acceptance rate of 92.86% (Table 26), while EPC assessors are positioned on the same positive side as well with a more moderate rate comparing to that.



(a)



(b)

Figure 12. a), b) End-users' evaluation graphs

Table 26. KPI6 End-users' acceptance/understanding rates

Definition	Value
Operational rating awareness rate	**67.86%**
Operational rating acceptance rate	**92.86%**

5.6.3 Number of dynamic EPCs issued

In total, 6 dynamic EPCs were issued through the D^2EPC Web Platform.

5.6.4 As designed/as operated EPC assessment comparison

The comparison results are shown in the following table. The difference between the results from the as-designed and as-operated assessments indicates the core reason for the existence of both schemes in a holistic certification platform. On the one hand, the Asset Rating methodology indicates the asset's energy performance under a pre-defined set of conditions regarding the weather, occupancy, level of comfort, etc. On the other hand, the Operational Rating represents the building's energy performance under actual operational conditions. To simplify the comparison between the two ratings, the resultant EPC class can be taken from each respective rating scheme.

CS1 has the largest gap between the two schemes, as the building's operation has a big difference between its actual and designed operational schedule. Moreover, the increased energy consumption from the electrical equipment is responsible for the energy gap presented. A similar instance is observed in CS4, where the increased energy consumption from electrical appliances creates a significant difference between the resulting EPC classes. For CS2, both schemes produce similar results, which is also indicated by the same EPC class (D). Major differences can be observed in the rest of the case studies; an extensive analysis is documented in D4.5.

Table 27. As designed/As-operated values od case studies

	As-designed		As-operated	
	EPC Class	EPC Results	EPC Class	EPC Results
CS1	A	Heating: 1.56 kWh/m² Cooling: 6.83 kWh/m² DHW/Lighting: 8.74 kWh/m²	E	Heating: 20.2 kWh/m² Cooling: 24.4 kWh/m²

		PV production: 69.72 kWh/m²		DHW/Electricity Appliances/Lighting: 98.7 kWh/m² PV production: 40.3 kWh/m²:
CS2	D	Heating: 104.78 kWh/m² Cooling: 0 kWh/m² DHW: 20.5 kWh/m² Lighting: 14.48 kWh/m²	D	Heating: 115.6 kWh/m² DHW: 13.1 kWh/m² Electrical Appliances/Lighting: 54.3 kWh/m²
CS3	D	Heating: 330.33 kWh/m² Cooling: 0 kWh/m² DHW: 1.94 kWh/m² Lighting: 2.82 kWh/m²	D	Heating: 641.3 kWh/m² Electrical Appliances/Lighting: 22.7 kWh/m²
CS4	C	Heating: 2.71 kWh/m² Cooling: 12.93 kWh/m² Lighting: 10.71 kWh/m²	E	Heating: 4.5 kWh/m² Cooling: 12.2 kWh/m² DHW/Electricity Appliances/Lighting: 288.3 kWh/m²
CS5	C	Heating: 464.1 kWh/m² DHW: 82.3 kWh/m²		Heating/DHW: 116 kWh/m²
CS6	E	Heating: 559.8 kWh/m² DHW: 65 kWh/m²	B	Heating/DHW: 64 kWh/m²

5.6.5 Number of energy end-uses included in the operational rating

The included energy end-uses for each Case Study are shown in the table below. CS1 and CS4 included most of the energy end-uses considered by the operational rating methodology, as the on-site infrastructure enabled the extensive energy monitoring. However, for all CSs, the minimum requirement for including the Heating and Cooling (if applicable) energy uses, was fulfilled.

Table 28. Energy-uses per case study

Case Study	Energy usage
CS1	• Heating • Cooling • DHW & Electricity Appliances & Lighting (aggregated) • RES (PV)
CS2	• Heating • DHW • Electrical Appliances & Lighting (aggregated)
CS3	• Heating • Electrical Appliances & Lighting
CS4	• Heating • Cooling

	• Electricity appliances • Lighting
CS5	• Heating • DHW (aggregated)
CS6	• Heating • DHW (aggregated)

5.6.6 dEPC maximum setup & execution time

The setup and execution time for issuing the dEPC for each case study is shown in the table below.

The maximum total setup time for any case study does not exceed 30 minutes, while the execution time remains always under 15 seconds.

Table 29. Setup and execution time for case studies

	Setup	Execution
CS1	• Upload & Validation of BIM file: 5-10 min • Registration of devices: 5-10 min	Data fetching, calculation, visualization: 10-15 sec
CS2	• Upload & Validation of BIM file: 10-20 min • Registration of devices: 2-3 min	Data fetching, calculation, visualization: 1-3 sec
CS3	• Upload & Validation of BIM file: 10-20 min • Registration of devices: 2-3 min	Data fetching, calculation, visualization: 1-3 sec
CS4	• Upload & Validation of BIM file: 5-10 min • Registration of devices: 15-20 min	Data fetching, calculation, visualization: 5-10 sec
CS5	• Upload & Validation of BIM file: 10 20 min • Registration of devices: 5-10 min	Data fetching, calculation, visualization: 1-3 sec
CS6	• Upload & Validation of BIM file: 10-20 min • Registration of devices: 5-10 min	Data fetching, calculation, visualization: 1-3 sec

5.7 KPI7: Drawbacks and discrepancies of the current EPC scheme, contribution to standards

5.7.1 EPC assessors' feedback

As the questionnaire indicated it, the EPC assessors' feedback concerning the drawbacks and discrepancies was eye-opening since the majority agreed fully (25%) or partially (50%) on noticing or identifying some kind of shortcomings or inconsistencies in the standardization of the buildings' energy performance. This is depicted in more detail in Figure 13, as well as in Table 30, where it is mentioned that the drawback rate of the standardization inconsistencies, according to the EPC assessors, goes up to 75%.

In a way to find a solution for these drawbacks, firstly, EPC assessors identified some major discrepancies in the current EPC scheme that they encountered during their engagement with it. These include the low-cost and low-quality approach without relevance, the poor UIs, and the need to collect data from the onset, as well as the low transparency of the values. Suggested solutions or recommendations by the EPC assessors concerning the improvement of the EPC scheme encompass the collection of data from existing repositories, e.g. BIM files, as well as an asset-based renovation plan, which could be operational every five (5) years, with additional cost forecast.

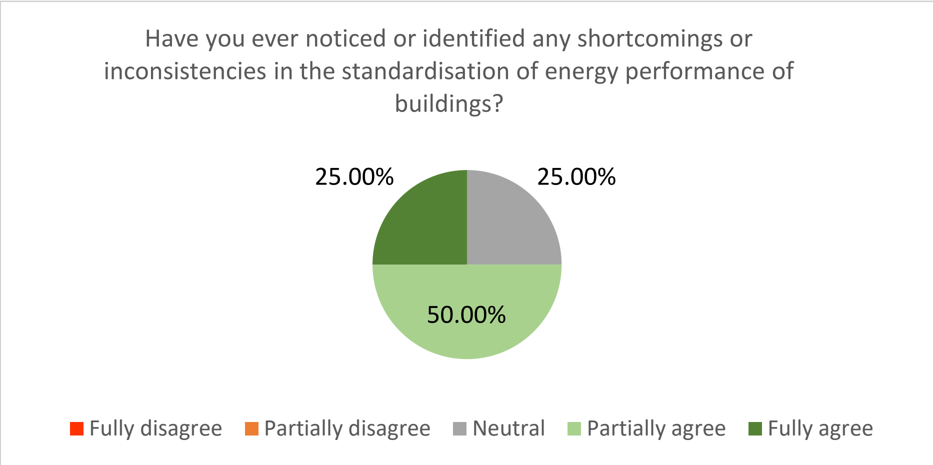


Figure 13. EPC assessors' feedback regarding drawback and discrepancies

Table 30. KPI7 Standards drawbacks rate by EPC assessors

Definition	Value
Identification of drawbacks rate	**75.00%**

5.7.2 Contribution to standards

Standardization played a pivotal role in ensuring consistency, compatibility, and reliability across various sectors. The importance of identifying drawbacks and discrepancies was paramount to drive this process efficiently. These insights served as the backbone for rectifying issues and ensuring a streamlined development framework. In this context, Task 7.3 and the D^2EPC's standardization initiatives presented a case in point. Firstly, it was crucial to comprehend the intricacies of Task 7.3. This task seemed to act as a sieve, meticulously identifying the drawbacks and discrepancies prevalent within a system or a procedure. The discrepancies might have ranged from minor procedural lags to major policy-related issues. The identification process served as a precursor for improvements, modifications, and rectifications, setting the stage for a robust and foolproof system. Parallelly, the standardization activities within D^2EPC served as the redressal mechanism. D^2EPC, by incorporating the findings of Task 7.3, ensured that the identified drawbacks did not recur. By its very nature, standardization demanded a paradigm where inconsistencies were minimal, if not completely eliminated. Therefore, the integration of the findings from Task 7.3 into D^2EPC was a strategic move to solidify the efficacy of the standardization process. The KPI findings further augmented the significance of the entire procedure. When employed in the gap analysis, these findings illuminated the areas that required immediate attention. Gap analysis, in essence, was a diagnostic tool that helped in highlighting the 'as-is' state versus the 'to-be' state, and the KPI findings acted as a compass guiding this analysis. Lastly, the mention of CEN TC371 WG5 brought forth the dimension of a structured framework. The Committee for European Standardization (CEN) and its technical committee (TC) showcased the involvement of an organized, higher-order body that supervised and ratified the standardization activities. Within such committees, working groups (like WG5) were usually specialized subsets focusing on specific areas. Incorporating the insights and findings into such frameworks ensured that standardization activities were not just effective but also aligned with broader European norms and benchmarks.

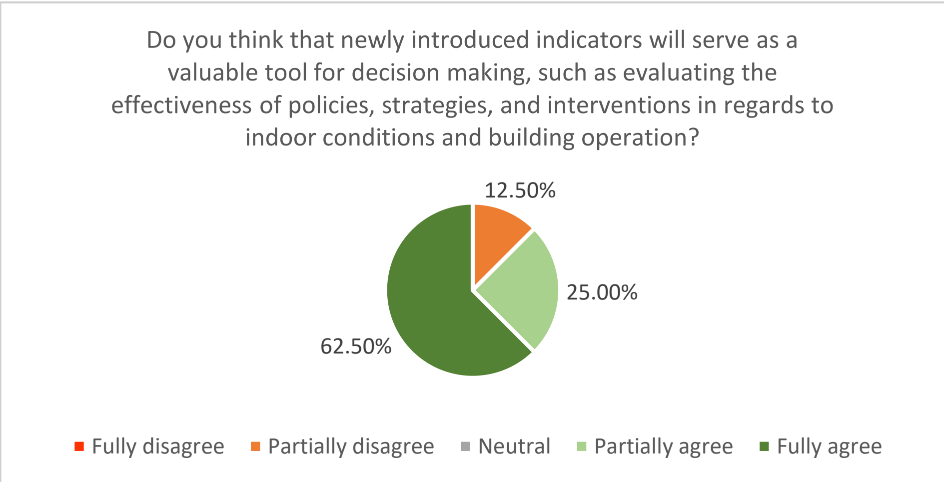
5.8 KPI8: The enhancement of EPCs through the coverage of environmental, financial, human comfort and technical aspects

5.8.1 EPC assessors' assessment

As part of the KPI8 calculation methodology, specific questions have been addressed to EPC assessors in order to capture their perception of the newly-introduced environmental, financial and human comfort indicators in the D^2EPC project. In Figure 14 (a) the results from the first question are presented. It is observed that the vast majority (i.e., 87.5%) strongly consider the innovative set of indicators as highly contributing to the overall decision-making. This leads to a pretty significant acceptance rate of the indicators (84.38%) in regard to the policies, strategies and interventions to be applied in the building operation towards improving the indoor conditions. Meanwhile, 12.5% appeared to be reluctant on whether any added-value is delivered by the D^2EPC indicators in such decision-making.

Regarding the attractiveness of the new-age EPC integrating the innovative indicators, the respondents were mostly positive (Figure 14 (b)). More precisely, 77.8% of the EPC assessors fully or partially agreed on whether the introduced indicators are able to increase the attractiveness of the enhanced EPC. The remaining 22.2% of the respondents were either neutral or partially disagreed.

Summarising, the total acceptance rate of the integrated indicators by the EPC assessors was quite satisfying reaching 82.93% (Table 31).



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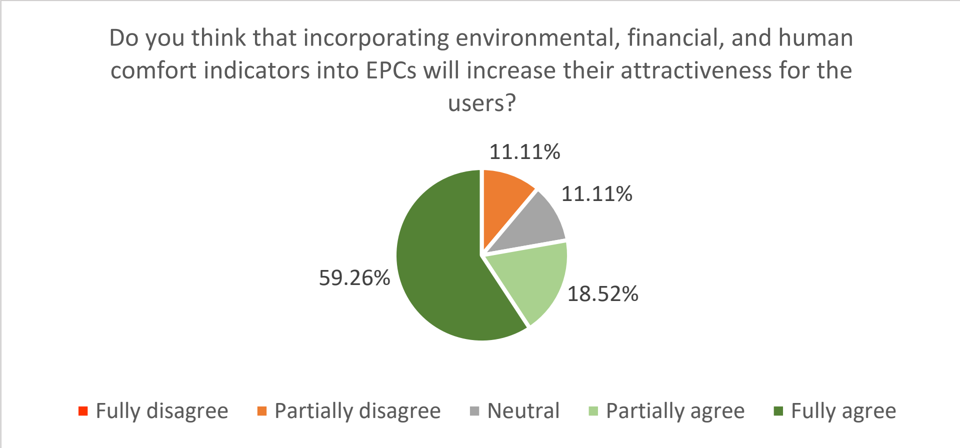


(b)

Figure 14. a), b) EPC assessors' evaluation graphs

Table 31. KPI8 EPC assessors' acceptance rates

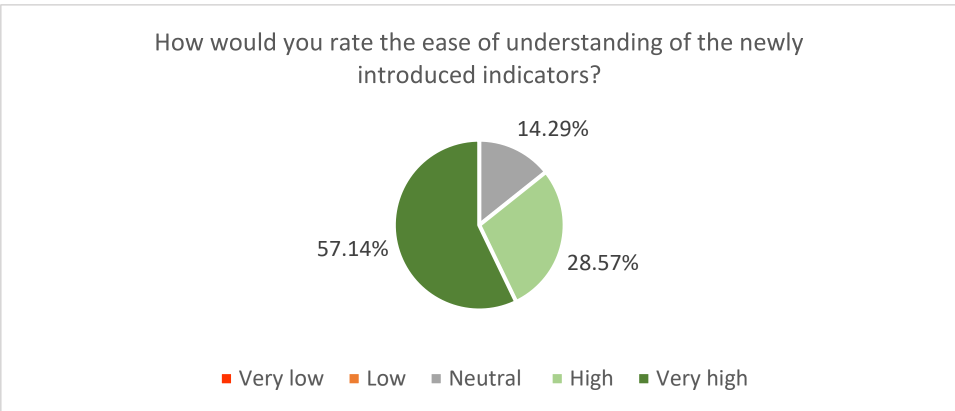
Definition	Value
Decision making acceptance rate	84.38%
Increased EPC attractiveness by new indicators rate	81.48%
Total acceptance rate	**82.93%**

5.8.2 End-Users' assessment

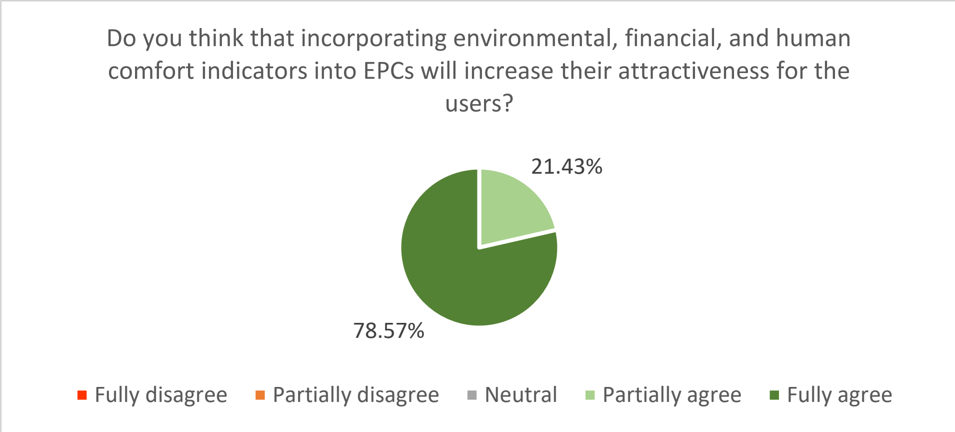
In different sessions, questions regarding the new performance indicators of the dynamic EPC have been addressed to building users as well. Their feedback is presented below (Figure 15(a)).

Regarding the ease of understanding the indicators and taking into consideration their relatively compound nature-, most of the users managed to grasp the basic concepts of the introduced KPIs (85.71%). Only 14.29% of the users appeared to be neutral in terms of the comprehension of the indicators.

In the context of increased attractiveness of the enhanced EPC, building users were extremely positive at a 94.64% rate as the absolute majority either partially or fully agreed. Similar results have been observed in the question that regarded the communication of environmental, financial and human comfort aspects through the introduced indicators. The acceptance rate reached 89.29% provided that all respondents considering the KPIs highly likely or likely to be helpful.



(a)



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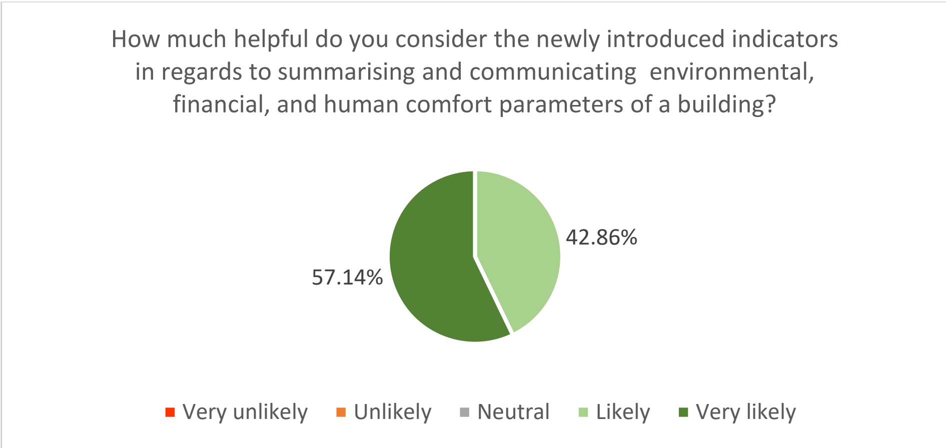


(c)

Figure 15. a), b), c) End-users' evaluation graphs

Table 32. KPI9 End-users' acceptance rates of newly introduced indicators

Definition	Value
Ease of understanding rate	85.71%
Increased EPC attractiveness by new indicators rate	94.64%
New indicators application rate	89.29%
Total acceptance rate	**89.88%**

Table 33. Total new indicators acceptance rate

Definition	Value
EPC assessors' acceptance rate	82.93%
End-users' acceptance rate	89.88%
Total new indicators acceptance rate	**86.40%**

The final results of KPI8 calculations - taking into consideration both EPC assessors and building users- corresponded to a total acceptance rate of 86.40% which is considered very indicative for the overall acceptance of the novel set of integrated indicators in the D^2EPC project.

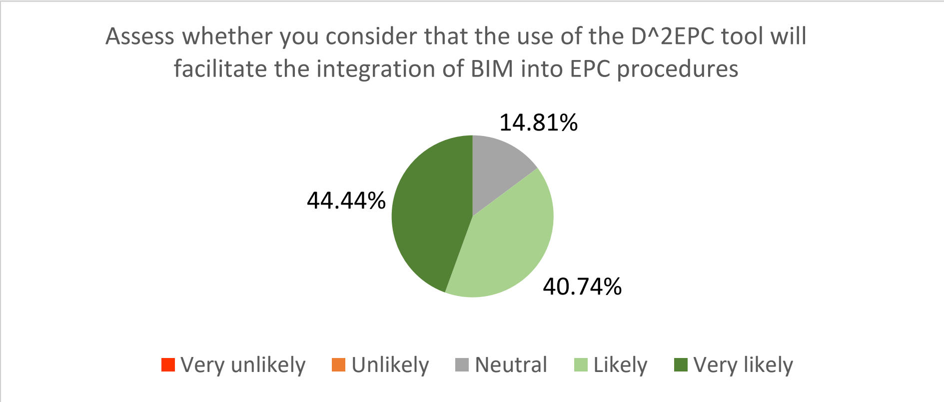
5.9 KPI9: The integration of actual operational data from buildings into the EPCs using advanced data collection infrastructure and BEPS tools integrated into BIM

5.9.1 EPC assessors' assessment

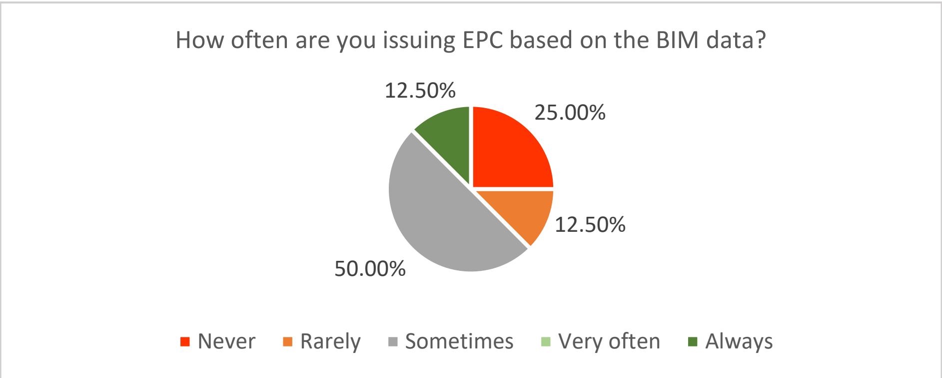
In order to assess the integration of BIM into the EPC procedure, a set of questions was addressed to EPC assessors. As presented in Figure 16 (a), most EPC assessors consider that the use of the D^2EPC tool is likely or very likely to facilitate the integration of BIM into the EPC process with an 82.41% rate. However, in most cases, the assessors have not been using BIM data for the issuance of EPCs with only 12.5% of the respondents always using BIM data.

All respondents consider that the integration of BIM will improve the accuracy and reliability of the assessment process, which resulted in a high accuracy improvement rate of **87.50%** (Table 34).

To summarize, EPC assessors agree with the integration of BIM into the EPC procedure with a total solution acceptance rate of 84.95% even though the current BIM application rate is a little below average (40.63%) as shown in Table 34**.**



(a)



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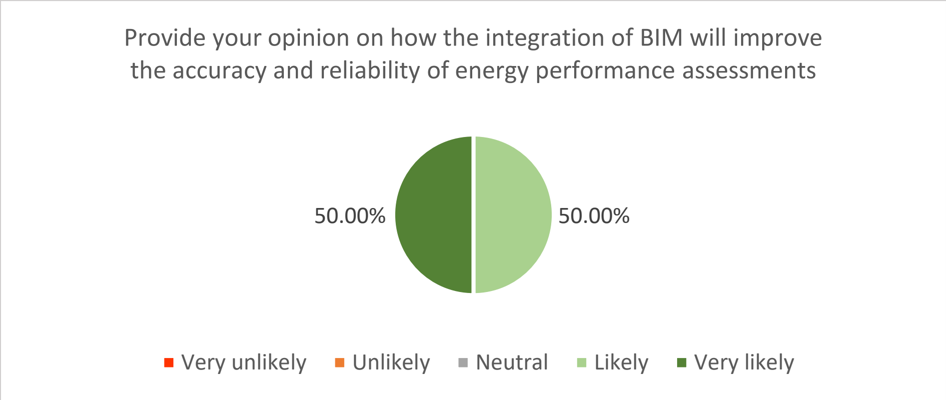


(c)

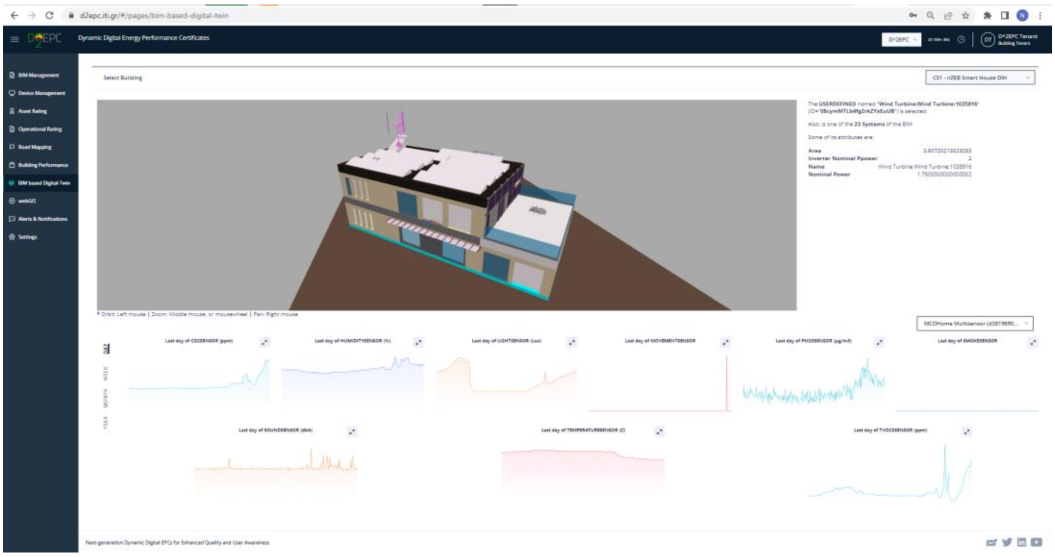
Figure 16. a), b), c) EPC assessors' assessment graphs

Table 34. KPI9 EPC assessors' acceptance rates

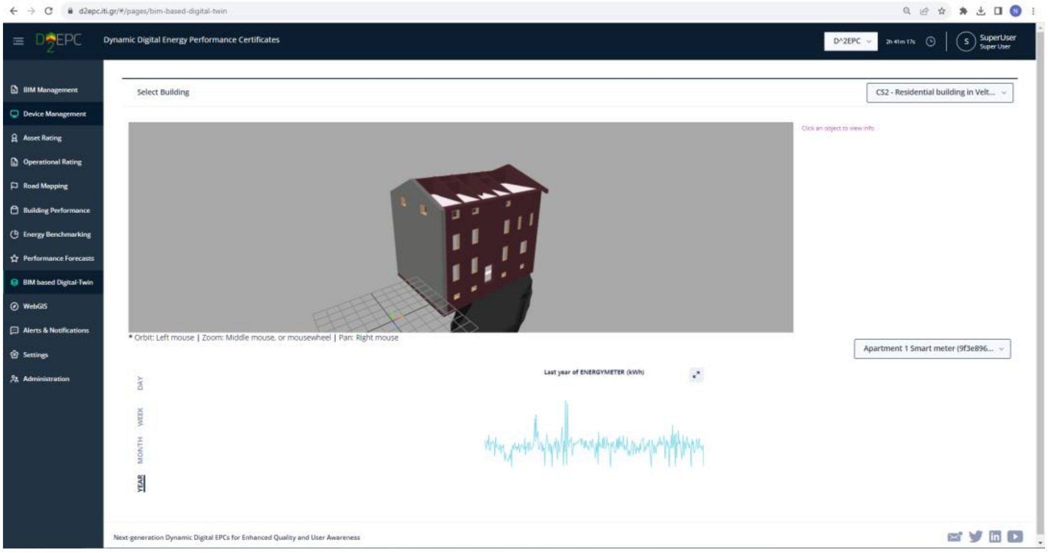
Definition	Value
D^2EPC tool BIM integration facilitation rate	82.41%
Accuracy improvement rate	87.50%
Total solution acceptance rate	**84.95%**
Total current BIM application rate	**40.63%**

5.9.2 Number of Building Digital Twin instances created

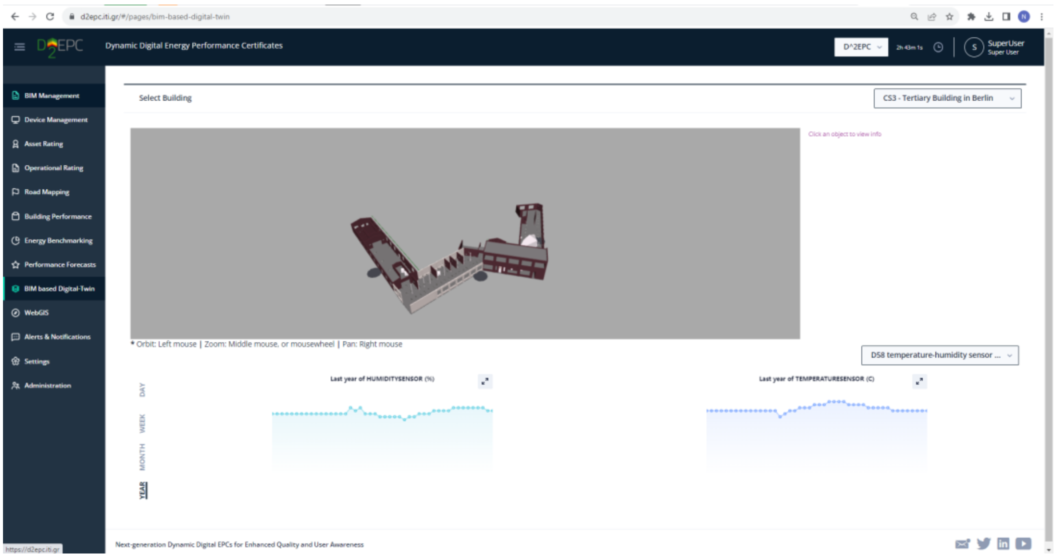
Six digital twin instances have been created, one for each Case Study, as shown in Figure 17.



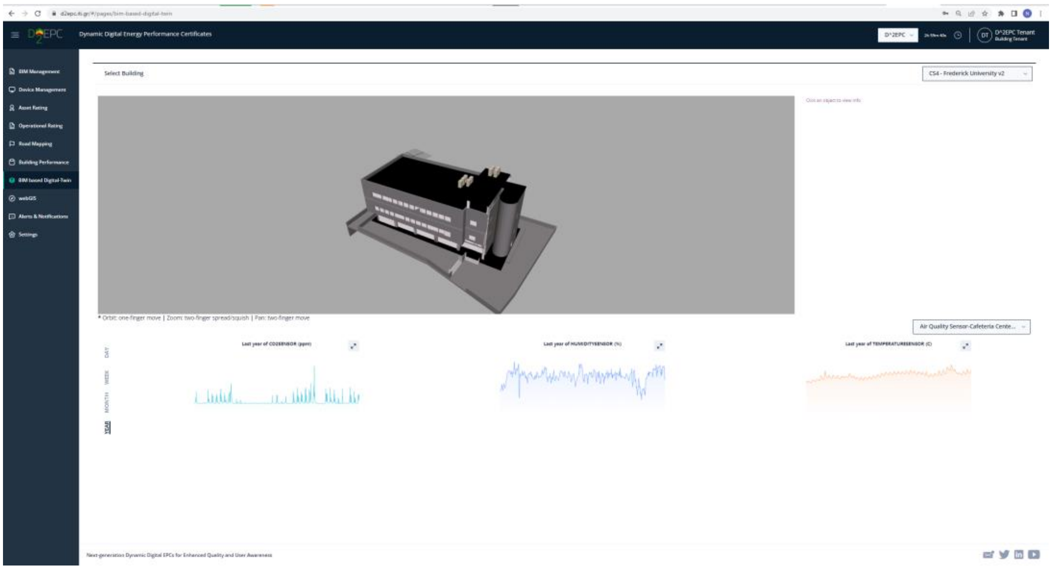
(a)


Dynamic Digital Energy Performance Certificates
Select Building
CS2 - Residential building in Velt...
BIM Management
Device Management
Asset Rating
Operational Rating
Road Mapping
Building Performance
Energy Benchmarking
Performance Forecasts
BIM based Digital-Twin
WebGIS
Alerts & Notifications
Settings
Administration
Apartment 1 Smart meter (9f3e896...
Last year of ENERGYMETER (kWh)
Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness

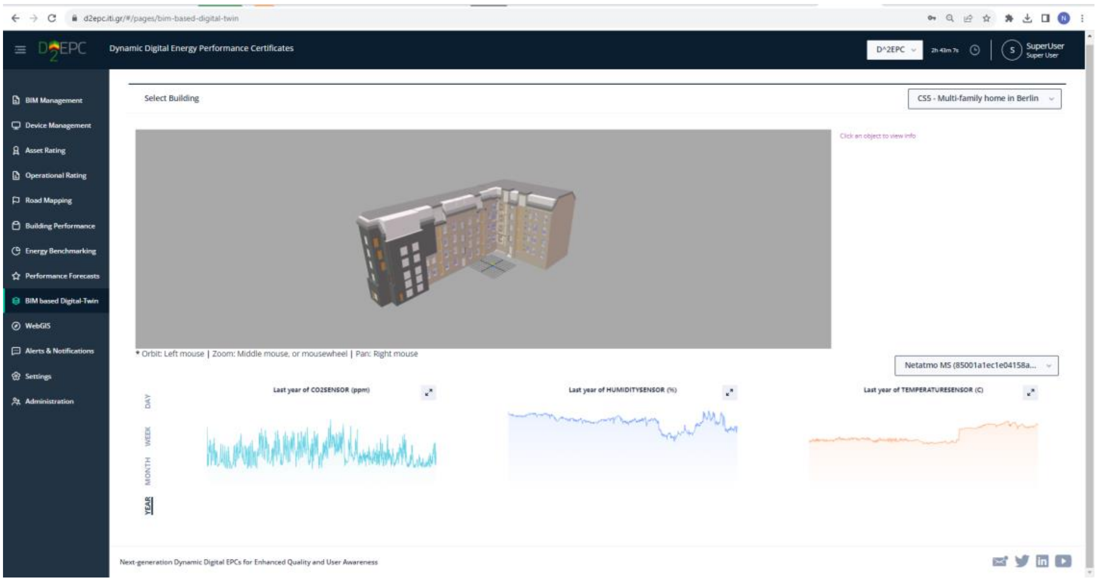
(b)


Dynamic Digital Energy Performance Certificates
Select Building
CS3 - Tertiary Building in Berlin
DS8 temperature-humidity sensor ...
Last year of HUMIDITYSENSOR (%)
Last year of TEMPERATURESENSOR (C)
Next-generation Dynamic Digital EPCs for Enhanced Quality and User Awareness

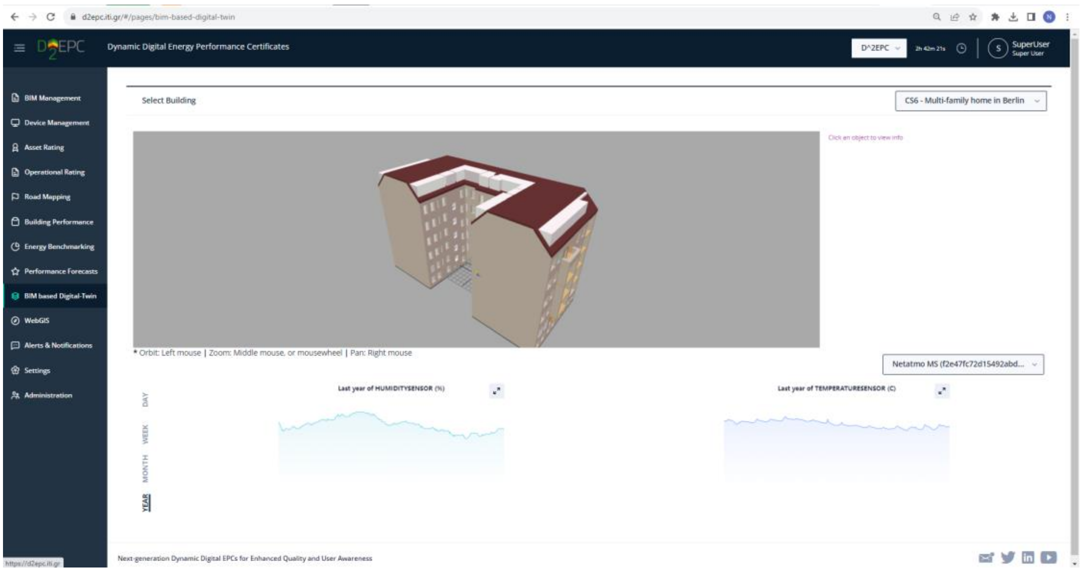
(c)


Select Building
CS4 - Frederick University v2
Air Quality Sensor-Cafeteria Cente...

(d)



(e)



(f)

Figure 17. BIM-based Digital Twin instances for the D^2EPC a) Case Study 1, b) Case Study 2, c) Case Study 3, d) Case Study 4, e) Case Study 5, f) Case Study 6

5.9.3 Number of available building data streams integrated by the Building Digital Twin

The number of sensing/metering equipment in the D^2EPC case studies that were able to stream the collected data and are integrated and accessible through the corresponding Building Digital Twin are shown in the table below.

Table 35. Monitoring devices in case studies

Case Study	Monitoring device
CS1	• CO_2, temperature (two spaces) • Luminance (two spaces)

	• Temperature, humidity, luminance and presence (two spaces) • Temperature, humidity, luminance, presence, CO_2, TVOCs and PM^2.5 (one space) • Total building energy and power consumption • Total building energy and power consumption for heating and cooling • Total building energy and power generation (PV)
CS2	• Electrical energy consumption (two building apartments)Temperature, humidity (building stairs) • Temperature, humidity and CO2 (two building apartments, two devices per apartment)
CS3	• Temperature, humidity (2 spaces) • Temperature, humidity, CO_2 (2 spaces)
CS4	• CO_2, temperature, humidity (seven spaces) • Building appliances energy consumption (for first and second floor) • Building lighting energy consumption (for first and second floor) • Building total energy consumption (total for ground, first, second floor and for the elevator) • Building energy consumption for heating and cooling (total for ground, first and second floor) • Building total energy consumption for heating and cooling
CS5	• Temperature, humidity, CO_2 (1 space) Heating energy demand
CS6	• Temperature, humidity, CO_2 (1 space) District heating energy demand

5.9.4 Amount of time for issuance of the asset-based EPC

The setup and execution time for issuing the asset-based EPC for each case study is shown in the table below.

The maximum total setup time for any case study does not exceed 20 minutes, while the execution time remains always under 7 seconds.

Table 36. Asset-based EPC issuance time

Case Study	Setup	Execution	Estimated time according to the national methodology

CS1	• Upload & Validation of BIM file: 10-15 min	Data calculation and visualization: 5-7 sec	5-7 hours
CS2	• Upload & Validation of BIM file: 5-10 min	Data calculation and visualization: 1-3 sec	10-15 hours
CS3	• Upload & Validation of BIM file: 5-10 min	Data calculation and visualization: 1-3 sec	10-15 hours
CS4	• Upload & Validation of BIM file: 15-20 min	Data fetching, calculation and visualization: 5-7 sec	10-15 hours
CS5	• Upload & Validation of BIM file: 15-20 min	Data fetching, calculation and visualization: 1-3 sec	10-15 hours
CS6	• Upload & Validation of BIM file: 15-20 min	Data fetching, calculation and visualization: 1-3 sec	10-15 hours

5.9.5 Amount of information extracted from BIM towards forming the Digital Twin/calculating the asset and operational rating

The calculation for each Case Study is performed according to the following equation:

$$BIM\ information\ extraction = 100 * \left(1 - \frac{Number\ of\ manually\ input\ data\ attributes}{Number\ of\ all\ data\ attributes}\right)$$

The “completeness” of the BIM file concerning information required for the asset and the operational rating exceeds 95 % for all case studies.

Table 37. BIM attributes number per case study

Case Study	BIM attributes
CS1	Number of manually input data attributes: 94 Number of all data attributes: 2197 **BIM information extraction: 95.7 %**
CS2	Number of manually input data attributes: 21 Number of all data attributes: 5058 **BIM information extraction: 99.6%**
CS3	Number of manually input data attributes: 5 Number of all data attributes: 1953 **BIM information extraction: 99.7 %**
CS4	Number of manually input data attributes: 13 Number of all data attributes: 7821 **BIM information extraction: 99.8%**
CS5	Number of manually input data attributes: 12 Number of all data attributes: 6907 **BIM information extraction: 99.8%**
CS6	Number of manually input data attributes: 14 Number of all data attributes: 7502 **BIM information extraction: 99.8 %**

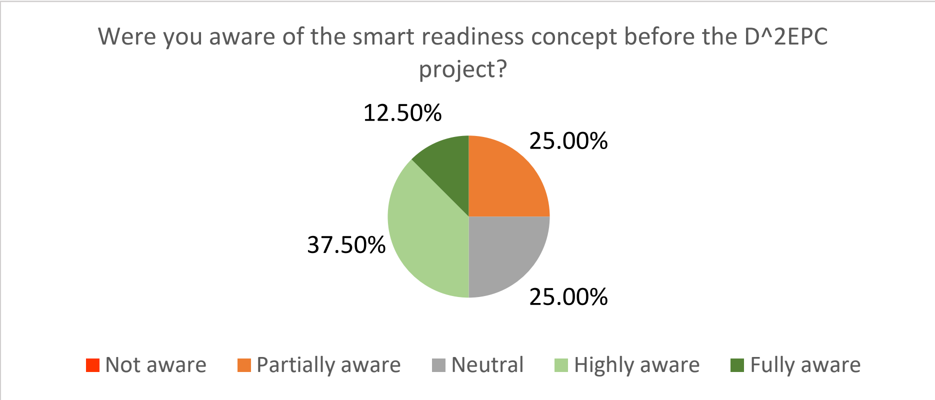
5.10 KPI10: The integration of smart readiness rationale into the building's energy performance assessment and certification

5.10.1 EPC assessors' assessment

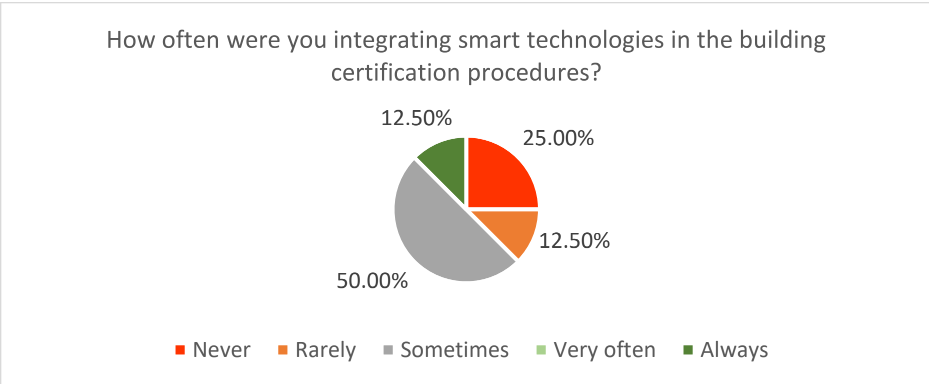
KPI10 calculation methodology evaluated the effectiveness of integrating smart readiness concepts into the assessment and certification of building energy performance. As presented in Figure 18 (a), the awareness of SRI concept before the D^2EPC project varied. Around 50% of the responders were adequately aware while the rest were neutral (25%) or partially (25%) aware of the SRI concept.

Considering the integration of smart building technologies (SBTs) in the building certification, the responder's opinions are divided in Figure 18 (b). 62,5% stated at least some degree of engagement of SBT in certification procedure while 37,5% rarely or never use them. The results clearly show a room for improvement towards the integration of SBTs in building certification procedure as well as the need to educate relevant stakeholders (especially EPC assessors).

Despite the room for improvement, the majority of the responders agree that integrating smart readiness indicators into building energy performance evaluation procedures will improve EPC accuracy (74,07%) suggesting a relatively high degree of acceptance (Table 38).



(a)



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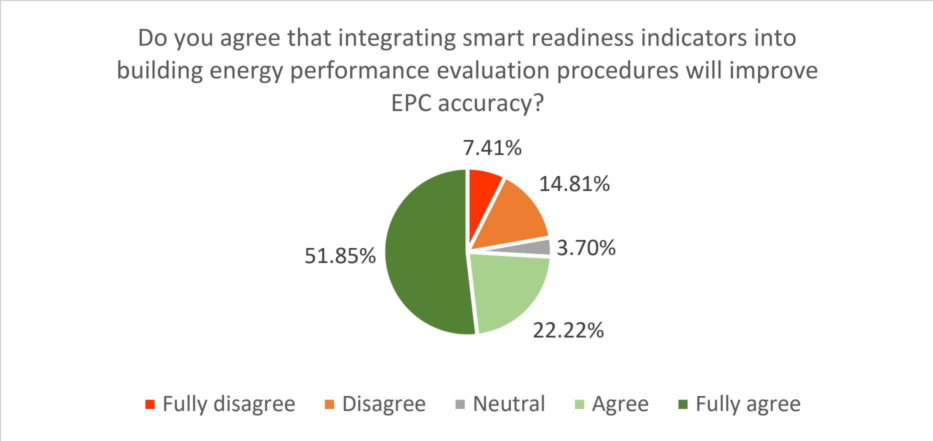


(c)

Figure 18. a), b), c) EPC assessors' evaluation graphs

Table 38. KPI10 EPC assessors' SRI awareness and acceptance rates

Definition	Value
SRI awareness rate	59.38%
SRI application rate	40.63%
Total awareness rate	**50.00%**
Total acceptance rate	**74.07%**

5.10.2 End-Users' assessment

With regards to the end-user's opinion, a relatively high acceptance rate was documented. In particular 83,34% of the responders find the inclusion of the SRI for understanding of buildings' performance at least helpful while 16,67% remained neutral. Despite the fact that the majority of respondents responded positively to the inclusion of SRI, the calculations based on the weighting of the responses showed that the level of acceptance of SRI is 75.00% (Table 39).

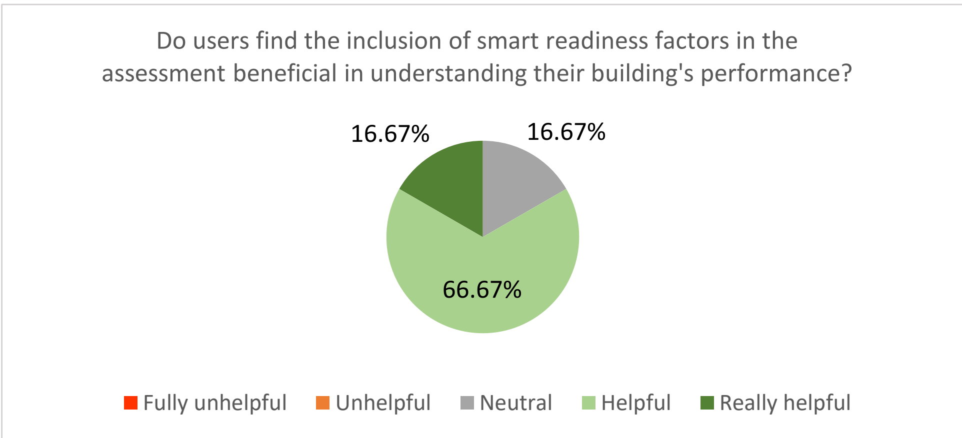


Figure 19. End-users SRI acceptance graph

Table 39. KPI10 End-users' SRI acceptance rate

Definition	Value
SRI acceptance rate	**75.00%**

The table below shows, on the basis of the views of the EPC assessors and the end-users, that there is no difference of opinion between them and that the overall level of acceptability of the SRI is 74.54%.

Table 40. Total SRI acceptance rate

Definition	Value
EPC assessors' SRI acceptance rate	74.07%
End-users' SRI acceptance rate	75.00%
Total SRI acceptance rate	**74.54%**

5.11 KPI11: Demonstration and validation of intelligent dynamic platform for dynamic EPC

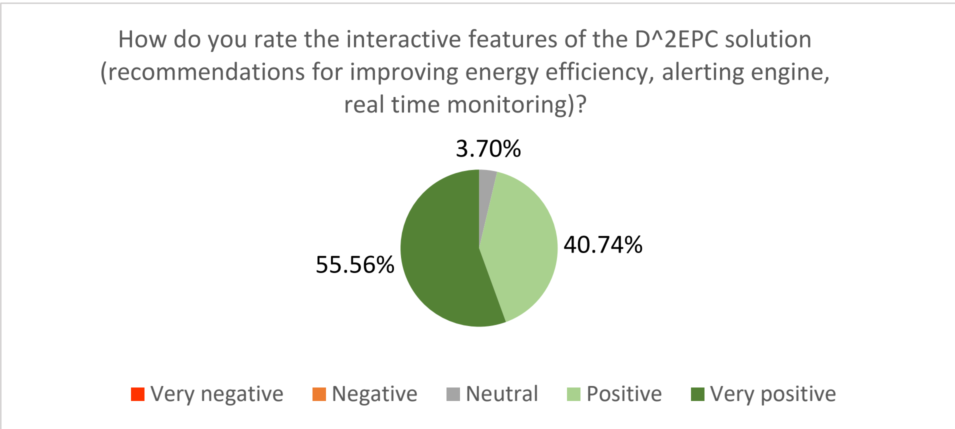
5.11.1 EPC assessors' assessment

KPI 11 concerns the demonstration and validation of the dynamic EPC platform. Its calculation was based on three questions with the view of rating the interactive features of the D^2EPC platform, their level of stimulation of building innovations and their impact on the overall acceptance of new-age EPCs.

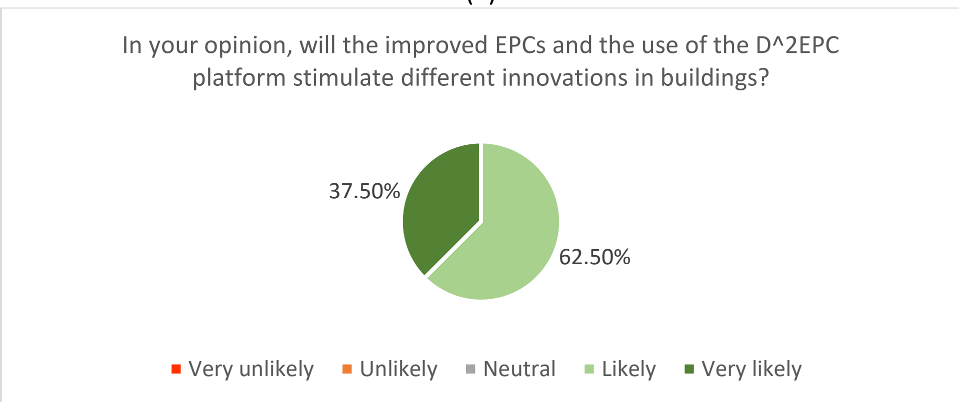
Regarding the assessors, their feedback was quite positive for all three matters raised (Figure 20). More specifically (Table 41).

- The interactivity of features was accepted at a rate of 87.96%
- The promotion of innovation of the integrated features was accepted at an 84.38% rate and
- The overall user acceptance rate of the added features reached 82.41%

Based on the above, the total acceptance rate expressed in KPI11 for the EPC assessors was calculated at 84.92% which is highly indicative of the effectiveness and added-value of the introduced features in D^2EPC web platform.



(a)



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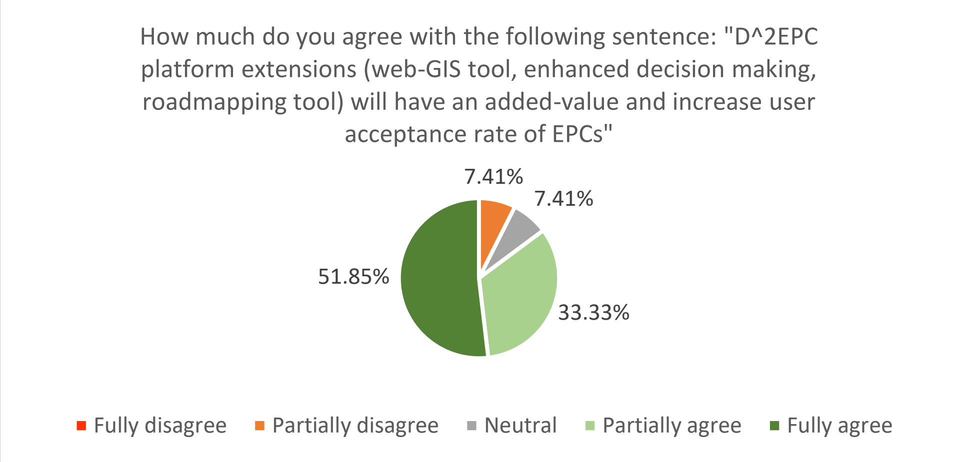


(c)

Figure 20. a), b), c) EPC assessors' evaluation graphs

Table 41. KPI11 EPC assessors' D^2EPC platform acceptance rates

Definition	Value
D^2EPC tool interactivity rate	87.96%
Innovation promotion rate	84.38%
D^2EPC platform extensions acceptance rate	82.41%
Total D^2EPC platform acceptance	**84.92%**

5.11.2 End-Users' assessment

Apart from EPC assessors, similar questions have been addressed to building users in order to capture their point of view on the added features of D^2EPC platform. The users were expected to provide their feedback on the interactivity and acceptance rate of the extensions (as in the EPC assessors case) as well as their view on the overall quality of the platform's user interface.

The results were also pretty satisfying. In Figure 21 (a) the interactivity rate is presented. It is observed that over 85% of the users were very positive/positive regarding the interactive features. A total rate of 82.14% was reached. The same rate was achieved in the interface acceptance rate (Figure 21 (b)) receiving exclusively 'good' or 'excellent' grades in most responses. Lastly, the biggest rate (92.86%) was reached in the acceptance rate of extensions in the platform where users partially or fully agreed with the added-value of the newly-integrated features.

The total acceptance rate determined by all three questions was finally calculated at 85.71% (Table 42).

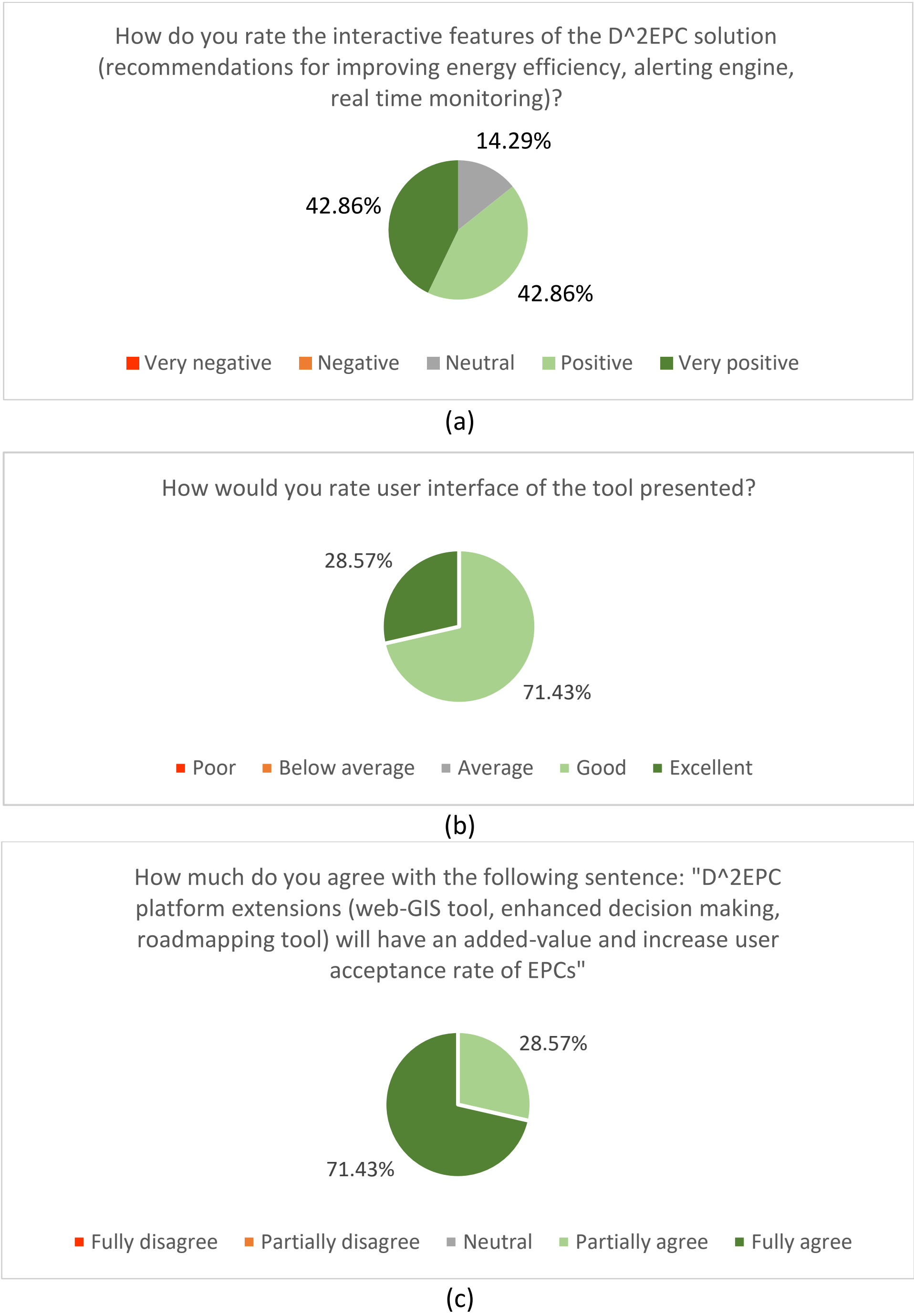


Figure 21. a), b), c) End-users' evaluation graphs

Table 42. KPI11 End-users' D^2EPC platform acceptance rates

Definition	Value
D^2EPC tool interactivity rate	82.14%
Interface acceptance rate	82.14%
D^2EPC platform extensions acceptance rate	92.86%
Total D^2EPC platform acceptance	**85.71%**

Table 43. Total D^2EPC platform acceptance rate

Definition	Value
EPC assessors' D^2EPC platform acceptance rate	84.92%

End-users' D^2EPC platform acceptance rate	85.71%
Total D^2EPC platform acceptance rate	**85.31%**

The final calculation of KPI11 was based both on EPC assessors and building user's feedback. Combining the results from both surveys, the total acceptance rate of the added features was finally 85.31% (Table 43).

5.12 KPI12: Increasing partners' absorptive capacity

5.12.1 Understanding and implementation of energy efficiency measures

The extent of an organization's involvement in training programs, workshops, knowledge-sharing sessions, and collaborative initiatives can significantly influence its grasp of energy efficiency measures and subsequent implementation strategies. The question posed to participating organizations sought to quantify the spectrum of their engagement in activities geared towards enhancing their comprehension and application of energy efficiency measures. The responses revealed a range of involvement strategies, each shedding light on distinctive patterns of interaction. A percentage of the surveyed organizations expressed regular involvement in conferences, fairs, and workshops. Such events present opportunities for exposure to cutting-edge research, innovative solutions, and networking possibilities.

Another subset of organizations reported active engagement in research projects, particularly those funded by programs like H2020 and HE, that focus on energy efficiency. This proactive involvement suggests a dedication to advancing the theoretical underpinnings of energy efficiency measures. The organizations' participation in standardization committees underscores a broader engagement in shaping industry guidelines and best practices. However, it is intriguing to note that despite this participation, the application of acquired knowledge to organizational procedures remains somewhat limited. This paradoxical trend may be attributed to various factors, such as structural impediments, resource constraints, or inadequate translation of theoretical insights into actionable strategies.

A segment of the surveyed organizations reported a more general "many" or >5 level of engagement. While not providing specific insights, this response suggests an inclination towards various initiatives that enhance energy efficiency. These organizations are likely involved in multiple avenues, potentially spanning conferences, workshops, and collaborative projects, which cumulatively foster a holistic approach to energy efficiency. Organizations participating in training programs and workshops affiliated with EU-funded projects exhibit a strategic alignment with broader European initiatives. Such endeavours often serve as conduits for transnational knowledge exchange and harmonization of energy efficiency practices across borders. This active participation reflects a commitment to contributing to the collective advancement of energy efficiency goals on a regional scale.

On the other hand, organizations engaging in bi-yearly workshops and annual hackathons as part of their research projects signify a dynamic approach to energy efficiency enhancement. These events not only facilitate periodic knowledge infusion but also encourage hands-on collaboration and ideation through hackathons. Such initiatives can foster a culture of innovation and practical problem-solving within the organization.

In summary, from consistent attendance at conferences to participation in research projects, from comprehensive involvement to diverse engagement strategies, each approach reflects the varying priorities and resources of the organizations. As the energy landscape evolves, these insights can inform strategic decisions to optimize organizational participation and ensure effective integration of energy efficiency measures.

5.12.2 Definition of implemented activities

The successful execution of training programs, workshops, and collaborative activities is pivotal in disseminating knowledge, fostering innovation, and cultivating a community of experts within various domains. In response to the inquiry regarding the definition of the implemented training initiatives, this discussion elucidates the scope and significance of the diverse activities that have been undertaken.

One prominent channel for showcasing innovations, disseminating product features, benefits, and technical intricacies is through participation in trade fairs, which can significantly contribute to brand visibility and recognition. A wider audience can be reached by repeatedly presenting the product at different fairs, ensuring maximum exposure and engagement opportunities. Incorporating participation in events such as Sustainable Places and Knowledge Valorisation Week further exemplifies a commitment to engaging with thought leadership and emerging trends within the relevant domain. These events not only provide a platform for dissemination but also foster discourse that contributes to the enrichment of the collective body of knowledge.

The integration of training and information sessions within the ambit of Klimaaktiv—an initiative dedicated to climate protection—underscores a commitment to sustainability and environmental consciousness. Such sessions equip participants with the requisite tools to address the challenges posed by climate change, aligning with broader governmental objectives in this regard.

The collaboration among different research initiatives, such as D^2EPC and Chronicle, engenders an environment of knowledge exchange and cross-pollination of ideas. Events like standardization meetings enable professionals from diverse backgrounds to converge, fostering dialogue on common challenges and potential solutions. These interactions are instrumental in ensuring the coherence of approaches and methodologies across disparate projects. The organization of bi-yearly workshops through entities like IsZEB Cluster and i4bydesign signifies an ongoing commitment to continuous learning and professional development. These workshops allow participants to delve deeper into complex topics, engage in hands-on activities, and network with peers, promoting a culture of learning and innovation.

In conclusion, the delineation of the implemented training programs, workshops, and collaborative activities showcases a multifaceted approach to knowledge dissemination, networking, and skill development. The interplay between various initiatives underscores a commitment to fostering a vibrant ecosystem that not only champions innovation but also contributes to the collective advancement of the relevant domain. These activities collectively propel the field forward by equipping stakeholders with the necessary tools and insights to navigate contemporary challenges and harness emerging opportunities.

5.12.3 Improvement of understanding and implementing energy efficiency measures

The results of the survey illustrate the multifaceted nature of energy efficiency enhancement efforts within the surveyed organizations. The responses reflect both status quo adherence and active engagement, underscoring the significance of adapting energy consumption behaviors to external events and remaining informed about emerging energy efficiency methodologies. By holistically considering these findings, organizations can strategically tailor their energy efficiency initiatives to create a more sustainable and resource-efficient operational framework. Any affirmative responses concerning the subject indicate an active commitment to modify energy consumption behaviors and patterns, suggesting an increased awareness of the benefits associated with energy efficiency.

In one of the responses, it is indicated that the organizations have maintained a consistent approach to organizing their energy demand and usage despite the presence of external events. This finding suggests that the organization has not proactively adapted its energy consumption patterns based on contextual changes, potentially indicating a missed opportunity for optimizing energy utilization. This response underscores the importance of proactive energy management strategies that respond to dynamic environmental factors, thereby maximizing energy efficiency.

Another response showcases the organizations' dedicated allocation of experts who engage in diverse activities and closely monitor emerging methodologies and regulations. By doing so, the organization demonstrates a commitment to staying informed and up-to-date in matters relevant to energy efficiency. This proactive engagement with evolving practices and regulations signifies a conscientious effort to maintain a high level of understanding in the realm of energy efficiency. Such an approach not only bolsters the organization's operational efficacy but also establishes it as a proactive contributor to sustainability objectives.

5.13 KPI13: Improving partners' market knowledge

5.13.1 Enhancing market knowledge within the energy sector

The investigation into the depth of organizational engagement within the energy sector, as ascertained through involvement in diverse training programs, workshops, knowledge-sharing sessions, and collaborative initiatives, yields a spectrum of responses. The diversity of responses underscores the multifaceted nature of market knowledge enhancement strategies within the energy sector. Organizations exhibit varying levels of commitment, spanning from active physical participation to virtual engagement. The emphasis on online sources and periodic workshops reflects the fusion of traditional and contemporary methods in pursuit of well-rounded insights.

Some respondents indicated their active participation in conferences, fairs, and workshops. This suggests a commitment to ongoing engagement and an acknowledgment of the significance of industry events in fostering enriched market insights.

A noteworthy proportion of respondents indicated their participation with a succinct response of more than ten or many distinct activities reinforces the dedication of certain organizations towards fostering a multifaceted understanding of the energy sector. It aligns with the principle that diversification of learning opportunities can facilitate a more comprehensive grasp of market dynamics. The bi-yearly periodicity of such workshops implies a balanced strategy, allowing organizations to both dedicate focused time for learning and simultaneously engage in day-to-day operational endeavours.

On the other hand, the acknowledgment of online platforms as a primary source of market information underscores the contemporary relevance of digital media. This response reflects the evolving landscape of knowledge acquisition, where virtual spaces play a pivotal role in staying informed.

5.13.2 Definition of implemented activities

The successful execution of training programs, workshops, and collaborative activities is pivotal in disseminating knowledge, fostering innovation, and cultivating a community of experts within various domains. In response to the inquiry regarding the definition of the implemented training initiatives, this discussion elucidates the scope and significance of the diverse activities that have been undertaken.

Events like standardization meetings enable professionals from diverse backgrounds to converge, fostering dialogue on common challenges and potential solutions. These interactions are instrumental in ensuring the coherence of approaches and methodologies across disparate projects. The collaboration among different research initiatives, such as D^2EPC and Chronicle, engenders an environment of knowledge exchange and cross-pollination of ideas. Integration of solutions and training on technological tools fosters practical skills and cultivates a culture of adaptability in the face of evolving energy landscapes. Specialized training modules enhance participants' technical proficiencies and equip them with tools to navigate the intricacies of real-world energy contexts.

Networking conferences, as a second dimension, create opportunities for researchers and practitioners to engage in dialogues that transcend disciplinary boundaries. These conferences catalyze multidisciplinary collaboration, enabling participants to bridge gaps between energy, technology, and policy. Such interaction nurtures a holistic understanding of the complexities inherent in energy-related challenges and offers a forum for the exploration of innovative solutions. Active participation in external conferences and workshops, exemplified by attendance at Enlit—a prominent inclusive energy forum—serves to broaden perspectives and infuse fresh insights into ongoing research endeavours. Enlit's comprehensive coverage of diverse energy aspects amplifies participants' exposure to cutting-edge trends, fosters dialogue, and reinforces their roles as contributors to the energy discourse. The organization of bi-yearly workshops through entities like IsZEB Cluster and i4bydesign provides a recurring platform for in-depth exploration of specific themes, enabling researchers to delve into nuanced topics and forge lasting networks of collaboration.

5.13.3 Improvement of market knowledge within the energy sector

This inquiry sought to gain insights into strategies employed by participants to enhance their market knowledge within the energy sector. The responses provided by the participants reveal a nuanced understanding of the approaches taken to improve market knowledge in this dynamic and evolving sector.

One notable finding from the results is the indication that the participants' organizational energy demand and usage remained largely unchanged despite external events. This observation reflects a certain level of stability in their operational practices, suggesting that the participants have not altered their energy consumption patterns in response to events. This outcome could be attributed to various factors, such as established energy management protocols, industry-specific requirements, or a lack of immediate incentives to modify consumption behaviors in light of external events.

Another prominent approach highlighted by the participants is their engagement in networking conferences. This strategic move demonstrates the recognition of the significance of external interactions in expanding market knowledge. Networking conferences provide a platform for professionals to exchange ideas, share experiences, and gain insights from industry peers. Another strategy involves leveraging the expertise of colleagues within their organization to stay informed about energy efficiency measures and market trends. Participants benefit from continuously updated information and insights by actively involving expert colleagues. This practice reflects an internalized knowledge-sharing culture where seasoned professionals contribute to the professional development of their peers. This strategy exemplifies a peer-to-peer learning dynamic, which has been recognized as an effective means of disseminating specialized knowledge within organizational contexts.

5.14 KPI14: Enhancing exploitation potential

Increasing the potential for deployment assesses the effectiveness of initiatives to maximise the uptake and commercialisation of energy efficiency solutions in the energy sector. These initiatives, including market and technology assessments, aim to scale up and commercialise these solutions. The evaluation indicator measures various aspects, gathers feedback and helps to improve initiatives aimed at a more sustainable and economically viable energy sector. (Figure 22-Figure 30).

5.14.1 General

Partners' involvement in commercialization survey results (Figure 22) show that a majority of respondents, approximately 66.67%, have never been involved in commercializing solutions related to building energy performance. About 22.22% indicated they had been engaged a few times, while only 11.11% reported being involved often. Above mentioned suggests that a significant portion of the surveyed individuals need more experience commercializing solutions in this specific field, which may have implications for adopting and scaling energy-efficient technologies in the building sector.

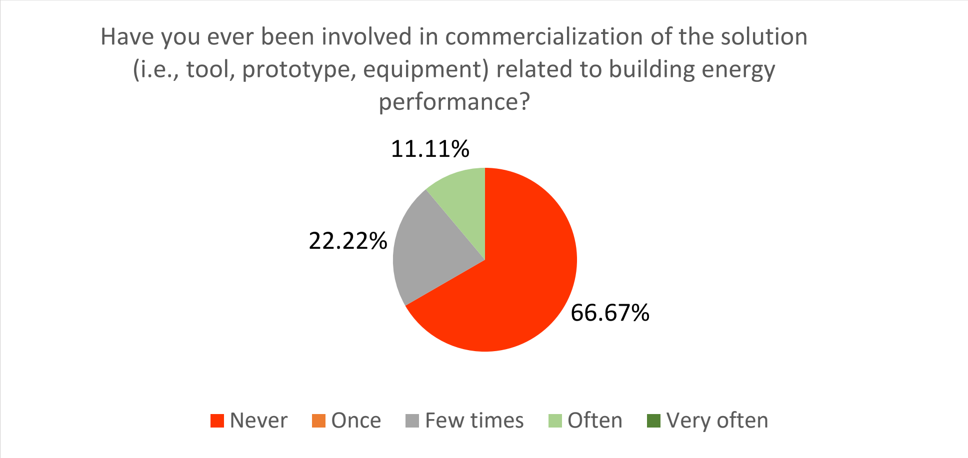


Figure 22. Partners' involvement in commercialization

Speaking of how initiatives have been effective in enhancing the exploitation potential of energy performance solutions that most respondents, approximately 62.5%, recognize the initiatives aimed at enhancing the exploitation potential of energy performance solutions as moderately effective. 25% consider them effective, and 12.5% view them as very effective (Figure 23).

These results show that the overall perception of the effectiveness of these initiatives is positive, with a large proportion considering them to be at least moderately effective. However, there is room for improvement, in particular by increasing the proportion of respondents who consider these initiatives to be very effective. Further analysis of the feedback and specific areas for improvement can help to refine these initiatives to achieve even better results in promoting the use and commercialisation of energy efficiency solutions.

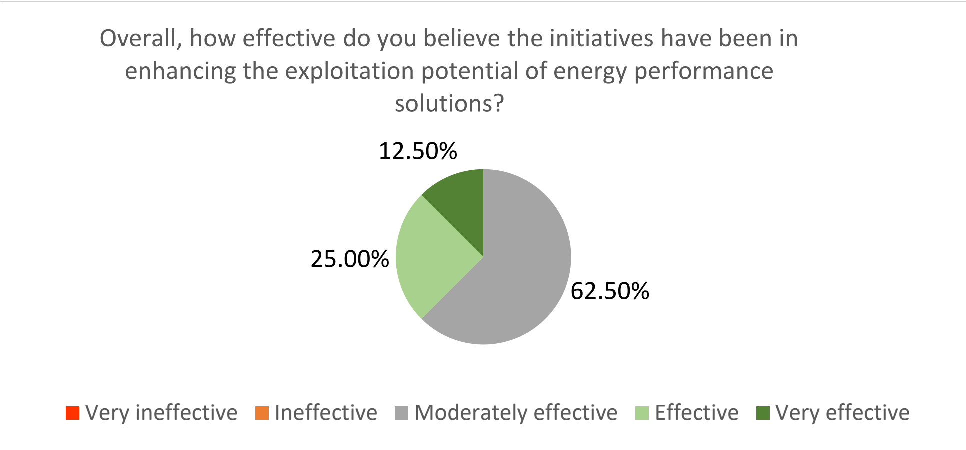


Figure 23. Effectiveness of exploitation potential

5.14.2 Market Demand and Viability

The results of Figure 24 indicate that a substantial majority of respondents, approximately 75%, recognize the current market demand for energy performance solutions in their region as high. Additionally, 12.5% of respondents rate it as very high, while another 12.5% express a neutral view.

These findings show that the market demand for energy efficiency solutions is strong and positive. The high and very high ratings indicate that there is a strong demand for such solutions in the region. This positive attitude bodes well for initiatives to commercialise and scale up these solutions, as strong market demand can lead to their deployment and success.

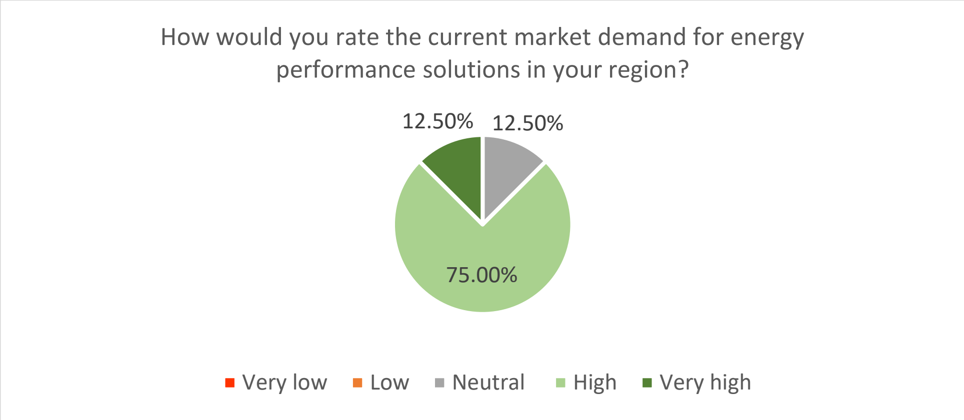


Figure 24. Market demand results

The survey results (Figure 25) provide valuable insights into the factors that respondents believe influence the market demand for energy performance solutions in their region.

Not surprisingly, 33.33% of respondents consider energy prices a key factor. Higher energy prices often drive individuals and businesses to look for energy-efficient solutions to reduce costs. 28.57% of respondents states that Government rules and incentives are a strong incentive for energy efficiency solutions. These policies can include tax incentives, rebates and regulations to encourage adopting energy-efficient practices and technologies.

19.05% of respondents emphasized that growing environmental awareness increases the demand for energy efficiency solutions as individuals and organisations strive to reduce their carbon footprint and contribute to sustainability goals. 9.52% assume that advances in energy efficiency technologies can make them more attractive and accessible to consumers, which stimulates demand by making these solutions more efficient and cost-effective. 4.76% mentioned awareness and knowledge of the benefits of energy savings. Better information and education on the benefits of energy-saving solutions can influence consumer choice and encourage their adoption. According to the results of this survey, consumer preferences and behaviour are also important to 4.76% of respondents, although this seems to be a relatively minor factor.

These results show that the factors influencing the market demand for energy efficiency solutions are multifaceted. Addressing these factors collectively through policy, education, technological innovation and incentives can further stimulate demand and support the shift towards more energy efficient practices.

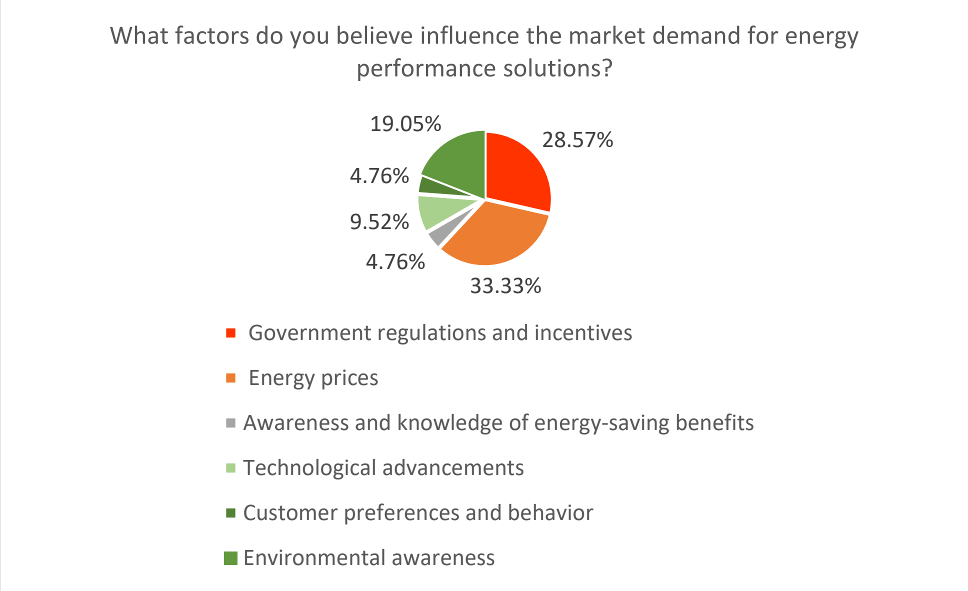


Figure 25. Influencing factors

The respondents were asked to comment additionally what are the primary barriers to the adoption of energy performance solutions in the market. The results highlight a range of significant barriers to the adoption of energy performance solutions in the market. The answers can be divided into four groups: cost and investment, lack of understanding, regulatory and policy complexity and the last one - information overload.

- **Cost and Investme**nt. The main barrier is price-related problems, including high upfront investment and additional costs for end-users. Limited financial resources and affordability problems were also mentioned, especially for households and small businesses.
- **Lack of Understanding.** The main barrier lack of understanding of the benefits of energy efficiency solutions. This points out the need to improve education and awareness-raising campaigns to bring the benefits of these solutions to a wider audience.
- **Regulatory and Policy Complexity**. Unclear national regulations and complex policies need to be clarified and hamper decision-making. Simplifying and clarifying the regulatory environment can streamline the decision-making process.
- **Information Overload.** Many of the possible solutions can be inaccessible to non-experts, making it difficult to choose the right solution and to trust a particular service provider. This barrier can be reduced by simplifying information and providing guidance.

These responses suggest that addressing barriers should involve a multifaceted approach, including cost reduction measures, education to raise awareness, simplifying policies, and efforts to streamline the processes for selecting energy efficiency solutions and building trust.

5.14.3 Technology Readiness and Scalability

The survey results give an insight into how respondents perceive the technological maturity of energy efficiency solutions (Figure 26).

A significant proportion of respondents, 36.36%, consider that energy performance solutions are in the pilot testing phase. Above mentioned indicates that these solutions have been initially tested to assess their effectiveness and feasibility. More than a quarter of respondents - 27.27% have reached the commercial deployment stage. The result indicates that many of these solutions have already moved beyond the testing phase and are ready for wider use in real-life conditions. The survey shows that some solutions are currently in the process of scaling up (18.18%). The result indicates that active efforts are being made to expand the scope and impact of these technologies. A similar proportion of respondents - 18.18% - are in the prototyping phase, indicating that they are still fine-tuning and refining their energy efficiency solutions before moving on to wider testing or deployment.

These results reflect the diversity of energy efficiency solutions at different stages of development. Many of them are already at the commercial deployment stage, as this shows that they are applicable and can be more widely deployed in the market. Furthermore, the fact that there are solutions in the pilot and scale-up phases shows continuous innovation and development in the sector, which is framing well for the future of energy efficiency technologies.

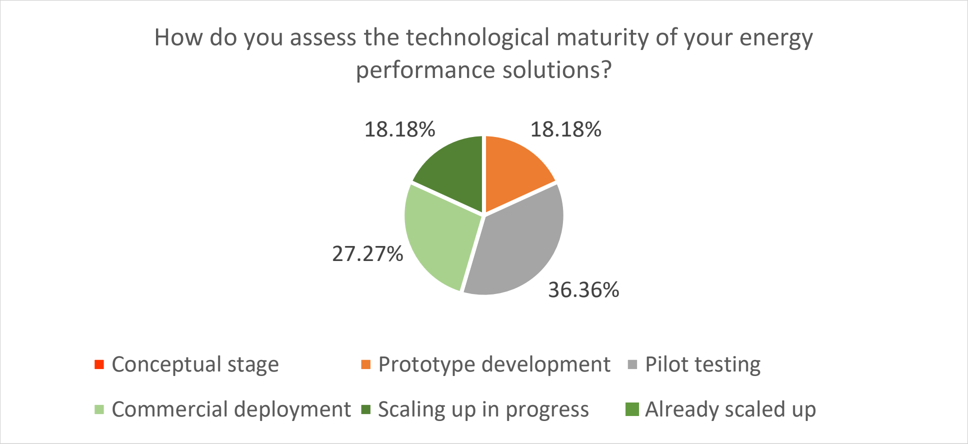


Figure 26. Technological maturity of partners' solution

Respondents additionally commented on the challenges they face in extending their energy efficiency solutions to wider markets. The responses from the survey shed light on the challenges faced by respondents when scaling up their energy performance solutions to broader markets. These challenges can be categorized into several key areas such as: Cost and Affordability, Lack of Understanding, Legal and Regulatory Environment, Data and Connectivity, IoT Integration. Each of mentioned is described below:

- **Cost and Affordability.** Cost-related issues, including additional costs for stakeholders such as EPC issuers and consultants, can hamper the scaling-up process. These costs may affect the overall feasibility and attractiveness of the solution in wider markets.
- **Lack of Understanding.** Lack of understanding of the benefits of energy efficiency solutions remains a major problem. To increase the uptake of these solutions is necessary to inform potential users of their benefits.
- **Legal and Regulatory Environment.** Different markets face different legal environments and policies, which can lead to difficulties and obstacles. Navigating the regulatory environment can be a barrier to scale-up.
- **Data and Connectivity.** Problems related to data availability and meter connection can cause technical difficulties. These challenges are particularly acute for solutions that rely on data collection and processing, as they require a reliable data infrastructure.
- **IoT Integration**. Some respondents are integrating more and more IoT devices to extend their energy efficiency solutions. This expansion aims to cover a wider range of use cases and business scenarios, which may pose technical and logistical challenges.

These responses illustrate the multifaceted nature of energy efficiency solutions. Addressing these challenges may require various strategies, including cost management, educational efforts, regulatory compliance and technical improvements to integrate data and the Internet of Things.

5.14.4 Value Chains and Business Models

The survey results show (Figure 27) a generally positive perception of value chains and key stakeholders in the energy sector. The vast majority of respondents - 77.8% - report a good understanding of value chains and key stakeholders in the energy sector. Results show that they are well aware of the subtleties of energy production, distribution and consumption and the key players in the industry. A smaller proportion of respondents - 11.11% - indicated that they have some understanding, which means that they may have a basic understanding of the dynamics of the energy sector but may need to be fully aware of all aspects. The same proportion of respondents with good knowledge, i.e. 11.11%, indicates a fair understanding. This indicates that a proportion of respondents consider themselves to have a more average level of knowledge of the energy sector than those with a 'good' understanding.

Overall, the majority of respondents who self-reported a good understanding of the value chains and key stakeholders in the energy sector is positive, as it represents a solid knowledge base that can be valuable when working on initiatives related to energy efficiency solutions and their commercialisation.

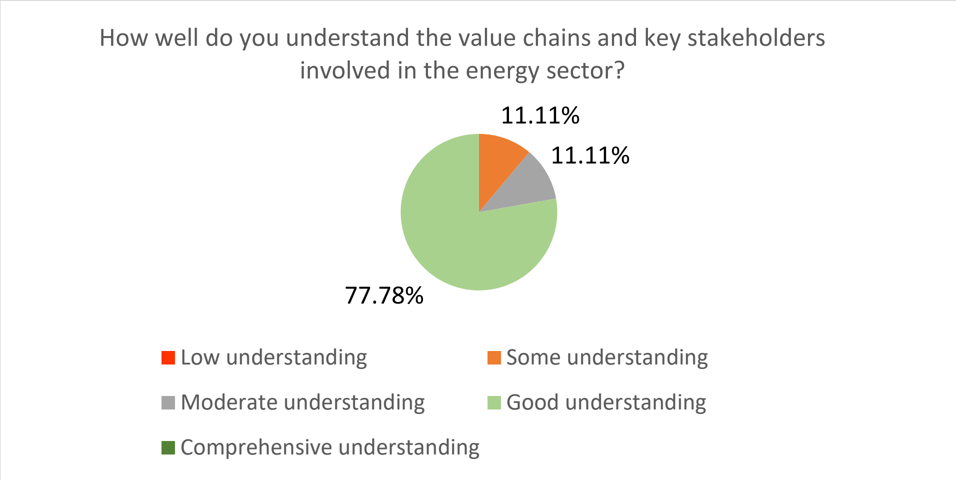


Figure 27. Level of understanding value chains and key stakeholders

Respondents were asked to share their thoughts on whether there are any specific business models or strategies that they believe could accelerate the process of wider commercial deployment of energy efficiency solutions. They were invited to provide additional information and clarification to elaborate their views. The responses provide valuable insights into specific business models and strategies that can accelerate the commercialisation of energy efficiency solutions:

- **Clear demonstration of benefits.** Effective clarification and communication of the benefits of energy efficiency solutions to individuals and businesses can stimulate their uptake. This points to the importance of improved education and marketing efforts.
- **Government support.** Government support in the form of regulations, subsidies and incentives can significantly boost the commercialization of these solutions. Policy frameworks that promote energy efficiency are essential.
- **Cost recovery and payback**. A business model that recovers the initial implementation costs and allows users to recover the savings in the future is a practical approach. This is in line with the idea that energy efficiency improvements often have long-term financial benefits.
- **Energy efficiency incentives.** Energy efficiency incentives, such as tax incentives or emphasizing the long-term economic benefits, can motivate energy efficiency behavior and encourage investment in these solutions.

- **User-friendly solutions.** it is essential to develop solutions that are user-friendly and accessible to both experts and non-experts. Ease of use can increase the attractiveness and adoption of these technologies.
- **Multiple means of use.** Multiple means of use, such as licensing of specific services or software-as-a-service (SaaS) models, allow for flexibility in how these solutions are delivered and monetized.
- **Increasing property value**. Recognizing that an Energy Performance Certificate (EPC) rating can increase the market value of a property, the positive impact on property value can be a compelling selling point.

These insights show that a multi-faceted approach is important to accelerate the commercialisation of energy efficiency solutions, including effective communication, political support, financial models, user-friendliness and a range of income generation opportunities.

5.14.5 Intellectual Property Protection

100% of respondents (Figure 28) indicated that they had not taken any action so far to protect the intellectual property of their energy efficiency solutions and research results. This suggests that there may be a significant gap in IP protection in this sector. Intellectual property protection is essential to ensure that innovative solutions are not misused or copied. It may be appropriate to consider exploring intellectual property protection measures to protect valuable innovations and research results. This could include patents, trademarks, copyrights or trade secrets, depending on the nature of their solutions. Towards that direction, the finalization of the D7.13 for D^2EPC Exploitation Report and IPR Protection Plan can be of great support.

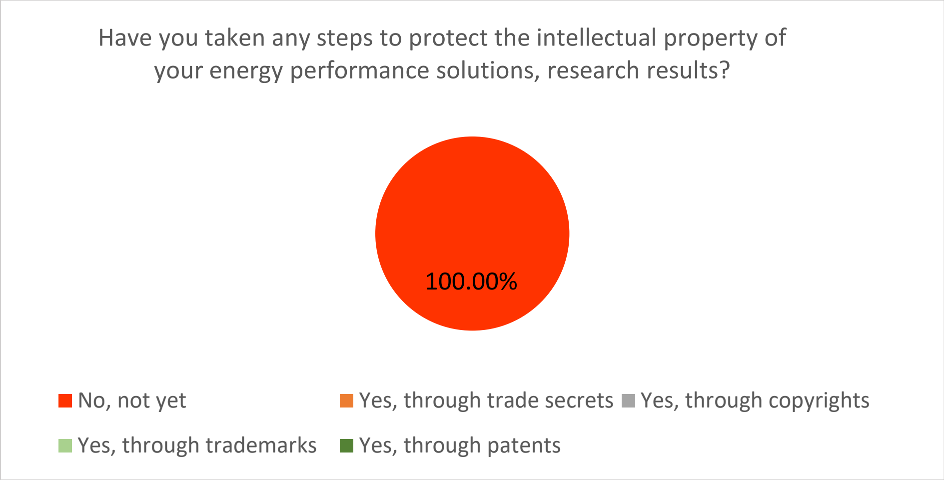


Figure 28. Intellectual property protection status

Respondents were asked to comment: “If you have protected your intellectual property, what benefits have you experienced from doing so?” An additional comment by a respondent (“I think however that the use of copyright for the software solutions doesn't need any particular steps”) reveals an interesting approach to IP protection, particularly software solutions and copyright.

This statement indicates that the respondent considers that copyright protection may not require specific actions for software solutions. While it is true that copyright protection is automatically granted upon creating original work, including software, it is important to clarify that registering the copyright with the relevant authorities may offer certain advantages.

5.14.6 Access to Finance and Funding Mechanisms

The results of the survey revealed a mixed situation regarding the availability of financial resources to support the development of energy efficiency solutions: A large proportion of respondents, 37.5%, still need financial resources to develop energy efficiency solutions. This may indicate that they are in the early stages of development or have yet to explore external financing options. The same percentage of respondents (37.5%) have received financial resources from EU grants. This shows that EU funding has played an important role in supporting the scale of these solutions, which aligns with the EU's emphasis on energy efficiency and sustainability. A smaller share (25%) received financial resources from alternative funding mechanisms. This category can include a variety of sources such as private investment, venture capital or other grant schemes outside the EU. Interestingly, none of the respondents indicated they could obtain financial resources from local grants or loans. This may mean a potential gap in using local resources for energy efficiency solutions.

These results show the importance of different funding sources in scaling up energy efficiency solutions, particularly the role of EU grants. Investigating local grants and loans can also be a valuable tool for further development of solutions.

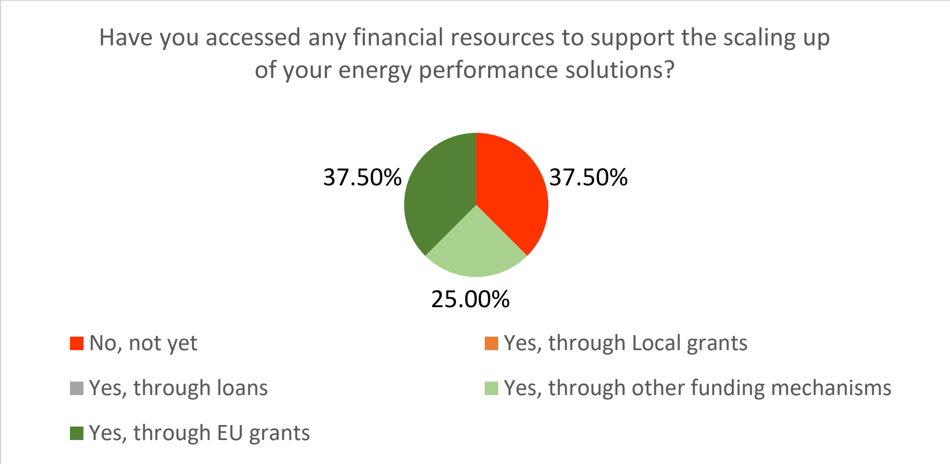


Figure 29. Access to financial resources

When respondents were additionally asked to comment on the challenges they face when trying to secure financial resources for their energy efficiency solutions, the responses revealed that:

The most frequently mentioned challenge is competition. Respondents noted a lot of competition when applying for funding through grants or platforms. This suggests that securing financial resources can be highly competitive, with many organisations and projects competing for limited funds. Some respondents indicated needing help finding financing for energy efficiency solutions. This shows the importance of having funding options tailored to the needs of the energy efficiency sector. One respondent mentioned that success in securing financial resources may depend on the presence of parties interested in the results. This suggests that it is important to effectively communicate the value and potential impact of one's decisions to potential funders.

These challenges reflect some of the common barriers faced by organisations and projects seeking financial support for energy efficiency solutions. Overcoming these challenges may require strategic approaches, such as increasing the competitiveness of grant applications, advocating for more targeted funding opportunities, and effectively communicating the value of their work to potential investors or grantees.

5.14.7 Market Entry Strategies

The survey responses (Figure 30) show that respondents are planning several strategies to enter new markets and expand the scope of their energy efficiency solutions:

Many respondents (35.29%) see joint ventures with local companies as a key strategy. This approach involves working with established local partners, their knowledge, networks and resources to enter new markets effectively. Other 23.53% of respondents prefer partnerships with local companies or institutions. This strategy involves jointly establishing cooperative relationships to promote and disseminate energy efficiency solutions. A similar percentage (23.53%) would prefer to enter the market utilizing licensing agreements. 17.65% of respondents use direct sales and marketing. This approach involves directly promoting and selling their solutions to target customers and markets.

These responses show a range of collaborative and direct approaches to market development, suggesting that energy efficiency solutions are a thoughtful and scalable approach to expanding coverage. Joint ventures and partnerships with local actors indicate a willingness to tap into local expertise and networks. At the same time, direct sales and marketing is a more hands-on approach to market penetration.

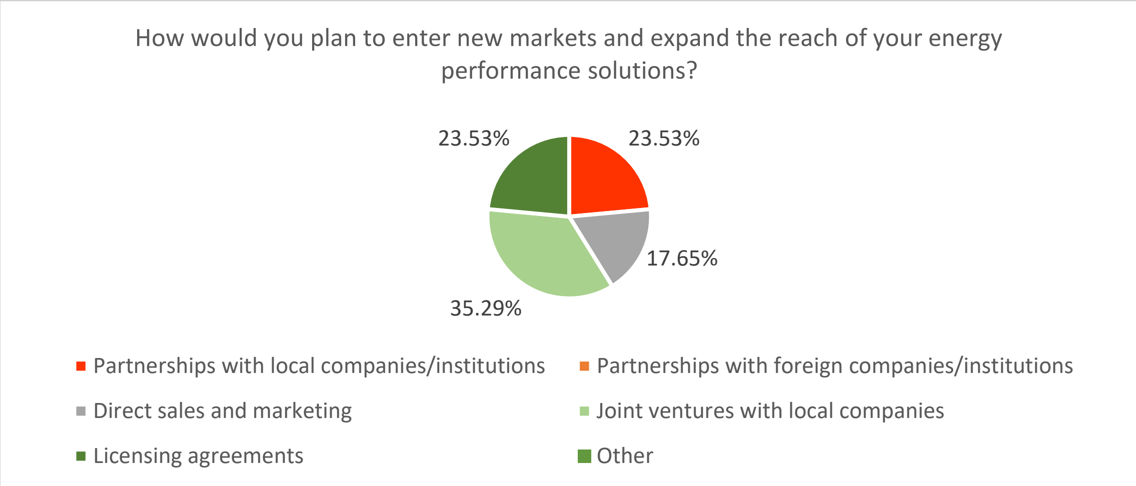


Figure 30. Market entry strategies

Additional question: "What factors do you consider most crucial in successful market entry?" revealed valuable information on the factors they consider important for the successful market penetration of their energy efficiency solutions.

- **Attitudes towards people**. Recognizing the importance of engaging with people, especially potential customers, indicates a customer-oriented approach. Building relationships and understanding the needs and preferences of the target audience can be key to market entry.
- Compliance with local legal requirements. Compliance with local legal requirements is essential for smooth market entry. Compliance with legislation demonstrates a commitment to responsible business practices.
- **Local market knowledge**: Local market knowledge is vital. This knowledge can help tailor solutions to the specific needs and preferences of the target market, which can provide a competitive advantage.
- **An effective advertising strategy.** An effective and well-planned advertising strategy can significantly increase the attractiveness of a market. Effective marketing and advertising efforts can increase awareness and generate interest.

- **Solution advantages and benefits.** Compared to competitors, the distinctive advantages and benefits of energy efficiency solutions can be a compelling selling point. Highlighting these differences can attract customers.
- **Effective marketing campaign**. An effective marketing campaign presenting the opportunities and benefits of the solution is essential. Clear and compelling messages help potential customers understand the value proposition.
- **Close cooperation with stakeholders.** Building relationships with different stakeholders can facilitate market access. Collaboration and partnerships can open doors to new opportunities and customers.
- **User-friendly design**. The focus on user-friendly design, with a 'good look' and easy navigation, underlines the importance of a positive user experience. Customers are more likely to make user-friendly decisions.
- **Economic viability.** The economic viability dimension shows that a solution's cost-effectiveness and long-term financial benefits are important factors. Evidence of a positive return on investment can be compelling.

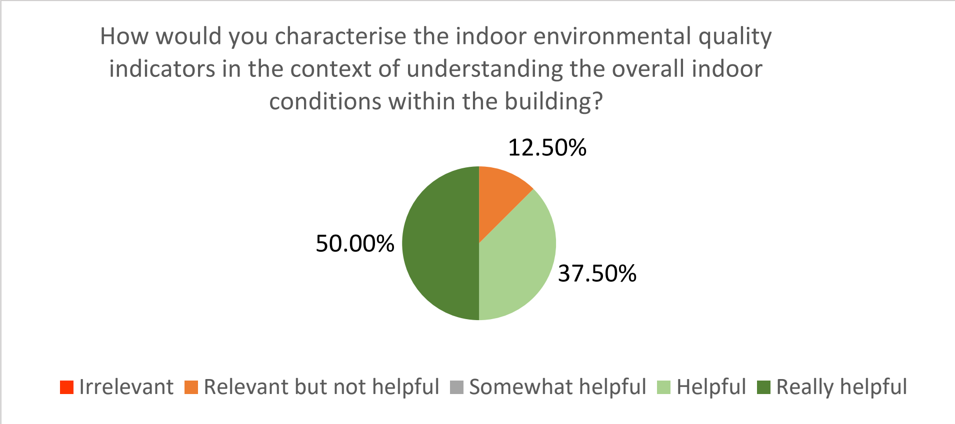
These factors reflect a comprehensive approach to successful market entry, including customer engagement, regulatory compliance, local market knowledge, effective advertising, competitive differentiation, strong networks, consumer-oriented design and economic feasibility. Understanding and addressing these factors can contribute to a more successful and sustainable market entry strategy.

5.15 KPI15: Upgrading indoor environmental quality

5.15.1 EPC assessors' assessment

A part of the newly-introduced indicators of the dynamic EPC covers human comfort and well-being aspects of the occupant. In the EPC assessor's case, three different questions have been addressed. The first one referred to how helpful are the indoor environmental indicators in understanding the building's indoor conditions. In Figure 31 (a), 87.5% of the respondents considered them as helpful/really helpful leading to an acceptance rate of 81.25% (Table 44). The second question highlighted the amount of influence the indicators have on an EPC assessor in quantifying the environmental performance of a building. 62.50% of the respondents stated that they consider the IEQ indicators highly/very highly influential for the characterization of the building's performance in regards to the indoor conditions. A significant number of EPC assessors (37.50%) were neutral or indifferent about the indicators which were proven determining factor for the perception rate, finally calculated as 68.75%. The last question concerned the indicators effectiveness rate. EPC assessors were asked for their feedback on how potent they find the indicators in identifying building issues related to the indoor conditions and areas of improvement. All respondents were positive and the effectiveness rate reached 85.71%

The total accepted rate of the IEQ indicators was calculated based on the abovementioned results at 78.57%, highly affected by the relatively low perception rate.



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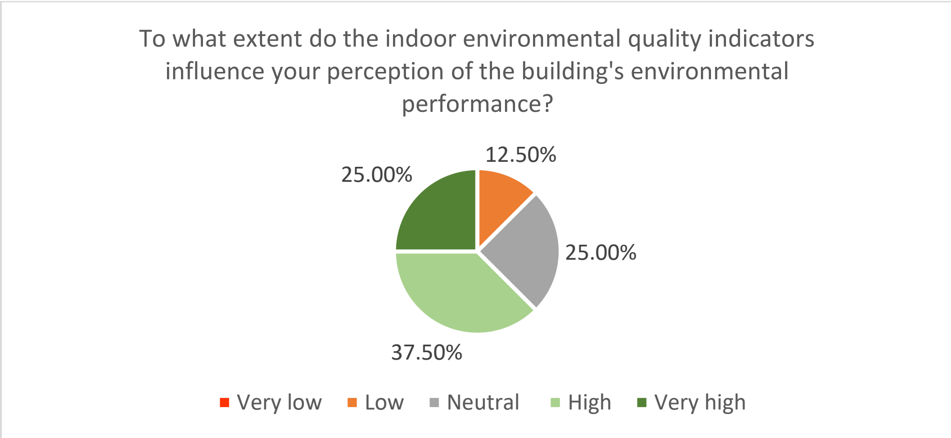

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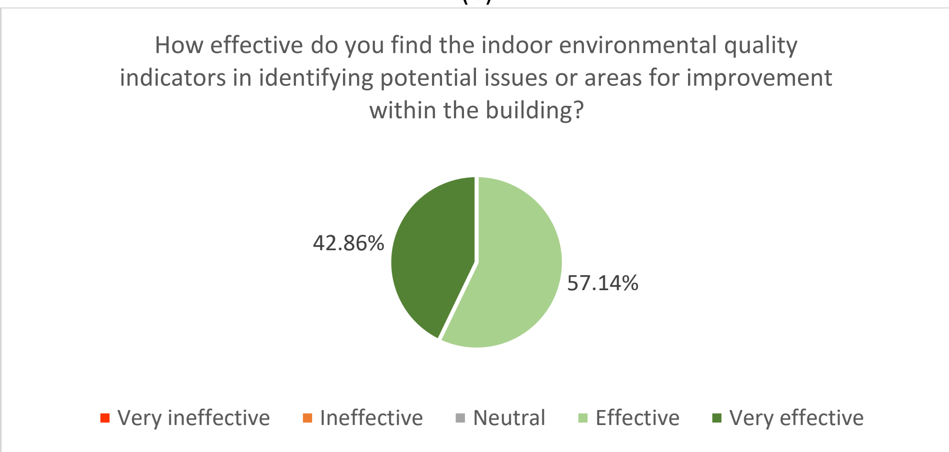


(c)

Figure 31. a), b), c) EPC assessors' evaluation graphs

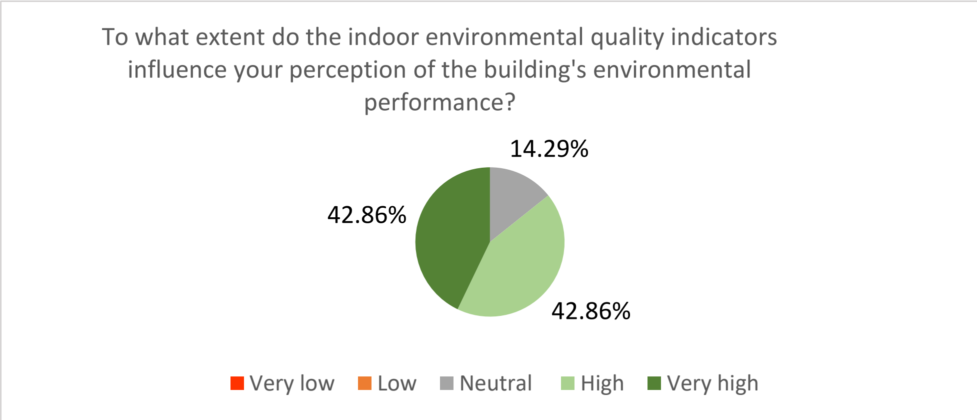
Table 44. KPI15 EPC assessors' IEQ indicators acceptance rate

Definition	Value
IEQ in defining indoor conditions rate	81.25%
IEQ indicators influence to indoor conditions perception rate	68.75%
Indicators effectiveness rate	85.71%
Total IEQ indicators acceptance rate	**78.57%**

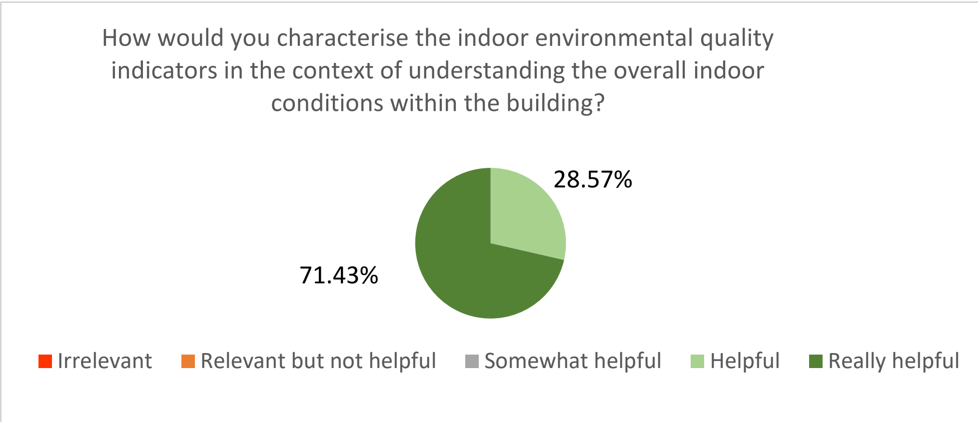
5.15.2 End-Users' assessment

A similar assessment was realised in the building users' case. The circulated questionnaire included four questions relevant to the IEQ indicators. Two of the questions coincided with the EPC assessor's case. How helpful in the understanding of indoor conditions the indicators are and how much they influence the perception of a user in regards to the building's environmental performance. The users appeared to be more positive in both questions leading to an increase of the rates, especially in the perception rate. The calculated values were 92,86% and 82.14% respectively Table 45.

The third question covered the willingness of the building users to alter their behavior according to the IEQ indicator results. All respondents considered likely/very likely to change their behavior leading to a score of 85.71% rate. Finally, the building users appeared to be even more positive in regards to the improvement of the IEQ indicators impact in the indoor conditions. 71,43% considered significant the contribution of indicators in the enhancement of the overall indoor experience leading to a 92.86% rate. The combined score for the total IEQ indicators acceptance rate was 88.39% significantly higher than the respective rate in the EPC assessors' case.



(a)



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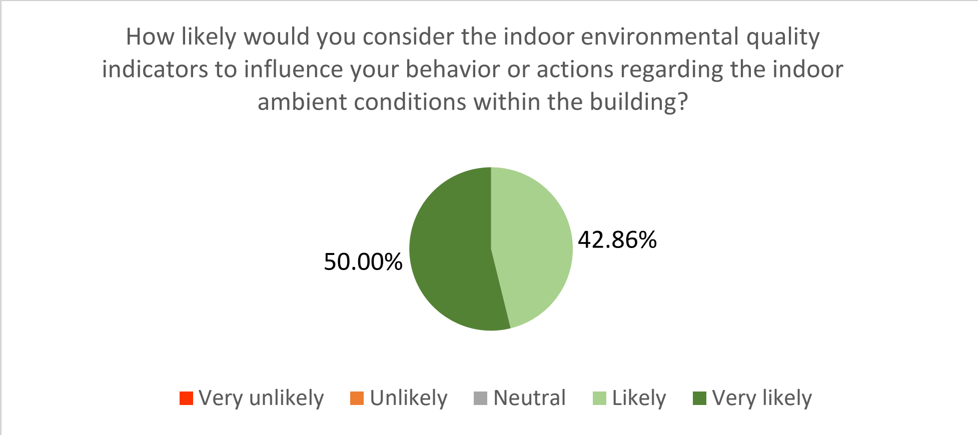

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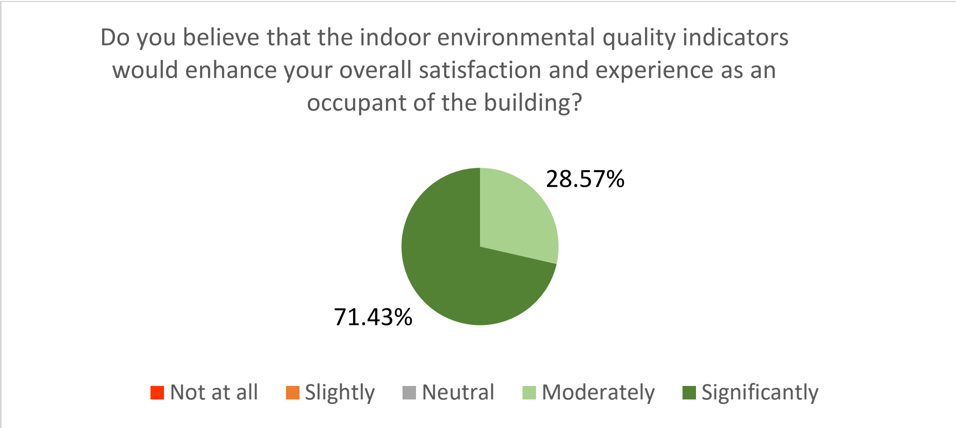


(d)

Figure 32. a), b), c), d) End-users' evaluation graphs

Table 45. KPI15 End users' IEQ indicators acceptance rate

Definition	Value
IEQ in defining indoor conditions rate	92.86%
IEQ indicators influence to indoor conditions perception rate	82.14%
IEQ indicators influence to user behaviour rate	85.71%
Satisfaction increasement	92.86%
Total IEQ indicators acceptance rate	**88.39%**

Table 46. Total IEQ indicators acceptance rate

Definition	Value
EPC assessors' IEQ indicators acceptance rate	78.57%
End-users' IEQ indicators acceptance rate	88.39%
Total IEQ indicators acceptance rate	**83.48%**

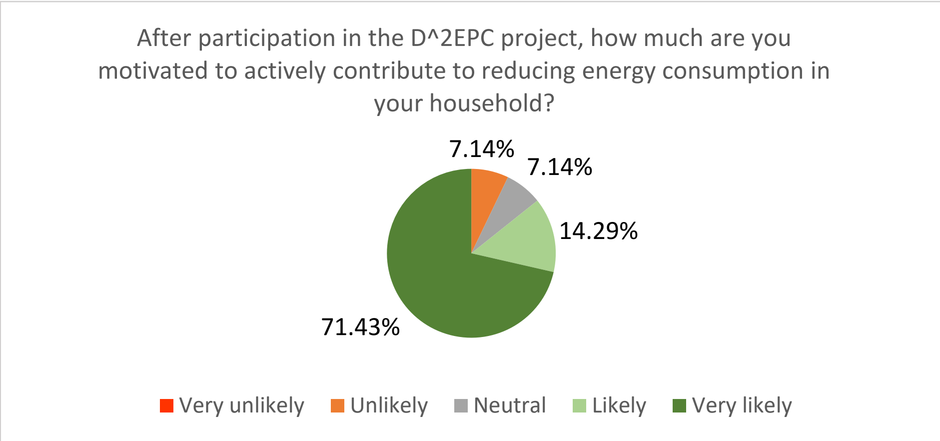
Based on the aforementioned calculations, the total IEQ acceptance rate was determined taking into consideration both building users and EPC assessors. The final score for the KPI15 reached 83.48% (Table 46).

5.16 KPI16: Boosting energy efficiency

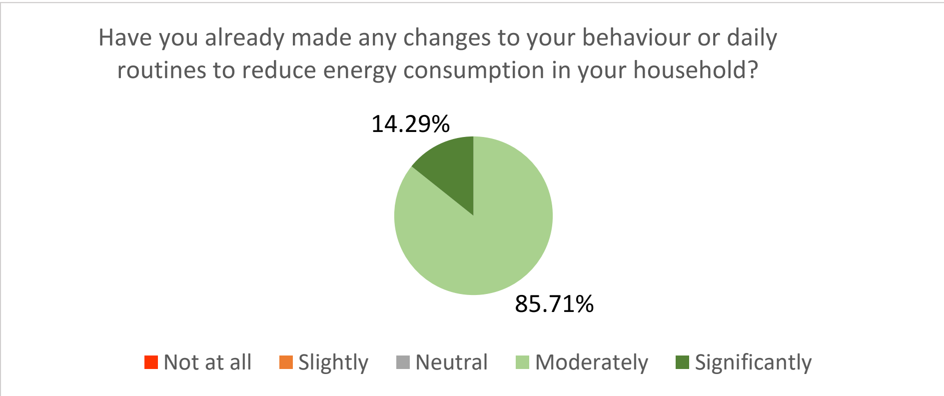
5.16.1 End-Users' assessment

KPI16 calculation methodology included evaluation of end-users' perception of the improvement of energy efficiency through observing the energy used and monitoring activities. As it is presented in Figure 33 (a, b), the users indicated that participating in the piloting activities of the project motivated them to reduce their energy consumption and make behaviour changes in their daily routine. Most of the end-users (answers "likely" and "very likely" together 85%) are ready to reduce their energy consumption. All have indicated that have started to change their behaviour, at least moderately by 85%. This shows the effectiveness of monitoring the use of energy and involving the end users.

As it is presented in Table 47 positive end-user perception of the D^2EPC solution resulted in an 87.50% of energy reduction contribution rate, with contribution to user behaviour changes at 78.57%. In total, end-users' contribution in boosting energy efficiency rate is 83.04% (Table 47).



(a)



(b)

Figure 33. a), b) End-users' evaluation graphs

Table 47. KPI16 End users' boosting energy efficiency rate

Definition	Value
Energy reduction contribution rate	87.50%
Change in user behaviour rate	78.57%
Total boosting energy efficiency rate	**83.04%**

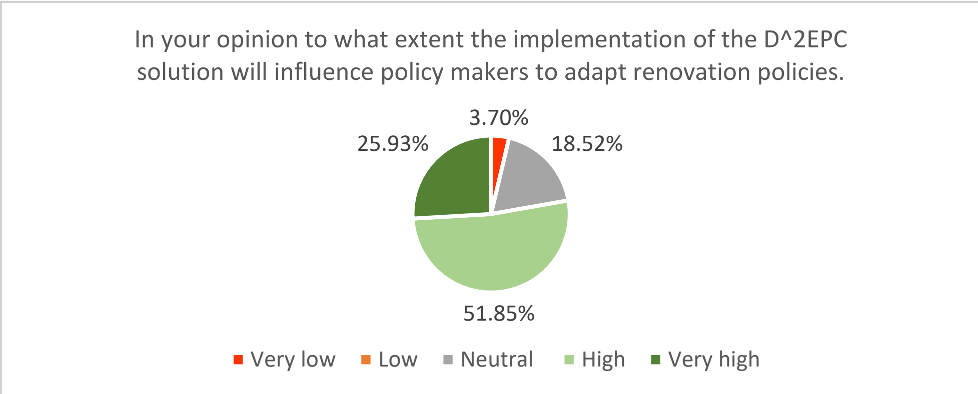
5.17 KPI17: Improving renovation rate

5.17.1 EPC assessors' assessment

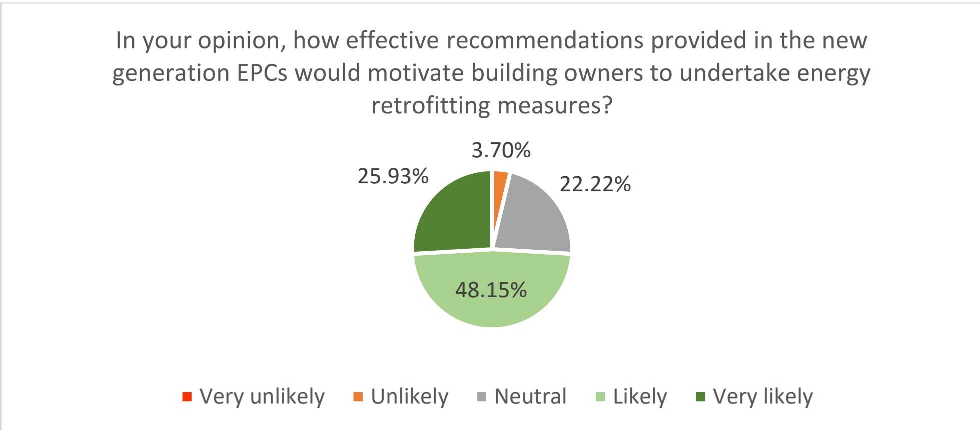
KPI17 calculation methodology included evaluation of EPC assessors' answers regarding the implementation of the solutions by the project in the processes of policy making regarding renovation policies. In Figure 34 (a), more than 51% indicated that the outcomes have high influence on renovations policies and further 25% of the respondents were of the opinion that the influence is very high (Figure 34 (a)).

Almost 74% of the respondents to the questionnaire indicated that the recommendations provided in the NG EPCs would motivate the building owners to undertake energy renovation measures to improve energy efficiency and therefore, reduce the maintenance costs during the life cycle of the buildings and raise the comfort of the users (Figure 34 (b)).

EPC assessors' perception converted to total numerical values are presented in Table 48, it is expected that D^2EPC solution will have an impact on improving renovation rate up to 72.97%.



(a)



(b)

Figure 34. a), b) EPC assessors' evaluation graphs

Table 48. KPI17 EPC assessors' renovation promotion perception

Definition	Value
D^2EPC influence to policy makers rate	71.88%
D^2EPC renovation motivation rate	74.07%
Total improving renovation rate	**72.97%**

5.17.2 End-Users' assessment

Almost 50% of the respondents to the end-users' questionnaire indicated that the recommendations provided in the NG EPCs would motivate the building owners to undertake energy renovation measures (Figure 35) to improve energy efficiency and therefore, reduce the maintenance costs during the life cycle of the buildings and raise the comfort of the users. This response can be linked to the challenges, ownership structure and costs that will occur during the renovation work, and therefore, scoring the lower agreement rates of the end users. Users' answers converted into improved renovation rate was calculated to be 70.83%.

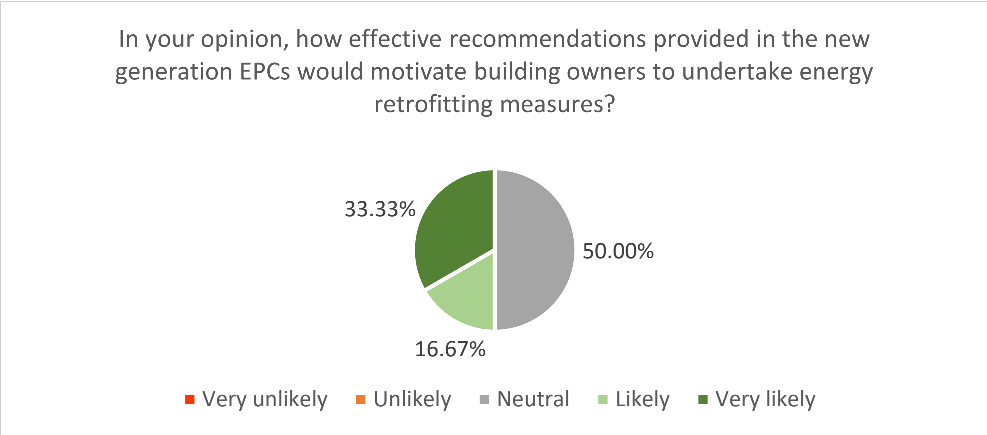


Figure 35. End-users' motivation perception

Table 49. KPI17 End users' improved renovation rate perception

Definition	Value
Total improved renovation rate perception	**70.83%**

Table 50. Total improved renovation rate perception

Definition	Value
EPC assessors' renovation rate perception	72.97%
End-users' renovation rate perception	70.83%
Total improving renovation rate	**71.90%**

End-users' and EPC assessors' perception on improved renovation rate are very similar in value and in total it is calculated to be 71.90%. It is worth mentioning that based on Figure 34 b) and Figure 35 it is visible that end-users' and EPC assessors' perception differs, EPC assessors have more positive view of the project impact. This may be the result of their experience in building energy.

6 Conclusions

The purpose of this task was to define the list of KPIs and quantify them for the evaluation and impact assessment of the D^2EPC project. The assessment was carried out taking into account the technical, economic, environmental and social aspects of the project. With the aim to have a thorough and comprehensive assessment of the project, both numerical analysis and qualitative survey methods were employed. This approach allowed for a comprehensive evaluation based not only on numerical data but also on the experiences of stakeholders.

To have a full understanding of project success and completion of its initial objectives and reach of expected impacts, a total of 17 KPIs were defined. All KPIs were defined to reflect the level of success in achieving the project's initial objectives or in reaching the expected impact. The methodology for calculating the KPIs for each indicator has been described in order to successfully capture and quantify results. Based on the methodology developed, either a numerical analysis or qualitative survey questions were provided depending on the nature of the indicator. In total, three different types of surveys were carried out, targeting different stakeholder groups. The results of the survey were then processed, taking into account the weighting of each response, to calculate acceptance, success and other indicators.

Analysis carried out for this task concluded the project's success, which can be summarised as follows:

- Improved user-friendliness of EPCs – for the assessment of this impact the clarity of information, intuitiveness, visual representation and user-friendliness of the D^2EPC solution was taken into consideration. The initial target of improving user-friendliness by at least 80% was successfully achieved, with an indicator of 82.59% for the EPC assessors and 86.83% for the end-users of the building, resulting in a final rate of 84.71%.
- The assessment of the impact of increased user awareness of the energy efficiency of buildings covered various aspects related to increased user willingness to contribute to the energy efficiency of buildings and awareness in general. The value achieved for the indicator on increased awareness of energy efficiency is estimated to be significant at 88.10%. As the project aimed at >80% satisfaction of the participants of the pilot project, this value was also successfully achieved (85.71%). The assessment of this impact took into account the clarity, intuitiveness, visual presentation and user-friendliness of the information in the D^2EPC solution.
- The primary energy savings triggered by the project were initially estimated at 80 GWh/year, as described in the proposal. The calculations that led to that value have been updated based on the latest reliable EU data. Two scenarios have been considered. In the first one, EU statistics data have been used for calculations. In the other one, D^2EPC Pilots and questionnaires data have been used. Depending on the source of the data, significant variations in the estimation of primary energy savings have been obtained, from 49.52 GWh/year for the first scenario to 119.38 GWh/year for the second.
- The investments in sustainable energy triggered by the project were initially estimated at 56 million €/year. As made for energy savings, the calculations that led to that value have been updated, considering the same two scenarios as well. In this case, since the EU average renovation cost has been considered 11.724 €/building, both scenarios provide estimated investments greater than the initial estimation. First scenario estimates the investments in sustainable energy in 68.8 million €/year and the second one, estimates it at 87.6 million €/year.
- The reduction of the greenhouse gas emissions and air pollutants triggered by the project were initially estimated at 17.1 tons of CO_2-eq/year. As for the two previous indicators, the calculations that led to that value have been updated, considering the same two scenarios as well. Depending on the source of the data, significant variations in the estimation of CO_2 reductions have been obtained, from 10.6 tons of CO_2-eq/year for the first scenario to 25.60 GWh/year for the second.

- D^2EPC project aimed to introduce dynamic EPC based on the regular basis, it appeared to be very essential topic, as 62.50% of EPC accessors were aware or applied (37.50%) such approach, despite that dEPC acceptance rate among EPC assessors was calculated to be 74.55%. As for the building users dEPC awareness rate is 67.86%, while acceptance rate reached significant 92.86%. Another metric to highlight successful introduction of dEPC is the number of dynamic EPC issued through the D^2EPC platform which was 6, matching the six D^2EPC case studies. The execution time of dEPC does not exceed 15 seconds for the project pilot sites.
- According to the EPC assessors, only a quarter of them did not notice or identify any shortcomings in the existing standardisation of the energy performance of buildings. In order to improve this metric, identification of drawbacks (T7.3), the standardisation efforts of D^2EPC, the findings of the KPIs and the oversight of bodies such as CEN TC371 WG5 have led to the development of a comprehensive framework aimed at ensuring consistent, reliable and harmonised standardisation processes that promote effective improvements in the buildings sector. A set of recommendations from the D^2EPC project on the updating of standards can be found in the "D^2EPC Policy Brief v2".
- One of the objectives of the project was to introduce environmental, financial, occupant comfort and technical indicators in order to simplify the understanding of the building's energy performance and behavior. Considering the value of the new indicators for decision making and the increased attractiveness of EPCs, the EPC assessors accepted the improvement at an 82.93% rate. In contrast, the end-users had a more favourable opinion of the indicators with a rate of 89.88%, resulting in an overall acceptance rate of the new set of indicators reaching 86.40%.
- D^2EPC project also aimed to develop required building of digital twins as well as to integrate actual data into EPC calculation procedures. For this purpose, a total of six digital twins were developed with the high completeness of the base BIM models. BIM models data extraction by the platform reached significant 99.06%. In addition, the attitude of EPC assessors towards the use of BIM models for EPC procedures was assessed. Results reveals that currently BIM application rate by EPC assessors is 40.63%, while D^2EPC solution in terms of BIM applicability acceptance rate reached 84.95%.
- To complement the previously mentioned set of indicators, D^2EPC aimed to include SRI in the EPC calculation procedures. Following the technical implementation and presentation, the perception of EPC assessors and end-users on the awareness and acceptability of SRI was documented. Although the EPC assessors were 50% aware of the SRI, an acceptance rate of 74.07% was calculated, compared to an end-user acceptance rate of 75%.
- Considering the aim to develop intelligent dynamic platform for dynamic EPCs issuance, the assessment methodology consisted of targeted questions for EPC assessors and building end-users. The results revealed that considering interactive features, innovation in building sector and platform extensions (web-GIS tool, enhanced decision making, road-mapping tool) these improvements were highly accepted by EPC accessors at the total rate of 84.92%. Based on the same criteria, and with the additional evaluation of the user interface of the intelligent EPC platform, the end-users of the buildings also gave very positive feedback to the platform, with a calculated acceptance rate of 85.71%. This resulted to the total intelligent and dynamic platform reaching an 85.31% of acceptance rate.
- The analysis presented in this report on improving the absorption capacity of partners highlights the different ways to achieve this objective. From participation in seminars to involvement in various research projects and standardisation committees. The implementation of the strategies underlines the commitment to innovation and sustainability. Continuous information and training on evolving methodologies and regulations promotes a sustainable operating system.
- In line with the development of partners' market knowledge, activities range from physical presence to virtual participation in various training programmes, seminars and knowledge-sharing sessions. By participating in conferences, collaborating in research initiatives and promoting knowledge sharing internally, the organisations aim to develop a comprehensive understanding of

market dynamics, thus demonstrating their ability to adapt to the changing energy sector and their commitment to stay informed.

- The assessment of the enhancing exploitation potential of energy efficiency solutions reveals some key findings, including the need to increase commercialization experience, the potential for improving the effectiveness of initiatives, the high market demand, the multiple demand drivers, the different barriers to deployment, the various stages of technological maturity, the scaling-up challenges, and a good understanding of value chains, and the importance of factors such as clear benefits, government support and user-friendly solutions to accelerate commercialization, while highlighting the need for intellectual property protection, access to financial resources and strategic approaches to market entry, emphasizing the importance of removing barriers, raising awareness and fostering cooperation for a sustainable and economically viable energy sector.
- As one of the aims of the project was to shift the focus of the NG EPC towards a user-centred approach and to improve the quality and comfort of the indoor environment, IEQ indicators were also included in the updated EPC scheme. The assessment took into account the EPC assessors' perception of the IEQ indicators in the context of the general indoor conditions, as well as the effectiveness in identifying potential problems. EPC assessors rated the IEQ indicators to be effective at the rate of 78.57%. The level of acceptance by building end-users was higher at 88.39%, resulting in an overall acceptance rate of 83.48% for the IEQ indicators.
- As far as the D^2EPC project is building energy efficiency oriented, it is also important to evaluate its impact on building end-users' knowledge and behavior in terms of energy efficiency. The qualitative analysis shows that during the project implementation period, users' motivation to contribute to energy efficiency is in very high rate – 87.50%, as well as their willingness to adapt their behavior for a better performance (78.57%), which results boosting energy efficiency rate to reach 83.04%.
- As the D^2EPC project focuses on improving the energy efficiency of buildings, it is also important to assess its impact on the energy efficiency knowledge and behavior of the end-users of buildings. The qualitative analysis shows that during the project implementation period the motivation of the users to contribute to energy efficiency improvement reach very high level (87.50%), as well as their willingness to adapt their behavior to achieve better results (78.57%), achieving a total energy efficiency indicator rate 83.04%.
- To support the renovation of existing buildings, the features of the D^2EPC platform encourage and assist building owners and policy makers to take action to improve energy efficiency. The EPC evaluators consider that the D^2EPC solution will have an impact on the renovation rate improvement of 72.97%. At the same time, the end-users of the buildings consider that this measure will have an impact of 70.83% on increasing the renovation rate.

In addition to the KPIs presented, the "Cost-Benefit Analysis" section of the document presents the detailed methodology and evaluation results developed by the D^2EPC project. It highlights the importance of these results in influencing decision-making on implementation. The effectiveness of different scenarios and factors such as energy consumption, costs and interest rate are highlighted graphically, thus showing the financial viability of the proposed solutions. The CBA analysis provides a clear picture of the financial impact of the project and suggests potential avenues for further research in optimising energy efficiency solutions.

In summary, this exercise has successfully identified and quantified a comprehensive set of 17 KPIs that assess the technical, economic, environmental and social impacts of the D^2EPC project. A combination of numerical analysis and qualitative surveys ensured a holistic assessment that captured the experience of stakeholders. The level of acceptance achieved, the innovative implementation and the successful impact on energy efficiency confirm that the project has been successful in achieving its objectives and delivering the expected impact.

ANNEX A: EPC Assessors Survey

1. Introduction and Background

We kindly request your valuable feedback regarding the content presented during the workshop held on June 29th. Your professional input and insights are highly appreciated as they will contribute to the assessment of acceptability and relevance of improved EPCs. Please take a moment to share your thoughts and opinions on the following aspects presented and discussed during the workshop.

2. General Information

This part of the survey collects demographic and background information on respondents, which will help to establish a unified profile of respondents. The background information will help to understand the experiences and key human characteristics that will provide a valuable context for the analysis of the responses.

Q1: Please provide your country.

____

Q2: What is your age?

a) 18 – 25
b) 26 – 35
c) 36 – 45
d) 46 – 55
e) 56 and above
f) Prefer not to say

Q3: What is your gender?

a) Male
b) Female
c) Prefer not to say

Q4: What is your experience as an EPC assessor?

a) Less than 1 year
b) 1-5 years
c) 6-10 years
d) 11-20 years
e) 21 and above

Q5: How often do you issue Energy Performance Certificates?

a) Multiple times per day
b) Daily
c) Weekly
d) Monthly
e) Once a year or less

3. Main Section

The evaluative questions are presented on a scale of 1 to 5, so that the respondent can indicate the extent to which he/she agrees or disagrees with the statements or questions in the questionnaire. An explanation of the scale is given below:

1 = **Very Low** – **fully disagree**: This option indicates that the respondent strongly disagrees with the statement or question being asked. It represents a complete lack of agreement.

2 = **Low – partially disagree**: This option suggests that the respondent has some disagreement with the statement or question, but not to the same extent as the first option. It represents a partial disagreement.

3 = **Medium –** neutral**:** This option reflects a neutral or middle-ground stance where the respondent neither agrees nor disagrees with the statement or question. It represents a state of being impartial or having no strong opinion.

4 = **High – partially agree**: This option suggests that the respondent has some level of agreement with the statement or question, but not to the same extent as the next option. It represents a partial agreement.

5 = **Very High – fully agree**: This option indicates that the respondent strongly agrees with the statement or question being asked. It represents complete agreement and a high level of conviction.

Q6: The energy performance information provided by the improved EPC format is concise and clearly understandable.

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q7: The interface of the D^2EPC tool is intuitive and the arrangement of functions and features are logical.

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q8: The layout of the D^2EPC tool, the colour scheme and the use of graphical elements look attractive and reasonable.

4. Fully disagree
5. Partially disagree
6. Neutral
7. Partially agree
8. Fully agree

Q9: Were you aware of the operational rating before the D^2EPC project?

1. Not aware
2. Partially aware
3. Neutral
4. Highly aware
5. Fully aware

Q10: Have you ever issued an EPC based on the operational data?

1. Never
2. Rarely
3. Sometimes
4. Very often

5. Always

Q11: Do you consider the operational rating methodology more accurate than the asset-based rating?

1. Fully disagree
2. Disagree
3. Neutral
4. Agree
5. Fully agree

Q12: Assess whether you consider that the D^2EPC tool provides a clear and comprehensive dynamic EPC calculation process for operational features?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q13: Have you ever noticed or identified any shortcomings or inconsistencies in the standardisation of energy performance of buildings?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q14: Please describe the main drawbacks or discrepancies you have encountered in the current EPC scheme.

____

Q15: Please provide potential solutions or recommendations for the improvement of the EPC scheme, if any.

____

Q16: Do you think that incorporating environmental, financial, and human comfort indicators into EPCs will increase their attractiveness for the users?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q17: Do you think that newly introduced indicators will serve as a valuable tool for decision making, such as evaluating the effectiveness of policies, strategies, and interventions in regards to indoor conditions and building operation?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q18: How often are you issuing EPC based on the BIM data?

1. Never
2. Rarely
3. Sometimes
4. Occasionally
5. Always

Q19: Assess whether you consider that the use of the D^2EPC tool will facilitate the integration of BIM into EPC procedures.

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q20: Provide your opinion on how the integration of BIM will improve the accuracy and reliability of energy performance assessments?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q21: Were you aware of the smart readiness concept before the D^2EPC project?

1. Not aware
2. Somewhat aware
3. Neutral/Vaguely aware
4. Highly aware
5. Fully aware

Q22: How often were you integrating smart technologies in the building certification procedures?

6. Never
7. Rarely
8. Sometimes
9. Very often
10. Always

Q23: Do you agree that integrating smart readiness indicators into building energy performance evaluation procedures will improve EPC accuracy?

1. Fully disagree
2. Disagree
3. Neutral
4. Agree
5. Fully agree

Q24: How much do you agree with the following sentence: "D^2EPC platform extensions (web-GIS tool, enhanced decision making, road mapping tool) will have an added-value and increase user acceptance rate of EPCs"

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q25: In your opinion, will the improved EPCs and the use of the D^2EPC platform stimulate different innovations in buildings?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q26: How do you rate the interactive features of the D^2EPC solution (recommendations for improving energy efficiency, alerting engine, real time monitoring)?

1. Very negative
2. Negative
3. Neutral
4. Positive
5. Very positive

Q27: How would you characterise the indoor environmental quality indicators in the context of understanding the overall indoor conditions within the building?

1. Irrelevant
2. Relevant but not helpful
3. Somewhat helpful
4. Helpful
5. Really helpful

Q28: To what extent do the indoor environmental quality indicators influence your perception of the building's environmental performance?

1. Very low
2. Low
3. Neutral
4. High
5. Very high

Q29: How effective do you find the indoor environmental quality indicators in identifying potential issues or areas for improvement within the building?

1. Very ineffective
2. Ineffective
3. Neutral
4. Effective
5. Very effective

Q30: In your opinion, how effective recommendations provided in the new generation EPCs would motivate building owners to undertake energy retrofitting measures?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q31: In your opinion to what extent the implementation of the D^2EPC solution will influence policy makers to adapt renovation policies.

1. Very low
2. Low
3. Neutral

4. High
5. Very high

Q32: Please provide additional feedback, if any:

____

Annex B: Pilot End-users Survey

1. Introduction and Background

Thank you for participating in this survey. Your valuable input will contribute to our analysis of the D^2EPC project, which aims to enhance the energy performance evaluation of buildings. This survey will help us understand your experiences, perspectives, and suggestions regarding the improved EPC format and the D^2EPC tool. The following sections will collect demographic information, evaluate key performance indicators, and gather your opinions on various aspects related to energy performance assessments.

Energy Performance Certificates (EPCs) play a crucial role in assessing and improving the energy efficiency of buildings. They provide valuable information to building owners, tenants, and policymakers about a building's energy consumption and potential for improvement. The D^2EPC project seeks to enhance the traditional EPC scheme by introducing dynamic and interactive features that enable more accurate and user-friendly evaluations.

In this survey, we aim to gather insights on different aspects of theD^2EPC project and its potential impact on the energy performance assessment process. We will explore your perceptions of the improved EPC format, the usability of the D^2EPC tool, the integration of operational data, the inclusion of environmental and comfort indicators, the concept of smart readiness, and the potential influence of the D^2EPC solution on policy-making and renovation efforts.

Your responses will help us assess the effectiveness and acceptance of the D^2EPC project and identify areas for improvement. We encourage you to provide honest and thoughtful feedback throughout the survey. Your participation is greatly appreciated, and your responses will remain confidential and anonymous.

2. General Information

This part of the survey collects demographic and background information on respondents, which will help to establish a unified profile of respondents. The background information will help to understand the experiences and key human characteristics that will provide a valuable context for the analysis of the responses.

Q1: Please provide your country.

____

Q2: What is your age?

a) 18 – 25
b) 26 – 35
c) 36 – 45
d) 46 – 55
e) 56 and above
f) Prefer not to say

Q3: What is your gender?

a) Male
b) Female
c) Prefer not to say

Q4: What is your connection with the building?

a) Building owner

b) Building manager
c) Apartment owner
d) Tenant
e) Building occupant (non-owner, non-tenant)
f) Other

Q5: How aware are you of Energy Performance Certificates (EPCs)?

a) Completely unaware
b) Partially aware
c) Moderately aware
d) Highly aware
e) Fully aware

Q6: How often do you use EPCs when making decisions about energy upgrades, property purchases, or rentals?

a) Never
b) Rarely
c) Sometimes
d) Very often
e) Always

3. Main Section

The evaluative questions are presented on a scale of 1 to 5, so that the respondent can indicate the extent to which he/she agrees or disagrees with the statements or questions in the questionnaire. An explanation of the scale is given below:

1 = **Very Low** – **fully disagree**: This option indicates that the respondent strongly disagrees with the statement or question being asked. It represents a complete lack of agreement.

2 = **Low – partially disagree**: This option suggests that the respondent has some disagreement with the statement or question, but not to the same extent as the first option. It represents a partial disagreement.

3 = **Medium –** neutral**:** This option reflects a neutral or middle-ground stance where the respondent neither agrees nor disagrees with the statement or question. It represents a state of being impartial or having no strong opinion.

4 = **High – partially agree**: This option suggests that the respondent has some level of agreement with the statement or question, but not to the same extent as the next option. It represents a partial agreement.

5 = **Very High – fully agree**: This option indicates that the respondent strongly agrees with the statement or question being asked. It represents complete agreement and a high level of conviction.

Q7: Have the revisions made to the EPC format improved its clarity and ease of understanding for users?

1. Fully disagree
2. Disagree
3. Neutral
4. Partially agree
5. Fully agree

Q8: Do users find the revised EPCs more user-friendly compared to the previous versions?

1. Fully disagree

2. Disagree
3. Neutral
4. Agree
5. Fully agree

Q9: The interface of the D^2EPC tool is intuitive and the arrangement of functions and features are logical.

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q10: The layout of the D^2EPC tool, the colour scheme and the use of graphical elements look attractive and reasonable.

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q11: Has the project increased your awareness of the importance of building energy efficiency?

1. Fully disagree
2. Disagree
3. Neutral
4. Agree
5. Fully agree

Q12: Do you consider that improved EPCs provide more information regarding building energy efficiency?

1. Fully disagree
2. Disagree
3. Neutral
4. Agree
5. Fully agree

Q13: To what extent has the D^2EPC motivated you to regularly monitor your building's energy performance or your personal energy consumption?

1. Not at all
2. Very limited
3. Limited extent
4. Moderate extent
5. Great extent

Q14: How well do you understand the specific benefits of renovation plans presented in the D^2EPC platform for improving your building's energy performance?

1. Not at all
2. Limited understanding
3. Moderate understanding
4. Good understanding
5. Excellent understanding

Q15: Will the customised recommendations provided by the road mapping tool encourage you to consider renovation plans?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q16: To what extent do you believe that implementing the renovation plans presented by the D^2EPC tool will lead to tangible energy savings and improved energy performance for your building?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q17: Were you aware of the operational rating before the D^2EPC project?

1. Now aware
2. Partially aware
3. Somewhat aware
4. Moderately aware
5. Fully aware

Q18: How much do you agree with the following statement: "Dynamic EPCs will contribute to the understanding and tracking of building's energy performance over time"?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q19: How would you rate the ease of understanding of the newly introduced indicators?

1. Very low
2. Low
3. Neutral
4. High
5. Very high

Q20: Does incorporation of environmental, financial, and human comfort indicators into EPCs increase its attractiveness for users?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q21: How much helpful do you consider the newly introduced indicators in regards to summarising and communicating environmental, financial, and human comfort parameters of a building?

1. Very unlikely
2. Unlikely
3. Neutral

4. Likely
5. Very likely

Q22: Do users find the inclusion of smart readiness factors in the assessment beneficial in understanding their building's performance?

1. Fully unhelpful
2. Unhelpful
3. Neutral
4. Helpful
5. Really helpful

Q23: How much do you agree with the following sentence: "D^2EPC platform extensions (web-GIS tool, enhanced decision making, road mapping tool) will have an added-value and increase user acceptance rate of EPCs"?

1. Fully disagree
2. Partially disagree
3. Neutral
4. Partially agree
5. Fully agree

Q24: How would you rate user interface of the tool presented?

1. Poor
2. Below average
3. Average
4. Good
5. Excellent

Q25: How do you rate the interactive features of the D^2EPC solution (recommendations for improving energy efficiency, alerting engine, real time monitoring)?

1. Very negative
2. Negative
3. Neutral
4. Positive
5. Very positive

Q26: How would you characterise the indoor environmental quality indicators in the context of understanding the overall indoor conditions within the building?

1. Irrelevant
2. Relevant but not helpful
3. Somewhat helpful
4. Helpful
5. Really helpful

Q27: To what extent do the indoor environmental quality indicators influence your perception of the building's environmental performance?

1. Very low
2. Low
3. Neutral
4. High
5. Very high

Q28: How likely would you consider the indoor environmental quality indicators to influence your behavior or actions regarding the indoor ambient conditions within the building?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q29: Do you believe that the indoor environmental quality indicators would enhance your overall satisfaction and experience as an occupant of the building?

1. Not at all
2. Slightly
3. Neutral
4. Moderately
5. Significantly

Q30: After participation in the D^2EPC project, how much are you motivated to actively contribute to reducing energy consumption in your household?

4. Very unlikely
5. Unlikely
6. Neutral
7. Likely
8. Very likely

Q31: Have you already made any changes to your behaviour or daily routines to reduce energy consumption in your household?

1. Not at all
2. Slightly
3. Neutral
4. Moderately
5. Significantly

Q32: In your opinion, how effective recommendations provided in the new generation EPCs would motivate building owners to undertake energy retrofitting measures?

1. Very unlikely
2. Unlikely
3. Neutral
4. Likely
5. Very likely

Q33: Overall, how satisfied are you with your experience as a pilot user in the D^2EPC project?

1. Very dissatisfied
2. Somewhat dissatisfied
3. Neutral
4. Somewhat satisfied
5. Very satisfied

Q34: Please provide additional feedback, if any:

____

ANNEX C: D^2EPC Partners Survey

Introduction and Background

Thank you for participating in this survey. This short questionnaire is a part of T5.4 "Evaluation and Comparative assessment of NG EPC" activities, particularly focused on assessment of exploitation potential in the energy sector as well as evaluation of increasing partners' absorptive capacity and improving partners' market knowledge.

We very much appreciate your insights and experience in assessing the effectiveness of initiatives aimed at increasing the potential of energy efficiency solutions in the energy sector. Your feedback is crucial for improving strategies to maximise the value and impact of these solutions for a more sustainable and economically viable energy sector. This survey aims to assess various aspects related to exploitation potential, absorptive capacity and market knowledge.

Your responses will help us assess the exploitation potential related to the D^2EPC project and its partners and identify areas for improvement. We encourage you to provide honest and thoughtful feedback throughout the survey. Your participation is greatly appreciated, and your responses will remain confidential and anonymous.

General Information

This part of the survey collects demographic and background information on respondents, which will help to establish a unified profile of respondents. The background information will help to understand the experiences and key human characteristics that will provide a valuable context for the analysis of the responses.

1. Have you ever been involved in commercialization of the solution (i.e., tool, prototype, equipment) related to building energy performance?

1. Never
2. Once
3. Few times
4. Often
5. Very often

2. Your affiliation

____

Main Section

The evaluative questions are presented on a scale of 1 to 5, so that the respondent can indicate the extent to which he/she agrees or disagrees with the statements or questions in the questionnaire. An explanation of the scale is given below:

1 = **Very Low** – **fully disagree**: This option indicates that the respondent strongly disagrees with the statement or question being asked. It represents a complete lack of agreement.

2 = **Low – partially disagree**: This option suggests that the respondent has some disagreement with the statement or question, but not to the same extent as the first option. It represents a partial disagreement.

3 = **Medium –** neutral**:** This option reflects a neutral or middle-ground stance where the respondent neither agrees nor disagrees with the statement or question. It represents a state of being impartial or having no strong opinion.

4 = **High – partially agree**: This option suggests that the respondent has some level of agreement with the statement or question, but not to the same extent as the next option. It represents a partial agreement.

5 = **Very High – fully agree**: This option indicates that the respondent strongly agrees with the statement or question being asked. It represents complete agreement and a high level of conviction.

Section 1: Market Demand and Viability

3. How would you rate the current market demand for energy performance solutions in your region?

1. Very low
2. Low
3. Moderate
4. High
5. Very high

4. What factors do you believe influence the market demand for energy performance solutions? (Select all that apply)

1. Government regulations and incentives
2. Energy prices
3. Awareness and knowledge of energy-saving benefits
4. Technological advancements
5. Customer preferences and behavior
6. Environmental awareness

5. In your opinion, what are the primary barriers to the adoption of energy performance solutions in the market?

____

Section 2: Technology Readiness and Scalability

6. How do you assess the technological maturity of your energy performance solutions?

1. Conceptual stage
2. Prototype development
3. Pilot testing
4. Commercial deployment
5. Scaling up in progress
6. Already scaled up

7. What challenges do you face in scaling up your energy performance solutions to broader markets, if any?

____

Section 3: Value Chains and Business Models

8. How well do you understand the value chains and key stakeholders involved in the energy sector?

1. Low understanding
2. Some understanding
3. Moderate understanding
4. Good understanding
5. Comprehensive understanding

9. Are there any specific business models or strategies that you believe can accelerate the commercialization of energy performance solutions? Please elaborate.

____

Section 4: Intellectual Property Protection

10. Have you taken any steps to protect the intellectual property of your energy performance solutions, research results?

1. Yes, through patents
2. Yes, through trademarks
3. Yes, through copyrights
4. Yes, through trade secrets
5. No, not yet

11. If you have protected your intellectual property, what benefits have you experienced from doing so?

____

Section 5: Access to Finance and Funding Mechanisms

12. Have you accessed any financial resources to support the scaling up of your energy performance solutions?

1. Yes, through EU grants
2. Yes, through Local grants
3. Yes, through loans
4. Yes, through other funding mechanisms
5. No, not yet

13. What challenges did you encounter in securing financial resources, if applicable?

____

Section 6: Market Entry Strategies

14. How would you plan to enter new markets and expand the reach of your energy performance solutions, if any?

1. Partnerships with local companies/institutions
2. Partnerships with foreign companies/institutions
3. Direct sales and marketing
4. Joint ventures with local companies
5. Licensing agreements
6. Other

15. What factors do you consider most crucial in successful market entry?

____

Section 7: Overall Feedback and Suggestions

16. Overall, how effective do you believe the initiatives have been in enhancing the exploitation potential of energy performance solutions?

1. a) Very ineffective
2. b) Ineffective
3. c) Moderately effective
4. d) Effective
5. e) Very effective

17. Please provide any additional feedback, success stories, or suggestions for further enhancing exploitation potential initiatives.

____

Section 8: Increasing partners' absorptive capacity

18. In how many training programs, workshops, knowledge-sharing sessions, and collaborative initiatives does your organization participate to enhance your organization's understanding and implementation of energy efficiency measures?

____

19. Please define the implemented training programs, workshops, and collaborative activities.

____

20. Please inform us about improving your understanding and implementing energy efficiency measures.

____

Section 9: Increasing partners' market knowledge

21. In how many training programs, workshops, knowledge-sharing sessions, and collaborative initiatives does your organization participate to enhance your organization's market knowledge within the energy sector (i.e., KPI13 for partners' market knowledge)?

____

22. Please define the implemented training programs, workshops, and collaborative activities.

____

23. Please inform us about improving your market knowledge within the energy sector.

____

Thank you for participating in this survey. Your valuable input will contribute significantly to our efforts in shaping a more sustainable and economically viable energy sector through enhanced exploitation potential. If you have any further comments or questions, please feel free to reach out to us.